AC 2011-1834: STUDENT TEAMS, A SIMULATION OR A REAL TEAM EXPERIENCE?

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Student teams, a simulation or a real team experience?

Abstract

The tradition in engineering education places students in teams during their senior year; likely as part of a capstone laboratory or design course. In most cases teams were done on a “pick your own partners” basis. Furthermore, no time was spent discussing teamwork, the importance of teams, how teams should be structured or the skill set one needs to be an effective team member. To some extent, changes made by ABET to their accreditation criteria in 2000 have forced the engineering community to at least assess student teamwork. This, in turn, has motivated many to take a serious look at teamwork training as part of what they teach. How to structure and provide real team experiences for students as part of the academic course of study is a subject of great importance. What do students know about teamwork coming in? What is their perception of the course-based team experience? Why are student teams frequently dysfunctional? Are course-based teams only a simulation or are they in actuality teams? These and other questions have been explored along with ways to enable effective team-based learning experiences that indeed help students grow as team members.

Introduction

The historical perspective on teamwork in the engineering curriculum is one in which teamwork was a somewhat obligatory activity that was relegated to either the capstone laboratory course or senior design or at best, both. Therefore, those of us that graduated prior to the introduction of the ABET Engineering Criteria 2000[1] would likely have received no formal teamwork training during our academic studies. With the introduction of the accreditation requirement by ABET, which states that, “Engineering programs must demonstrate that their graduates have an ability to function on multi-disciplinary teams.” the academic community has taken teamwork somewhat more seriously. The “multi-disciplinary” requirement aside, demonstrating that our students “have an ability to function on teams,” is a daunting challenge on its own. Furthermore, in surveys conducted by the author, student responses reveal that many students (about 1/3) think that course/lab related teams are a “simulation,” that is, they are not actually real teams. For clarity, a “simulation” is a depiction of reality, not reality; the equivalent of play acting or interacting with a computer game; it’s *World of Warcraft*[*], not really war; if you get killed in a simulation, you don’t really die. If we want students to be prepared to perform well on teams from day-one on the job, we must not permit students to think that course/lab related teams are simulations or to treat them as such. The following discovery-based team training strategy is an attempt to change this and other ineffective classroom teamwork perceptions.

[*] *World of Warcraft* is a fantasy video game involving warfare.

So, how should we conduct team training? What do students know about teams on the way in? Does anything we do actually make our students better team members? This paper endeavors only to address the first two questions. While an extensive student performance-based assessment of teamwork is done across the curriculum, this paper will only look at how to introduce students to teamwork using a discovery-based pedagogy that enables students to realize that "student teams" are "real team experiences" not "simulations" and that teamwork is a skill that can be developed and must be practiced and not just something *they will do when they get a job*. Limited course-level assessment is also discussed.

Context

In Department of Chemical Engineering at Tennessee Technological University (TTU), teamwork is a pervasive device used to both train students to become better team members and to enable them to learn in collaborative settings. With this in mind, teamwork is introduced at the freshmen-level in both the Departmental freshman offering (a Departmental and University *orientation* requirement) as well as in the freshmen Basic Engineering (BE) courses, one or more of which are required for all students. Although formal teamwork training is provided as part of the freshman BE course, Chemical Engineering students taking our Bio-molecular option are not required to take this course, amounting to about 1/3 of our students. Formal teamwork training is introduced to all Chemical Engineering students at the sophomore level as part of our integrated introduction to chemical engineering analysis course, a four semester hour course on material balances that utilizes an integrated lab and theory concept that is broadly applied across our curriculum[2]. From this point on, some form of teamwork is required in virtually all departmental courses including many of the electives, some of which involve true interdisciplinary interaction. The focus of this paper is on the formal teamwork training that is done at the sophomore level. The pedagogical foundation for this work is based on concepts introduced by Arce[3] and modified by the author. These foundations emphasize:

1. a discovery-based environment[4] wherein the instructor enables student inquiry,
2. that students must have a firm definition of what a team is and that definition must be restated by them again and again,
3. that students must acknowledge that team behavior is a skill that can be developed and learned in as much as playing a sport or musical instrument can be learned and refined,
4. that students must learn to recognize what the characteristics of a team is,
5. that students must learn to recognize good teamwork behaviors and counterproductive team behaviors,
6. that students must identify with a team-established *agreement of responsibilities*, and
7. that the instructor must repeatedly reinforce good team practices and that team behavior is a skill.

