

Evolution of Student Attitudes Toward Teamwork in a Project-based, Team-based First Year Introductory Engineering Course

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Abstract

Despite the growth of team-based design projects in first-year engineering courses, more research is needed into student attitudes toward teamwork and the characteristics of team experiences that lead to improvements in student attitudes toward working in teams. This study is an exploratory investigation of student attitudes toward teamwork at three time points during a first-year project-based, team-based design course: before students have begun working in teams, after they have completed an initial small-scale design project in a 4- or 5-person team, and after they have completed a larger-scale design project with a different, similarly-sized team. The general classroom approach on teaching teamwork is discussed with details on the variety of teaching methods used to engage students in learning and practicing good teaming skills. The quantitative and qualitative results from the survey are discussed, and conclusions drawn as regards students' perceived fun, frustration, and learning to understand what factors influence students' perceptions of these three aspects of teamwork.

Introduction

Collaborative learning has become increasingly common in K-12 and higher education, and it is particularly prevalent in the field of undergraduate engineering education. The increased use of project-based learning allows instructors to more easily convince engineering students of the relevance of the theoretical knowledge they are learning in their math and science classes, leading to both enhanced motivation and increased student retention in engineering disciplines.¹ Recent research on student perceptions of teamwork indicates the importance of an overall positive attitude toward teamwork.^{2,3} Therefore, it is critical that a first year introductory engineering course provide a firm base of good teaming skills that will lead to a life-long positive attitude toward teamwork.

Student teams and collaborative learning

Project-based, team-based learning is necessarily collaborative learning. A strict definition of collaborative learning differentiates a collaborative project from one that merely requires cooperation. In collaborative learning, students work in groups to together develop a shared understanding of and solution for an ill-structured problem.⁴ Teachers are redefined as coaches helping students work toward a set of possible open-ended solutions, and students take some ownership of their own learning through reflection. Typically, students learn about team skills in addition to the course content. Engeström⁵ identified three stages characteristic of collaborative learning. In his view, for learning to be truly collaborative, students must (a) work towards a shared problem definition, (b) cooperate to solve the problem, and (c) then engage in reflective communication, reconceptualizing the process. Similarly, Johnson et al.⁶ argue that there are five basic elements critical for cooperative work to be effective: positive interdependence among team members, individual accountability, face-to-face "promotive" interaction (encouragement, sharing resources), social skills evidenced, and group processing.

Use of collaborative learning in undergraduate engineering programs

Project-based, team-based collaborative learning has increased in undergraduate engineering education worldwide.⁷ In fact, substantial use of collaborative learning is required for undergraduate engineering programs to be accredited by the Accreditation Board for Engineering and Technology (ABET), the overseer of U.S. engineering programs.⁸ As mentioned, collaborative learning allows instructors to more easily convince engineering students of the relevance of the theoretical knowledge they are learning in their math and science classes. It encourages students to transfer knowledge across contexts and leads to the development of cooperative skills, which are valued by the profession.⁷

Challenges of collaborative learning in undergraduate engineering programs

There are, however, downsides to the increased use of collaborative learning in undergraduate engineering programs. If not carefully designed and monitored, group tasks can allow students to freeload, receiving credit for a team accomplishment without contributing substantially to it.⁷ More commonly, students may find in group work the opportunity to specialize in particular tasks and avoid others (e.g., CAD modeling, report writing), an issue when course outcomes are assessed at the team-level but skills are developed at the individual level.

Though students perceive participation on diverse teams as “real world” and therefore beneficial,⁹ their behaviors and experiences on diverse teams can be more problematic.^{10,11} For example, students of different genders tend to take different roles on teams, with females more likely to complete project planning and communication work and males more likely to do technical planning and hands-on building.¹⁰ It is unclear in the research whether students choose to take on gender-specific tasks or are pushed by teammates into those roles.

Team discussions tend to privilege some students at the expense of others. In engineering programs, women and under-represented minorities are more likely than other students to express dissatisfaction with teamwork in practice, reporting that they feel unheard and marginalized.¹⁰

Student attitudes toward teamwork

In our experience teaching a first-year introductory engineering course, describing good teaming skills and facilitating teams have been some of the most challenging aspects of the position. We use a number of diverse methods to convey the complexities of team interactions and guide our students through team projects, and we desire to know how effective these methods are. For this reason, we decided to conduct this exploratory study to examine students’ perceptions of three aspects of the class as they relate to team experiences: learning, fun, and frustration working in teams. These three aspects can be a simple indicator of overall positive attitude toward teamwork, and the data gathered will allow us to understand what factors influence students’ perceptions of these three aspects. The results will be used to improve the class in leading our students to a life-long positive attitude toward teamwork.

