

Teaching and Assessing Teamwork Skills in Engineering and Computer Science

Robert W. Lingard
California State University, Northridge
Northridge, CA 91330-8281

ABSTRACT

To be successful in today's workplace, engineering and computer science students must possess high levels of teamwork skills. Unfortunately, most engineering programs provide little or no specific instruction in this area. This paper outlines an assessment-driven approach toward teaching teamwork skills. Working with the Industrial Advisory Board for the College, a set of performance criteria for teamwork was developed. This set of criteria was used to build an assessment instrument to measure the extent to which students are able to achieve the necessary skills. This set of criteria provides a clear basis for the development of an approach toward teaching teamwork skills. Furthermore, the results from the assessment can be used to adjust the teaching techniques to address the particular skills where students show some weaknesses. Although this effort is in the early stages, the approach seems promising and will be improved over time.

Keywords: Teamwork, Group Process, Assessment, Peer Evaluation, Performance Criteria.

1. INTRODUCTION

Although it is commonly recognized by educators and scholars alike that to be successful in today's workplace high levels of teamwork are necessary, most Engineering and Computer Science programs provide little, if any, instruction in this area. Employers often report that new hires typically do not know how to communicate and that they have insufficient experience and preparation for working as part of a team. Yet little has been done to effectively address this issue. Most engineering and computer science education focuses on individual contributions rather than on managed group efforts; however, such groups are the norm in industry.

This is hardly a new problem either. In his 1992 article on "Educating a New Engineer," Peter Denning states that "a student must learn not only the technical side of engineering, but also skills of listening, completing and communicating." [1] Although engineers and computer professionals are stereotypically viewed as introverted independent specialists, it is important that students in these fields "learn the skills for working effectively as members of groups." [1]

For some time the Accreditation Board for Engineering and Technology (ABET) has emphasized teamwork skills in the criteria for accrediting both computing and engineering programs. Specifically, the engineering guideline states that graduates must demonstrate "an ability to function on multi-disciplinary teams" and the computing guideline requires "an ability to function effectively on teams to accomplish a common goal." [2]

Unfortunately, as Simon McGinnes states in regard to teaching information technology, "the skills of communication and collaboration . . . have often been undervalued in computing courses." [3] Similarly, Karl Smith observes that in engineering courses, "seldom is there explicit attention paid to helping students develop teamwork and project management skills." [4]

Although many universities have recognized the need to assign group projects and have begun efforts to improve engineering and computer science curricula in this regard, students seldom receive any specific training on how to function collaboratively before such assignments are given, and little attention is given to how teams are formed. Consequently, teams often fail to function effectively. More importantly, students do not learn much from participating on dysfunctional teams and often develop negative views about the value of teamwork. [5]

Teamwork is a well researched topic, and skills are taught and refined through university courses in communication studies and by consulting organizations working with industry. It seems that most engineering and computer science programs rely on these outside sources of instruction, assuming that students learn these skills elsewhere. They assume that all that needs to be done is to give them the opportunity to apply their teamwork skills to relevant problems in the field. Such is not the case. Most engineering students are ill prepared to function effectively on teams before they are asked to do so in a course. To solve this problem engineering programs must directly address the teaching of teamwork skills. This is the only way to insure the delivery of graduates with the necessary level of teamwork abilities and attitudes.

The fundamental question is, therefore, how do we effectively teach teamworking skills? Within the College of Engineering and Computer Science at California State University, Northridge (CSUN), we began to gain insight regarding this in an indirect way. Because of ABET's emphasis on assessment in accreditation, we began a rigorous program for assessing student learning outcomes. [6] Since teamwork was one of those outcomes, we needed to develop an approach to assess our students' ability to function effectively on teams. It was through this effort that we began to understand which teamwork skills needed to be taught and how to teach them.

2. ASSESSMENT-DRIVEN TEAMWORK SKILLS INSTRUCTION

Like the current trend in software engineering toward "Test-Driven Development" in which the development of test cases precedes the development of the code, we propose a similar approach toward teamwork education and training. Instead of assessing teamwork after we have developed an educational approach, we look at how to assess teamwork and then develop the methods of teaching it. Focusing on assessment first forces us to carefully consider what we mean by teamwork. In other

words, we must first develop an operational definition, or set of performance criteria, for teamwork.