A few words about discovery-based learning are appropriate at this point since it makes up the primary pedagogical tool. Discovery-based learning places the responsibility for learning with the student and places the instructor in the role of a coach[5], rather than the locus of all knowledge from which information, answers and edicts emanate. In a discovery-based learning environment, the instructor provides questions to be answered, instruction on critical thinking and feedback to students to affirm correct inferences and choices and usage of theory and to correct incorrect thought processes. The instructor's challenge is not to develop elegant lectures that are compelling and energetic, but rather to provided challenges and opportunities for students to find answers by a variety of methods, including collaborative, team-based interactions that utilize the *collective mind* of an ensemble of individuals, e.g. the team.

Finally, it is notable that no one can spend an entire term doing teamwork training, although it might be that we should. The activities described here are conducted over the course of the term, however, require no more than one or two three-hour lab sessions at the beginning of the term, followed by revisiting of concepts or introduction of new elements on an ongoing basis throughout the term requiring 15 to 30 minutes of lab or classroom time from time to time. If the course is not associate with a lab, then the instructor might sacrifice a bit of class time and may have to cut the training down to fit the available time. A more preferable approach would be to add a 1 hr lab to a targeted course wherein formal teamwork training would be conducted. This should be a course early in the curriculum. A 3hr course might be divided into 2 cr hr lecture plus 1 cr hr lab and the lab can then be held in a required 1 ½ or 2 hr time slot. Realistically, even though the ABET Engineering Criteria 2000 is clearly an industry driven accreditation schema, even industry does not spend much time actually training employees to be team members. Most Fortune 500 companies offer some form of formal team-based training for their employees, however, in most cases it involves a few day workshop in a retreat setting after which employees are sent back into the field, possibly no better prepared. With the advent of Engineering Criteria 2000, it is now, at least in part, the academic community's responsibility to provide requite undergraduate teamwork training or at least assess for teamwork skills at some level.

What students know about teams and teamwork

It seems rather important to learn what our students know about a subject prior to engaging them in an activity. After all, many courses have prerequisites, which we assume prepare our students for what we plan to teach. What do students know about teams and teamwork coming in? Hunter, et al[6] asked this question to 344 students (mostly freshmen) at TTU. The results suggest that even freshmen claim to have some level of prior formal teamwork training and considerable exposure to teamwork through extracurricular activities. Their prior experiences with teamwork, however, appear to be rather neutral, though 83% reported having been involved in a "prior successful team project."

To see how students at the sophomore level respond, an independent survey was given by the author, seeking information regarding prior teamwork exposure and experience with team-based activities. Somewhat consistent with Hunter, et al, student responses indicate that virtually all students have team-based exposure and most claim to have had some formal teamwork training. Surprisingly, when poled in a workshop setting, students identify extracurricular team training such as scouts (boy or girl) and sports rather than the formal teamwork training that they received as part of their freshman BE experience.

To ascertain additional information, students are led through a small group (three to five students) discovery-based activity wherein they are asked to respond to the following questions or tasks in the order listed here:

1. What are the characteristics of a "group," and a "team?"
2. Give some examples of groups and teams.
3. Write your own definition for what a team is.
4. What are the characteristics of good team dynamics?
5. What are some obstacles to good teamwork?

Not surprisingly, students clearly come into their sophomore year with a very good understanding of the difference between a "group" and a "team" and can identify groups and teams easily and even debate questionable examples with compelling arguments. Virtually every student workshop group writes a definition for the noun "team" that includes some of the following elements; a small number of people, common goals, shared responsibility. In conclusion, these students entering sophomore year in chemical engineering, know how to identify what a team is.