Classroom Approach

One of the most difficult-to-teach aspects of engineering education is effective teaming skills. A first-year engineering course must open students to the idea of life-long learning and practice of teaming skills.

We utilize design-build-test (DBT) projects to provide a framework for instruction on effective teaming skills. DBT projects mimic real-world team projects;¹² they require student teams to design a product, build it, test the product, and report on the results.¹³ A DBT project is intense, requiring much effort, communication, and time management. There is a significant learning curve to this type of project; therefore, we have our students do two cycles of DBT projects as illustrated in Figure 1 on the next page. The first project is a blitz-type, two-week project aimed at familiarizing the students with the DBT method and our expectations for them regarding professional conduct, presentations, and reports. The second project is a five-week project requiring a significantly more complex product and multiple presentations and reports. This two-cycle approach allows students to learn from their mistakes in the shorter, simpler project and immediately apply the lessons learned to the major project in the class.

In our class, we follow our understanding of best practices for student teamwork from the literature, relying heavily on Oakley et al.¹⁴ We form teams of four to five students, and this team size is influenced primarily by the size of the project: This is an appropriately small team given the workload for the projects. Teams are assigned by instructors. We avoid stranding women/minority students, though we sometimes are unable to prevent this. “Ideal teams” are first devised for the longer project. The teams are then shuffled for the shorter project (with fewer of the recommendations followed for the short project). This process is described in more detail in Meadows et al.¹⁵

We use a variety of teaching methods to engage our students in learning and practicing good teaming skills, including: the use of peer mentors, an ice-breaker exercise, a teaming sketch, a moderated team meeting, and the CATME Peer Evaluation with grade consequences. We also use one-on-one meetings, classroom observations, team meetings, presentation rehearsals, and so on to facilitate teams. The primary teaching methods are described in the next sections.

Peer Mentors

Peer mentors play a vital role in the success of student teams.¹⁶ Our peer mentors are alumni of the class and provide guidance throughout both the DBT cycles. Peer mentors are required to attend weekly lab sessions and meet with their teams at least once a week outside of lab. Their responsibilities include guiding the team through the design phase, monitoring the build phase to ensure teams remain on schedule, providing feedback on draft presentations and reports, liaising between the students and the instructors, and assisting at the competitions. Peer mentors have proved vital in identifying and solving problems in team communication and behavior. They also provide students with a confidant who is not an instructor, should a student feel uncomfortable talking to one of us directly for whatever reason.

