Improving the Teaching of Teamwork Skills in Engineering and Computer Science

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ABSTRACT

It is important that engineering and computer science students learn teamwork skills as an integral part of their educational development. These skills are often not explicitly taught, but rather it is expected that students learn them on their own through participation in various team projects. Furthermore, the actual skills that students are expected to learn are usually not well articulated, or even understood. The approach outlined here attempts to address these problems by first establishing a process for defining what is meant by teamwork, by using this definition to assess the extent to which students are learning teamwork skills, and by using the assessment results to formulate approaches to improve student learning with respect to these skills. Specific attempts at the definition, assessment, and instruction improvement process are discussed.

Keywords: Teamwork, Assessment, Program Improvement, Peer Evaluation, Performance Criteria.

1. INTRODUCTION

Few would dispute the importance of teamwork as a learning outcome for students in engineering and computer science. Engineering is by nature a collaborative process, and most production systems are designed by teams working over long periods of time. Those who employ the graduates from these programs look for these skills, and the Accreditation Board for Engineering and Technology (ABET) demands them. [1]

Most programs do little to teach these skills, however. Usually, they give students many opportunities to participate in team projects, but they do little to help students develop or improve specific teamwork skills.

Typically, programs fail in this area in three ways. First, they seldom identify the specific performance criteria that students should meet with respect to working on teams. The usual assumption is that "everyone knows what teamwork is", and therefore, there is no need to specify it further. Identifying exactly what is meant by teamwork is essential in order to make sure students learn the skills necessary to work effectively on teams.

Second, most programs do not effectively assess teamwork. The usual teamwork assessment is merely an assessment of the success of team projects. While there is almost certainly a direct correlation between project success and team effectiveness, this does not really help in understanding the degree to which individual team members can function effectively on teams. If a team project was highly successful, did it mean that every member of the team was a highly effective team member? Or, conversely, if the project was a failure, did every member of the team lack effective team skills? Furthermore, how does this help us to understand how to improve the program with respect

to teaching teamwork? Specific teamwork skills must be assessed in order to determine which aspects of working in teams need to be improved within the program.

Third, programs seldom address teamwork as a pedagogical issue. That is, little thought or effort is given to how to improve the way teaching is done in order to improve students' ability to function on teams. To the extent that it is addressed at all, the solution proposed when there is a perceived lack of teamwork skills among students is to merely require more team projects. This is an example of the "experience is the best teacher" model. Unfortunately, there is at least anecdotal evidence to suggest that this might not work well. Students have reported that frustration on ineffective teams has left them with negative feelings about teamwork in general. [2] Simply providing more teamwork experience might not result in improved teamwork skills.

The sections below outline the efforts taken to identify specific teamwork skills, to assess student achievement with respect to those skills, and to describe the steps taken to improve learning in the areas of relative weakness. These are illustrated with actual examples based on recent assessment activities and efforts to use the results to improve student learning.

2. IDENTIFYING THE TEAMWORK SKILLS TO BE LEARNED

It is fundamentally important to understand what we mean by teamwork before we can begin to address how to teach it. A previous paper focused on the identification of the specific teamwork skills desired of engineering and computer science students. [3] It discussed a strategy that involved the Industrial Advisory Board for the College to help define the meaning of teamwork from an industry perspective. In a collaborative effort, it was agreed that, with respect to team activities, a successful student should be able to:

- Attend meetings and arrive promptly
- Complete individual tasks promptly
- Gather information as appropriate
- Perform research when necessary
- Complete tasks with high quality
- Accomplish a fair share of the work
- Express him/herself clearly
- Introduce new ideas
- Openly express opinions
- Share opinions and knowledge
- Listen to views and opinions of others
- Consider the suggestions of others
- Adopt suggestions of others when appropriate
- Provide help to others
- Solicit help from others
- Be committed to team goals
- Show respect for other team members
- Distinguish between the important and the trivial

This list is provided as an example and is not suggested as the one and only correct list of teamwork skills. It is important, however, that such a list be developed for the students of any program. Without first establishing what skills should be learned, there is no effective way to develop strategies for teaching teamwork.

3. DETERMINING HOW WELL TEAMWORK SKILLS ARE BEING LEARNED

Even before we address how to teach teamwork skills, we can assess how well students are achieving the skills we have identified. This provides a baseline for our efforts to improve learning by determining the extent to which students already possess these skills, and it highlights the areas where improvements are most needed. In the paper referred to earlier [3], several approaches for assessing individual teamwork skills were identified: independent observation, evaluating individual contributions, and peer reviews. The pros and cons of each of these approaches was discussed, but the peer review approach was identified as the most valid since the team members themselves are in the best position to evaluate the performance of their teammates. They work with them continually during the course of the team project and are the ones who are directly dependent on their contributions. Furthermore, of the methods discussed, this is the only one in which all of the identified teamwork skills can be effectively assessed.