The discovery-based activity should conclude with validation so that what was discussed is internalized, therefore, student written definitions for what a team is are compared to an accepted definition. While there are many definitions available, see Brannick[7], some of which are lengthy, the following succinct definition is used:

> ***team****, a small number of people working together towards a common goal with shared responsibility.*

Notably, however, the definition of team is somewhat context sensitive, e.g. how large is the task and how many individuals might it require to get it done. In a follow-on activity, students are challenged to think about good team behaviors and obstacles to good teamwork and are asked to respond to questions (4) and (5) above. This activity is very revealing and helps both the instructor and students to focus on team dynamics and provides an entry point for discussing teamwork. Students can always list many times more obstacles to good teamwork than they can good team behaviors. If the activity is handled correctly, students will discover, that is, they will come to the realization, that good team dynamics require hard work and deliberate training on the part of the team members. A typical list generated by students during this activity is shown in Table 1. Keep in mind, this list is produced by students, and the list of bad team dynamic behaviors is even longer with some surprising insights.

Table 1. List of good and bad team behaviors generated during discovery-based teamwork activity.

Good Team Behaviors	Bad Team Behaviors
organization	disagreement
leadership	scheduling
united	communication (lack of)
mutual goal	selfishness
cooperative	poor work ethic
	lack of leadership
	differing levels of commitment
	contrasting views
	personality conflicts
	laziness
	sabotage
	procrastination
	rivalry
	meeting attendance
	accountability
	lack of focus
	attitudes
	egos
	work distribution
	gender difference

While students have a very difficult time identifying with good team behaviors they have no trouble describing ways to go wrong. When leading a discovery-based activity such as this, the instructor should utilize student responses to extend the depth of understanding by requiring students to find ways in which at least some of the bad team behaviors might actually be utilized for the benefit of the team. For example, “disagreement” is not always a bad thing. In fact, disagreement can be a good thing when focused and used correctly. Disagreement can lead to a higher understanding of the subject if combined with useful, moderated, focused debate and mutual trust and respect, both traits that many students miss when generating the good team behavior list. When training students about team dynamics, use their negatives to coach them to discover why *difference* is actually a good thing in teams. This activity can be used to lead into, how teams are picked.

Course teams, real or simulation?

Unfortunately, many students feel that teamwork in their course or lab is not real, that it is like play-acting, that it is only a simulation of reality. It is your job as instructor to persuade them to change this ideal. Do not introduce any concepts that would make them believe such nonsense, e.g. you will play roles, for this project your role on the team will be, etc. This type of language will perpetuate the simulation belief. So, why is the simulation concept anti-productive? If students believe it is a game, they will not deliver. So, why is the course or lab team not a simulation, after all, it isn't the "real world," is it? To answer this, question students about what is at stake to their team and therefore to them. It will take about ten seconds for those students that believe that course teams are real teams to answer, "my grade." That is all you need. Every student in the classroom will agree that their team outcomes are connected with an important real world assessment, their grade. Now, it might be that you have students that do not really care about their grades, there is nothing you can do about that. What have you achieved by this exercise which likely seems like a waste of time? If done correctly, and if "punctuated" in the right way by you, the instructor, with a stern posture, many of the students that thought that the course team was a simulation will now agree that it is not, and you have achieved a great victory on their behalf.

***Picking* teams**

Students universally will choose to pick teams of their own making and will always choose to work with friends. In the real world, however, teams will not be picked this way. Indeed, your colleagues may be your friends, but frequently, friendships develop after individuals are put together to function on a team of some description. Teams are chosen and assembled to serve a purpose and the *organization* determines who will serve. To enable a realistic environment in which teams can be chosen objectively and with purpose, students are coached by the instructor to discover how real world teams are formed. When ask the simple question, "How do you think teams will be formed in real world situations?" students quickly suggest that they will be picked based on skills. The objective of the discovery-based approach is to have such conclusions come from the students rather than be imposed by the faculty. Skills are indeed the basis upon which individuals are selected for teams. Skills may include many diverse characteristics and are not always literal skills such as, good computer programmer, or good experimentalist, but might include personality traits, e.g. Tom is very outgoing, cultural diversity, e.g. Rebecca was born and raised in Spain, or experiential perspectives, e.g. Henry has been with the company for a long time. Once students buy into the fact that, in the real world, teams will be chosen based on skills, they quickly come to the conclusion that it might be best to pick their class teams based on skills as well; after all, the class team is a real team, not a simulation.