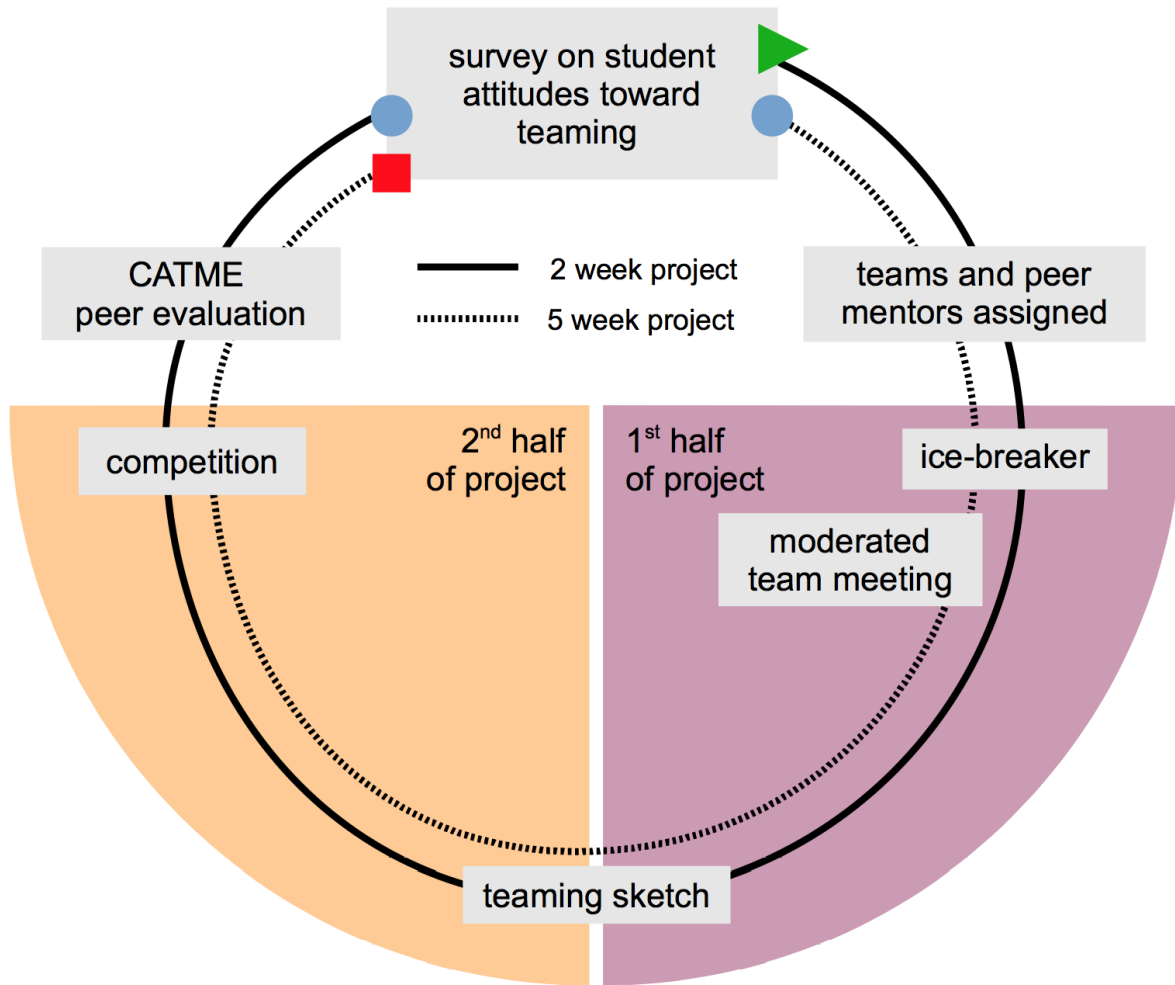


Figure 1. Illustration of the two Design-Build-Test cycles and our teaming strategies. The solid line represents the first (~2 week) DBT project; the dashed line represents the second (~6 week) DBT project. Teams are shuffled between projects, with the “ideal team” formed for the second, longer project. The survey on student attitudes toward teaming was administered three times: before the first project, immediately after the first project, and immediately after the second project.

Ice-Breaker

At the beginning of each project, we do an in-class activity with the team as an ice-breaker. Our particular ice-breaking activity for the first project is modified from a logic puzzle.¹⁷ The logic puzzle could be completed easily by a single person with pen and paper, but we have the teams work together without the benefit of writing things down. We believe the exercise is engaging and emphasizes effective communication. We debrief after the activity, encouraging students to consider their team’s communication style. Some semesters, we are able to anticipate and more quickly respond to issues with a team’s performance on the course projects because of patterns we first see in this ice-breaking activity (perhaps a student is ignored in the activity, or the group jumps in without considering alternative perspectives).

Teaming Sketch

Teaming skills are difficult to teach in a traditional lecture or discussion format. Theatre can be an excellent way to demonstrate human factors,¹⁸ such as the behavior of “good teammates” and “bad teammates.” Halfway through the first DBT project, we bring in a student theatre troupe to perform a sketch on teamwork.¹⁹ At this point, the students have had one lab period in which they are working in teams and have usually had another meeting outside of class to work on their presentation and report. Most teams have already experienced some kind of problem with miscommunication, a personality conflict, someone being late to a meeting, etc. The teaming sketch allows us to offload undesirable team behavior to fictitious people whom we can talk about without directing anything personally to a specific student or team. It is an incredibly useful teaching tool.

The teaming sketch is performed by a student theatre troupe and consists of meetings of a typical dysfunctional team comprised of three men and one woman. The actors assume stereotypical roles seen on engineering teams. Act 1 is the initial team meeting in which the team members struggle to communicate and ends by divvying up responsibilities to no one's satisfaction. An interlude relates the various problems the team members ran into with their assigned responsibilities. Act 2 reconvenes the team and demonstrates the necessity of communication, organization, and flexibility to successful teams. A discussion period after the sketch helps the students recognize the bad behaviors that can lead to poor team performance and then brainstorm ways to address or counteract those behaviors. A review sheet summarizing good teaming skills, as demonstrated by the sketch, is posted online to the students for their reference during the rest of class.