In our first attempt at assessing teamwork skills we utilized a peer evaluation instrument. In this approach each team member anonymously evaluated the performance of the other members of the team based on the criteria established. Every team member was given a team evaluation form in which each team member's name was written across the top and a series of yes/no questions, based on the teamwork criteria, was asked about each team member (see Figure 1). All members evaluated themselves along with the rest of the team. In this way the form remained anonymous.

This initial assessment using this instrument was conducted during the spring of 2009, and it involved the team projects for three computer science classes. One was a senior level course in software design, one was graduate level course in software metrics containing both graduate and undergraduate students, and the third was a software architecture course of graduate students only. In all there were ten teams and a total of 45 students involved. All students in all classes completed the peer evaluation as it was a requirement in each of the courses. The percentage of yes answers given for all evaluations of all students for each question was calculated. A summary of the results is shown in Figure 2.

The identified skills which were least achieved were the following:
- Solicit help from someone on the team (64%)
- Provide help to someone on the team (66%)
- Communicate clearly with other team members (68%)
- Show an ability to distinguish between the important and the trivial? (70%)

By contrast, the skills that seemed to be achieved to the greatest degree were as follows:
- Demonstrate an ability to do research and gather information (96%)

- Earnestly try to understand what other team members were saying (86%)
- Generally complete individual assignments on time (84%)
- Seem committed to team goals (83%)
- Do a fair share of the work (82%)
- Share knowledge with others (82%)

TEAMWORK ATTRIBUTES Did the Team Member…	Member 1	Member 2	Member 3	Member 4	Member 5
1. Attend nearly all team meetings?					
2. Arrive on time for nearly all team meetings?					
3. Ever introduce a new idea?					
4. Ever openly express opinions?					
5. Communicate clearly with other team members?					
6. Share knowledge with others?					
7. Ever consider a suggestion from someone else?					
8. Ever adopt a suggestion from someone else?					
9. Generally tried to understand what other team members were saying?					
10. Ever help someone on the team?					
11. Ask for help from someone on the team?					
12. Generally complete individual assignments on time?					
13. Generally complete individual assignments with acceptable quality?					
14. Do a fair share of the work?					
15. Seem committed to team goals?					
16. Generally shows respect for other team members?					
17. Demonstrate an ability to do research and gather information?					
18. Shows an ability to distinguish between the important and the trivial?					

Figure 1
Teamwork Evaluation Form

4. IMPROVING THE LEARNING OF TEAMWORK SKILLS

Once assessment results are analyzed, the areas where improvement seems necessary can be identified. It might be clear why student performance is weak in these areas or it may require some thought and further analysis. Once the reasons for the lack of acceptable achievement are known, one can begin to devise learning strategies to address the problems.

Teamwork Attribute	Percent Achieved
17. Demonstrate an ability to do research and gather information	96.3%
9. Generally tried to understand what other team members were saying	86.4%
12. Generally complete individual assignments on time	84.1%
15. Seem committed to team goals	82.6%
6. Share knowledge with others	82.0%
12. Generally complete individual assignments with acceptable quality	81.7%
7. Ever consider a suggestion from someone else	80.1%
3. Ever introduce a new idea	79.3%
2. Arrive on time for nearly all team meetings	78.8%
4. Ever openly express opinions	78.5%
14. Do a fair share of the work	77.3%
1. Attend nearly all team meetings	77.0%
8. Ever adopt a suggestion from someone else	76.2%
16. Generally shows respect for other team members	74.2%
18. Shows an ability to distinguish between the important and the trivial	69.9%
5. Communicate clearly with other team members	68.1%
10. Ever help someone on the team	66.4%
11. Ask for help from someone on the team	63.9%

Figure 2
Achievement of Teamwork Skills

Asking for and Providing Help: In the study done, the teamwork skills receiving the lowest scores were the ones related to asking for and providing help to other students on the team. It is not too surprising that this appeared as an issue since most people are reluctant to ask for help in any situation. No one wants to appear ignorant or incapable. The tendency is to struggle on one's own rather than admit to some inadequacy. In an educational situation, this is further complicated by the fact that students are constantly reminded that asking other students for help on assignments or exams is a form of academic dishonesty for which severe penalties exist. Students are encouraged to work independently and solve problems on their own. This, of course, can be quite problematic on a team project where others depend on a team member's completion of his or her assignments in a timely manner. The project schedule can suffer, not to mention that there is a considerable waste of effort due the lack of productivity of team members struggling to complete assignments independently.