The next question in the discovery sequence is, "How might an employer pick new people to join their workforce team?" While in most cases an employer will know their employees, in the classroom setting, not every student will know every other student and so it helps to frame this activity in terms of *new hires*. Students always arrive at the conclusion that a resume would be a good idea.

Students are required to prepare a one page "functional resume[8]." The concept here is; the resume should match the "function" of the job you are applying for. The job description, in this case is for a position on a team that will be conducting chemical engineering laboratory experiments related to mass continuity, thus, students are asked to develop and agree upon resume content.

Once the resumes are collected, names are removed and each resume is associated with a number. From among the students, the instructor selects a subset of students to review the resumes; this is the only element of selection that is to be done by the faculty. This select group of students then competes to *hire* (*employ*) students for their teams. Note that it is not necessary for the selected group of *employers* to be team captains or leaders; that will be decided later by the team members once teams are established. The instructor should simply select students based on any criteria he or she likes, the author typically chooses students that he feels will engage and honor the process of "hiring" a team and includes diversity in the select student group as best as possible given the student body demographics. The instructor should provide some guidance for the group of *employers*, encouraging them to be "honest" to the process, to hire based on skills and to avoid the temptation to defeat the process by identifying resumes that belong to their friends since such is difficult to avoid. Sauer and Arce[8] describe a similar process, however, in their original rendition of this concept students applied for "jobs" rather than were selected from the entire pool of students in the course.

Teams selected this way are more diverse, are assembled with student input and in a way that is consistent with practices that will at least in some cases be used in the real world. A post-course survey of the students chosen to select teams (the employers) reveals that they engage the process, take it seriously and feel that it is fair and representative of real world practices.

Team awareness

Priest[9] reports that teamwork training in corporate settings does improve team performance and is more effective when it includes periodic follow-up activities. These findings are extremely important since as educators we ask ourselves, "Does all this teamwork training really matter?" The answer is, yes, it does, but what we do also matters. It should not surprise us then that without repetitive reaffirmation that teamwork skills must be practiced and that they are skills that can be cultivated and developed, student teams will quickly regress into small groups or worse, they will fragment and become ineffective. To maintain team awareness, it is critical that the instructor interject various team related activities throughout the term and subsequent to the more intensive workshops conducted earlier that semester or quarter. Activities used by the author include mid-term progress reports, a brief proposal developed for at least one of the laboratory related assignments and meeting minutes. As with all of the discovery-based activities, it is best to have students develop a template for their meeting minutes. Most will not be familiar with what "meeting minutes" are, and so some discussion with students is appropriate. This is an excellent way to include a 10 or 20 minute mini-workshop mid-term on teamwork awareness.

Team co-responsibility

Above and beyond all, in the opinion of the author, it is critical to enable students to realize that "a small number of people working together" are not a team unless they have shared responsibility for outcomes. Larsen and LaFasto[10] report that there are three major pitfalls responsible for ineffective team performance: (1) lack of a unified commitment; (2) lack of external support and recognition; and (3) lack of collaboration among team members. While anecdotal, the author's experience is that student teams are frequently ineffective because of a lack of a unified commitment and collaboration among team members. Students must come to the realization, on their own, that they, as team members, must share the responsibility for the outcomes. As the instructor you must lead a discussion session or workshop that will enable students to discover this ever important element that will empower effective teamwork. Telling student that "team members share responsibility," is like a parent trying to get a teenager to believe that middle-aged people actually know *something*, so don't do it. Discovery-based learning is all about student discovery, not teacher pontification. When students discover for themselves, they will be more likely to buy-in. This is not necessarily as important when the subject is the Ideal Gas Law, but when it comes to controversial subjects and topics that are difficult to quantify, especially when students will resist, as they frequently do with teamwork, it is ever more important to get them to say *it*. Frequently, students will list "shared responsibility," in response to the Question (4) above (see "What students know about teams and teamwork"), note however, that it is not listed in Table 1 and so it is not necessarily in the minds of our students. Question students until you get what you want.