When we see a student or team exhibiting one of these undesirable behaviors, we can quickly and easily refer to the sketch to remind them of the consequences of that behavior. By saying, “It sounds like you might be being a little bit of a ‘Rob’” or “You might have a ‘Beth’ on your team,” we place the negative associations on the fictitious character and allow the student to more objectively view their behavior or the behavior of others. We can remove the personal feelings and thus help to defuse tension. We then have the student consult the review sheet from the sketch so they learn how to recognize both the bad behavior and remember strategies to correct or counteract that behavior. This unique approach gives students the skills they need to create more positive team experiences.

Moderated Team Meeting

Early in the second project, when student teams are in the brainstorming phase, we have teams meet online in a text-based chat environment rather than face-to-face. We are able to “observe” these meetings and the team dynamics, and this window into team functioning has sometimes led to further intervention with a team. The online team meeting also shakes up power structures on teams. Face-to-face, often a single student or a few students emerge as most vocal, and those students drive team decision-making. We have found that group conversations conducted via chat are more egalitarian, with greater participation from all team members. In particular, both female and non-native English speaking students, who participate at lower-than-average levels in traditional team meetings, show increased participation in online chat meetings. This research is presented in another session at this conference.²⁰

CATME Peer Evaluation

We use the CATME Peer Evaluation to assess five aspects of team contributions: contributing to work, interacting with teammates, keeping the team on track, expecting quality, and having knowledge/skills.²¹ Each student assesses their teammates and self in these five categories at the end of each DBT project. The assessment at the end of the first project is used both for practice in the assessment process and to explain how this peer evaluation allows a unique view into how one's behavior is viewed by one's peers. This evaluation is formative in nature.

The CATME peer evaluation is also used summatively, at the end of the second project, to help us better assign appropriate grades to the final team deliverables. CATME computes a scaling factor for each student on a team, based on the student's scores divided by the average team score. We use this information, plus our own knowledge of team functioning, to assign a scaling factor for each student, and the final team deliverables are multiplied by this number to create individual scores for the gradebook. The system is imperfect, but it is our best attempt at assigning fair scores to individual students based on the work of a team. In practice, we use the system conservatively, only penalizing students when we have converging evidence from peer evaluations, peer mentor perceptions, and our own observations in lab and team rehearsals to know that a student has dragged down a team. However, the threat of a low scaling factor decreases the likelihood of freeloaders on the course projects.

Student Feedback on Classroom Approach

Our diverse approaches to facilitating teams have evolved over many semesters, and we wanted to assess their effects on student attitude toward teamwork. Specifically, we decided to conduct an exploratory study to examine students' perceptions of their perceived learning, fun, and frustration on a team. These three aspects can be a simple indicator of overall positive attitude toward teamwork, and the data gathered will allow us to understand what factors influence students' perceptions of these three aspects.

Method

We created a short survey that asked students to describe their teamwork experiences before the course, asked them to rate their expected learning, fun, and frustration from learning via teamwork, and asked them about the experiences that influenced the ratings. Only responses from students 18 years or older were collected. There are six questions to the survey, and we include them here for reference:

1. Please briefly list the major teamwork experiences you've had in the past that have affected your attitude towards teamwork. (High school? College? Academic? Sports-related? Engineering?)
2. At this point in the class, what is your attitude toward teamwork? (Where 0=absolutely none and 100=the most I can imagine.)
 - a. the fun I have had/expect to have with a team
 - b. the frustration I have felt/expect to feel with a team
 - c. the amount I have learned/expect to learn with a team
3. What characteristics of a team or teaming situation, if any, have made your teamwork experiences particularly positive?

4. What characteristics of a team or teaming situation, if any, have made your teamwork experiences more negative than you would like?
5. (Skip until after the [first DBT project]). Was there anything specific about your [first DBT project] team experience that impacted your attitude about teamwork? If so, please describe.
6. (Skip until after the [second DBT project]). Was there anything specific about your [second DBT project] team experience that impacted your attitude about teamwork? If so, please describe.