Also, the fact that students tend not to offer help to fellow students is likewise understandable. The same cautions about academic dishonesty discourage the more knowledgeable students from helping others. Furthermore, competitive pressures may discourage some students from helping others for fear of raising the class average and thereby adversely affecting their own grades. For whatever reason students seem to be preconditioned to avoid seeking or giving help. The question is how can we change that behavior in team situations?

A classical method for changing behavior is to reward the desired behavior in some way. In a class situation, we want to give students some credit toward their grade for demonstrating the desired behavior. To this end we created a "Help Certificate" that students can earn, either by asking for help or by giving help. The certificate, shown in Figure 3, documents who has requested help, who has given help, and includes a brief statement of the help provided. These completed certificates are given to the instructor who gives some amount of extra credit for each one submitted. Although the real effect of this process has not yet been measured, it appears to have had a noticeable effect on student behavior. It seems that students now view asking for help as a good thing, not a bad thing, and students appear more willing to help others.

Figure 3
Help Certificate

The other thing this approach does is allows students to practice a desired behavior that they may have avoided in the past. One of the best ways to improve is to practice. The more often students engaged in this behavior, even if they are doing it initially only for the "money" (course credit), the more it becomes a natural way of working.

Clear Communication within the Team: Low scores in this area are probably caused, at least in part, by some of the same factors that prevent students from asking for or giving help. Namely, students have been conditioned to work independently in most of their educational careers, and are reluctant to freely talk to others on the team. However, for engineering and computer science students, additional factors also come into play. Previous studies [4] have shown that these students are more introverted and less inclined to communicate with others

than the general population of students. Use of the Help Certificate described above can encourage communication. Another approached that was utilized in some of our classes was one in which students were given an individual assignment relating to the team project, and, after completing it, were required to present it to the rest of the team. For example, in the design phase of project development, an assignment was given that required each student to independently outline the high level design for the system to be implemented. Once completed the team was asked to meet and have each member to explain his or her design to the rest of the team, and then the team was to develop the final design based on all the input from all team members. This approach required each team member to formulate his or her own ideas about the best way to design the system and to present these ideas to the rest of the team.

In the typical brainstorming approach toward developing a design, the most dominate members of the team tend to drive the design. Many team members are reluctant to speak up or suggest alternate ideas for a variety of reasons. In any case, by structuring the assignment so that each student is required to develop their own designs and present them to the team, each student is forced to communicate their independently developed ideas with the rest of the team. If this behavior is repeated frequently, it will often become natural for students.

Distinguishing between the Important and the Trivial: Engineering and computer science students have been shown to be predominately "fact finders" in the Kolbe sense. [4] The Kolbe Conative Index™ [5] attempts to characterize individuals based on their "instinctive" approaches to problem solving. Our students are typically classified as having dominate modes of operation that drive them to try to uncover all the details relating to a problem, before actually trying to solve it. This trait causes students and student teams to often become bogged down in the details.

Interestingly, this study provided some additional evidence supporting the claim regarding the "fact finder" tendencies among engineering and computer science students. The skill that overwhelmingly received the highest score was the ability to research and gather information.

One approach we have employed to deal with this issue is to mandate that teams identify important issues as part of their regular team meetings. It is hoped that when they do this, they will collectively resolve to focus their attention on these important aspects of the project. The goal is that they will agree on what is most important and make it clear that work on other tasks should not interfere with these activities. To help facilitate this we modified the Meeting Report Form that was currently in use to add a section where the team was asked to identify the most important issues or problems to be solved that affected the project (see Figure 4).

12. CONCLUSION

It is important that students in engineering and computer science learn how to function effectively on team projects. How

to provide a learning environment that supports this is less clear. The approach described here was to identify the specific skills important in effective teamwork, to assess students' abilities with respect to these specific skills, and to develop teaching techniques to help improve teamwork skills identified as weak. Although only future assessments of teamwork outcomes will validate the success of this approach, it has shown promise in changing student behavior in positive ways with respect to teamwork effectiveness.

MEETING REPORT

Team Name: _____ Date of Meeting: _____

Start Time: _____ End Time: _____ Meeting Location: _____

Moderator: _____ Recorder: _____

Other Members Present: _____

Members Absent: _____

Topics Discussed:

Decisions Made:

Tasks Assigned:

Most Important Issues or Problems at Present:

Time, Place, and Agenda for Next Meeting:

Figure 4
Meeting Report Form

13. REFERENCES

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