Since one of the primary goals of virtually all of our programs in engineering and computer science is to prepare students for the workplace, the obvious strategy was to involve our Industrial Advisory Board in helping to define the meaning of teamwork. In meetings with a committee of board members it became clear that from an industry perspective, teamwork could be assessed in two different respects: how well teams function as a whole, and how well individuals perform on a team. Although the first is certainly important, our main interest was in the second since we wanted to develop the individual skills of our students.

In concentrating on the individual skills needed by the graduates of our programs, we developed the following list of abilities each student should achieve:

- Attend meetings and arrives 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
- Seems committed to team goals
- Show respect for other team members
- Distinguish between the important and the trivial

3. HOW TO ASSESS TEAMWORK SKILLS

Previous studies have shown a strong correlation between teams' self evaluation of effectiveness and project success [7], but this does not help much when it comes to assessing the effectiveness of individual team members. Assessing individual teamwork skills is difficult. One may be able to see individual teamwork skills in a basketball game, but student engineering teams work over long periods of time both inside and outside the classroom. A more comprehensive approach is needed to accurately assess the individual teamwork skills of engineering students.

Based on our operational definition of teamwork, we can address the most effective way to assess it. Although there are undoubtedly more, we have identified three main approaches toward teamwork assessment: independent observation, evaluating individual contributions, and peer reviews.

The first of these, independent observation, requires that the instructor, lab assistant, or outside observer attend team meetings or other activities and assess individual performance against the established criteria. While this can provide an unbiased assessment of performance, the fact that the team members know that they are being observed might influence

their behavior. This approach is also limited since observation is only practical for activities such as team meetings. Teamwork involves much more than what goes on in meetings. Although this is certainly a useful tool in assessing teamworking skills, it is not sufficient.

The second approach involves evaluating the evidence of the individual team members' contributions. One method of doing this is to require that each team establish an online discussion group for communication among its members. The instructor can then monitor the contributions to the discussion group and evaluate the contributions of each individual based on the performance criteria established. The advantage of this approach is that although students still know that the instructor or others are monitoring what they say online, it does not have nearly the impact of an observer sitting in during a face-to-face meeting. Other evidence of individual contribution can also be examined, such as documents produced or code generated. This approach, however, is limited, as well, since not all team skills can be assessed based on the artifacts produced by the individual students.

The third approach is to conduct peer reviews. In this approach each team member evaluates the performance of the other members of the team based on the criteria established. To be most effective these evaluations should be anonymous. In the method used at CSUN, each team member is given a team evaluation form in which each team member's name is written across the top and a series of yes/no questions, based on the teamwork criteria, is asked about each team member (see figure). All members evaluate themselves along with the rest of the team. This way the form remains anonymous. This approach has several advantages. First the team members are in the best position to evaluate the performance of their teammates since they work with them continually during the course of the team project. They are the ones who are dependent on the contributions of others. Furthermore, all of the performance criteria can be evaluated in this manner. The main disadvantages of this approach are that students are often reluctant to negatively criticize other students, so the reliability of this measure suffers.

In spite of the limitations of each of these methods, when used together, they can provide an accurate picture of each student's individual performance with respect to the identified teamwork skills. Furthermore, if students know more precisely how teamwork is defined and evaluated, they will strive to learn and practice the identified skills.

4. DEVELOPING A TEACHING APPROACH

It is interesting to note that these assessment techniques can be applied regardless of the extent to which the teaching of teamwork skills has been specifically addressed in the program. In fact, the results of the assessment can help to identify the areas where instruction or additional attention is needed. This is the essence of what is meant by assessment-driven teamwork instruction. That is, the teaching of teamwork skills is focused on those aspects that seem to be most difficult for students based on the assessment results. The following sections describe some specific teaching techniques that have been found to be effective.

TEAMWORK ATTRIBUTES	Member 1	Member 2	Member 3	Member 4	Member 5
Did the Team Member. . .					
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
Teamwork Evaluation Form

The Group Process and Group Roles: Many of the difficulties students have are a result of not understanding the group processes and the roles that are played by the group members. Specific instruction on group process and roles can be provided, and students can be asked to participate in role playing exercises. When students are given specific roles to play (initiating, seeking information, giving information, questioning, clarifying, summarizing) and a problem to solve, they gain an appreciation for the various roles. When an exercise like this is done in front of the class, all students see the importance of each of the roles. An excellent guide explaining the group process is available online from the Derek Bok Center for Teaching and Learning at Harvard University. [8]