This was primarily an open-ended survey allowing students to tell us about what they perceived as affecting their experiences on a few outcomes we thought were important. At three time points (Fig. 1), students were invited to complete this fully anonymous Qualtrics-hosted survey. No incentive was provided, and our response rates were unsurprisingly fairly low (n = 22, 22, and 24 students, respectively, for each of the three time points, of 55 enrolled in the class). However, we found the students reported several common experiences that influenced their fun, frustration, and learning in team environments.

Results

The quantitative results from Question 2a-c are shown in Figure 2. Our goals are to maximize fun and learning while minimizing frustration in order to encourage a positive attitude toward teamwork. In general, there are overall trends toward more fun and learning and less frustration by the end of the class.

While the data for Questions 2a-c is provided here in quantitative form for the sake of completeness, this information is suspect because of the small sample size and low response rate. The interesting findings are really from a close analysis of the open-ended feedback, which helps us understand what factors of the students' experience affect their perceptions of the fun they have working on teams, of the frustration they have working on teams, and of learning from teamwork.

Sources of our students' pre-existing attitudes toward teamwork

To provide us with a general understanding of what teaming experiences our students were bringing to our course, we asked students to describe the experiences have they had with teamwork in the past. It should be noted that the students surveyed were allowed to define teamwork however they chose—we did not limit their responses to a particular kind of teaming experience.

Perhaps because of this, the experiences upon which our students based their understandings and expectations of teamwork varied widely—by far, the most students cited high school sports, high school clubs or activities, and/or group work in their high school classes as having helped develop their pre-existing attitudes towards working in teams. A few students also mentioned high school jobs, community service organizations, and/or marching band as having been fundamental in shaping these attitudes.