Once students realize that shared responsibility is key, ask them how to encourage and to enforce team norms which must foster shared responsibility. What will most employers require you to sign before you start working for them? How will your employer hold you "responsible" for the work you do with them? Ultimately, you would like students to realize that employers will requires a "contract" of one form or another, that is, some form of "Agreement of Responsibilities." While it is impossible to mandate that team members or employees be "responsible" to the team's objective or to the company's business, the contract (Agreement of Responsibility) is a way to formalize the commitment made when one joins the team.

Have each team draft their own Agreement of Responsibilities. Give them some guidelines such as: must fit on one page, must have each team members' name on it, must have spaces for each team members' signature, and must have a line on it for a witness' signature, name and date. The Agreement of Responsibility should clearly spell out what the team members' responsibilities are and what the consequences are for non-compliance. You will be surprised how most students will embrace this activity and how well crafted their Agreement of Responsibilities will be. A word of caution, do read each carefully since you will sign as witness and be sure that you endorse the language used.

***Observing* and *assessing* team performance**

Assessing team performance is possibly one of the most difficult challenges that we face as engineering educators. To objectively and authentically assess how well a team performs is not as easy as giving a written exam. Various authentic assessment strategies must be developed and then validated. And, while this paper is not about assessment, it is prudent to include at least some discussion and strategies that have been used, but admittedly have not been validated in the present context.

In their 1997 work, Brannick, et al[7] states that although teamwork is central to much that we do as a people, "there is still little known about the processes that occur within a team that help account for real differences in outcomes." Unfortunately, this makes it very difficult to know how to assess team performance. Nonetheless, considerable work has been done and methods to assess team performance have been proposed and tested widely. And, while there are many and varied ways to assess performance, among the frequently suggested strategies are meeting performance measures[11, 12], and direct measures of outcomes, e.g. did the team achieve its objectives. Rubrics associated with these two metrics as well as peer assessments have been used by the author in more than one course context.

Brannick, et al[7], suggests that there are likely seven key team behaviors that typify all teams: communication, orientation, leadership, monitoring, feedback, backup behavior, and coordination. They also define these metrics and suggest various ways to assign rubrics. To help to provide some degree of validation for the assessment strategy used, a mapping was developed to illustrate how simple assessment tools such as meeting minutes and observation, can be identified with research-based assessment logic such as Brannick's, et al seven key team performance behaviors. While this is an incomplete mapping, it illustrates how rather simple assessment tools, such as meeting minutes and observation, correlate directly to the behavioral factors that affect team performance. Even when only two assessment tools are used, in this case meeting minutes and direct observation, a complete mapping of all seven of Brannick, et al's key behaviors can be made.

Requiring that meeting minutes are take on occasion is a good practice and is an excellent assessment tool that can reveal the behaviors of both good and bad team interactions. Frequently, meeting minutes are returned with three out of five student names as "in attendance." Such should be used by the instructor to probe the reason for the absence. More often than not, a bit of investigation finds that the team is not functioning properly and offers an opportunity for the instructor to coach the team towards improved performance. A repeat meeting minutes assessment later in the term might also be used.

Table 2. Mapping of assessment tools to Brannick's seven key performance behaviors used here as team performance metrics.

Assessment Metric	Description	Assessment Tool		
		Meeting Minutes	Observation	Etc.
Communication	How well to team members communicate with each other?	X	X	
Orientation	The nature of the attitude that team members have toward each other.		X	
Leadership	Direction and structure provided by formal team leader.	X	X	
Monitoring	Each member must be competent at their task and each must have a substantive understanding of what others are doing.		X	
Feedback	Does the team adapt and learn from its own performance?	X		
Backup Behavior	Do team members help each other when necessary?	X	X	
Coordination	Do member respond as a function of the behavior of others?		X	

Direct observation of team interactions is also of great value and can be use qualitatively for coaching purposes and quantitatively if one chooses. Qualitative observation has been used by the author and has been found to be very helpful at assessing team dynamics and effectiveness. Teams are easily observed during classroom or laboratory workshops, either when computational, deliberation, or laboratory activities are being done. If agreeable, teams can be filmed or photographed. Candid still photos taken by a teaching assistant have also been found to be helpful at identifying ineffective team behaviors. Some common problems observed include: distracted students, e.g. using computer to surf or view Facebook or texting on cell phone during team meeting; unengaged students, e.g. a student that never contributes and works *off to the side* while others appear engaged; disconnected team, e.g. two or three or all members in a team of five are working alone; and total lack of leadership, e.g. team cannot achieve focus because there is no directed *energy*. In an inquiry-based setting, the instructor must deliberately observe and enable the teams; some teams will require individual coaching while others will function well on their own.