Developing Individual Skills: A teaching approach called “Think, Pair, Share”, developed by Frank Lyman at the University of Maryland, is an effective way to enable students to practice individual teamwork skills and get immediate peer feedback. Students are asked to think of possible solutions to a problem on their own. Then they collaborate with one other individual in the class comparing their results (pairing). Optionally, these pairs can then be combined with other pairs forming larger groups who examine all the results and arrive at a consensus solution. Each of the larger groups then shares their consensus results with the rest of the class. This exercise helps to develop both communication and collaboration skills

Oral Presentations by Teams: Requiring each team to present intermediate results to the rest of the class provides a way for the team to get some early feedback on their project. If each member of the team is required to give part of the presentation, individuals have an opportunity to practice their communication skills early in the course which may help to improve their participation in subsequent group activities.

Meeting Reports: Requiring each team to document meeting times, members present, and project accomplishments helps to encourage participation. These meeting reports should contain a record of decisions made, action items, assignments made, and other project related information. If students know that these reports are evaluated by the instructor, they are more likely to contribute in meaningful ways during the meetings.

Reflective Process: Students can be asked to reflect on the group process and the technical difficulties they had in designing their project. Class time can be spent sharing information and discussing how to improve the group process. At the end of the semester students can be asked to answer in writing a series of questions about the problems and benefits of the team project. Such reflection can help to improve individual teamwork performance on future projects.

Approaches to Problem Solving: Different individuals have different approaches to problem solving. These differences can often interfere with the group process. Each individual may think their approach is the only right way to proceed, when in fact a variety of approaches can be one of the advantages to a team effort. If students can be made to understand the approaches of others and their advantages, conflicts can be avoided. There are several instruments that can be utilized to evaluate individual tendencies, and the results for all team members when shared can help each to appreciate the approaches of others. One such instrument is the Kolbe A™ Conative Index [9] which provides specific information which is useful in teamwork situations. In particular, this index helps individuals to understand their instinctive methods of operation and those of others. This understanding helps to create a more effective group process and fosters greater team synergy.

5. CONCLUSION

In conclusion, serious attention should be devoted to teaching teamwork skills in engineering and computer science education. The importance of teaching communication and teamwork skills is well understood, but finding effective teaching strategies and meaningful ways of assessing those skills are challenging tasks. Formulating and utilizing an operational definition of teamwork can both simplify the task of assessment and provide guidance in the teaching of these necessary skills. Furthermore, the results of teamwork assessment can be used to improve the teaching of individual skills. The work described here is preliminary, and more effort is required to evaluate its success. The peer assessment instrument described is being used for the first time this semester. We will be using the results of this evaluation along with other assessment data obtained from observations student work products to make recommendations for improving the teaching of teamwork skills within the College.

6. REFERENCES

- [1] Denning, P. J., "Educating the New Engineer", **Communications of the ACM**, 35 (12), pp. 83-97, ACM, 1992.
- [2] Accreditation Board for Engineering and Technology, Inc., "Criteria for Accrediting Engineering Programs", www.abet.org/, ABET, 2009.
- [3] McGinnes, S., "Communication and Collaboration: Skills for the New IT Professional", www.ulst.ac.uk/misc/cticomp/papers/mcgin.html, University of London, 1995.
- [4] Smith, K. A., "Strategies for Developing Engineering Student's Teamwork and Project Management Skills", **Proceedings, 2000 ASEE Annual Conference**, Session 1630, ASEE, 2000.
- [5] Swan, B. R., et al. "A Preliminary Analysis of Factors Affecting Engineering Design Team Performance", **Proceedings, 1994 ASEE Annual Conference**, pp. 2572-2589, ASEE, 1994.
- [6] Lingard, R. "A Process for the Direct Assessment of Program Learning Outcomes Based on the Principles and Practices of Software Engineering", **Proceedings, 2007 ASEE Annual Conference**, Session 2582, ASEE 2007.
- [7] Lingard, R. and Berry, E., "Improving Team Performance in Software Engineering", **Selected Papers from the 11th International Conference on College Teaching and Learning**, Chambers, C. (ed.), Florida Community College at Jacksonville, 2000.
- [8] Derek Bok Center for Teaching and Learning, Working in Groups, <http://isites.harvard.edu/fs/html/icb.topic58474/wigintro.html>, Harvard University, 1997.
- [9] Kolbe, Kathy, **The Conative Connection**, Addison-Wesley, Reading, MA, 1990.