Peer assessments are surprisingly good tools and have been used by the author to help to quantify the contribution of individuals to overall team performance[13, 14]. Biernacki and Wilson[13] used the peer assessment tool to evaluate individual student performance in real interdisciplinary team environments. The author teaches a discovery-based interdisciplinary course entitled, "Interdisciplinary Studies in Ceramic Materials Processing," wherein teams of two to four Chemical and Mechanical Engineering students work together on a *product* design related term project to produce a material, e.g. recycled glass ceramic floor tile, and to characterize and test the product properties and performance. In this context, students clearly must apply their interdisciplinary background to achieve deliberately interdisciplinary results in the short fifteen to sixteen week semester. While the ChemE students typically do not have the background to conduct mechanical testing, the MechE's usually are unfamiliar with reaction processes, for example. The division of work is clear in most cases and the challenges apparent as students attempt to produce a product, define its characteristics and test its performance properties. Frequent team incompatibilities are observed, via methods described above. Since it is almost impossible to know who contributed what to reports or presentations, or even to lab work, a peer assessment is use. The strategy gives students 10×N points to be divided among the N members of the team. Each team member confidentially distributes the 10×N points. Table 3 illustrates an actual team assessment. Note the consistency in the way that each team member distributed the scores. One might expect that students will rate themselves higher than they should be, and while some artifacts of that sort likely occur statistically, the results are otherwise surprising and honest. Students know when they are not contributing or when they are and that becomes very clear when this tool is used. On occasion, teams will become divided. If used as a mid-term assessment strategy, this instrument can help the faculty to identify team division. Furthermore, this instrument provides a quantitative and documentable way for the faculty to scale grades based on extent of contribution to a team project, final report or presentation; see Biernacki and Wilson for more details[13].

As with virtually any form of self assessment, teams can deliberately defeat the instructor's attempt to use self assessment, meeting minutes or even written final reports as ways of ascertaining how well teams are functioning. The author's experience, however, is that team members will not cover for one or two that are non-compliant, in fact it is quite the opposite. Teams will honestly report that one or more member was not present or did not contribute. Such is a great point of entry for a mini-workshop on ethics. If one does not contribute, then they are not a co-author, students understand this and comply. If one is absent, then their name is not entered as present. Use teamwork as a vehicle to interject ethics or other ABET related content such as communications and even contemporary issues. Students that the author has worked with clearly self identify, gender, and even race, age and ethnicity as potential points of conflict within teams. Spend a few minutes during a follow-up mini-workshop to discuss these issues and take credit for it later during your ABET review.

Table 3. Peer and self assessment report for a cohesive team with one weaker contributing member.

	Score Given			
Score Giver	A	B	C	D
A	13	10	8	9
B	10	8	8	7
C	10	12	9	4
D	15	15	7	3
Average	12	11	8	6

Summation

Teamwork in the course/lab setting is controversial with students who frequently believe that it is a simulation; like play-acting. By using a discovery-based learning environment, it is possible to engage students in the process of teamwork by enabling them to realize what they already know and discover what they do not about how to define what a team is, how to identify good and bad team behaviors and that shared responsibility and a common goal is what separates "a small group of people" from a team. Students, in general, will buy-in when ideas and understandings emanate from their own thought processes. Teamwork is not a quantitative science and but rather a subjective process that many students do not like and have had prior bad experiences with. By empowering teams with an Agreement of Responsibility that spells out the commitment of the team member and the consequences for non-compliance, student teams can become self-governing and at-least have a starting point for developing good team behaviors and policing bad ones. Careful observation and requiring student teams to practice good team habits, such as effective meetings, can be used as authentic assessment tools and feedback measures for coaching teams to improved performance.

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