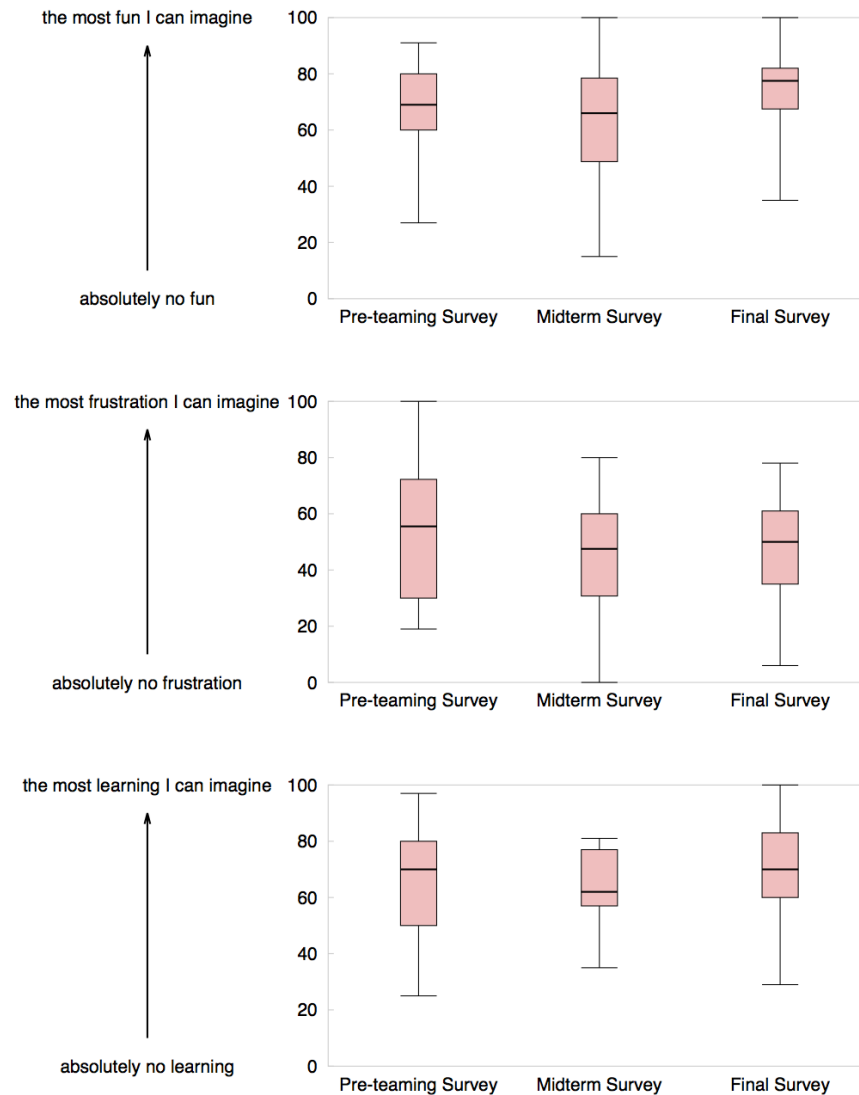


Figure 2. Student responses to Questions 2a-c (n = 22, 22, and 24 students, respectively, for each of the three time points). Our goals are to maximize fun and learning while minimizing frustration in order to encourage a positive attitude toward teamwork. No overall trends are evident, but this data is presented for completeness.

While this initial survey question about pre-existing teaming experiences intentionally did not invite a statement about whether those experiences had been positive or negative, several students included this information anyway, with a few students sharing positive experiences (e.g., the benefits of being on a team with dedicated, hardworking teammates; the value and satisfaction of working on a team to achieve a shared goal) and twice as many students recounting negative experiences (e.g., being the only person on a team willing to do any work; being on a team with a domineering member who took control of the project/activity; issues with conflict on assigned teams as opposed to self-selected ones).

Several students also mentioned their expectations that given the reputation of the engineering program and the high academic achievement and perceived commitment of their fellow freshmen, their experiences on teams in our course would be much more positive than their high-school experiences had been, with one student stating that he was certain that “the idiots who bring the team down are the same kinds of people who would likely never get into this school.”

Experiences that affected student attitudes toward teamwork during the first team project

As mentioned previously, we surveyed our students again after each of the two main team projects in our course, asking them to identify specific aspects of the teaming experience that impacted their attitude toward teamwork, either positively or negatively. After the first team project, the majority of our students’ responses fell into one of four categories: Shared goals and expectations; Ability to deal with conflict; Communication; and Conflicting schedules. These categories, and some of the specific examples cited by our students, are discussed in more detail below.

Shared goals

Many students provided examples of experiences where the goals of their teams were aligned in a productive way, or conflicted in a way that made progress and success more difficult. Several students referenced a shared excitement and/or enthusiasm for the project that seemed to benefit the team. One student stated that he/she was glad that despite the other members of the team not intending to major in Naval Engineering, “all of them were still committed to working hard on [their] project.” Unfortunately, another student apparently had the opposite experience, complaining that some members of his/her team were content to pass the class with a C- and weren’t willing to put forth more than the minimal effort required to achieve that.

Ability to deal with conflict

A team’s ability to (or failure to) productively deal with internal conflict also affected students’ attitudes towards teamwork. Several students attributed the success of their first project teams to their ability to work through disagreements quickly and effectively, instead of getting bogged down in unproductive arguments, while others described conflicts about design ideas that split the team into factions, each wanting to move in a different direction, which resulted in some members of the team putting a lot of effort into ideas that didn’t end up being implemented.

Communication

Several students who felt their teams had functioned well cited the fact that all members of their team had an equal voice and all contributions were valued (though it was unclear from the comments whether the students thought this a reason for the smooth functioning of their team, or evidence of that smooth functioning). Other students complained that on their teams, ideas and opinions were sometimes discounted or ignored, and that effort wasn’t made to make sure everyone had an opportunity to be heard during team meetings.

Conflicting schedules

While one student did mention the ability to deal with conflicting schedules as a positive aspect of the teaming experience, saying “our ability to work on the team report without dividing up

specific roles or meeting in person gave me hope that teams with varying schedules can still work together,” the majority of the students mentioned schedule conflicts did so to complain about the negative impact on the team. One student commented on the “selfishness” of one of his/her teammates who requested easier project assignments due to the time demands of the fraternity he was pledging and another student expressed frustration that few members of his/her team showed up to the optional “open lab” hours to work on their project outside of class. Another student complained that he/she felt bad at not being having the available time to go “above and beyond” like the rest of the team, and felt his/her teammates questioned his/her commitment to the team and the project as a result.

Experiences that affected student attitudes toward teamwork during the second team project

After the second and final team project, we again surveyed our students, asking them to recount any experiences, positive or negative, that affected their overall attitude toward teamwork. While the breakdown of positive to negative experiences remained roughly the same as we saw in the responses after the first project, the specific experiences cited were different, with only one category from the first project responses, Communication, making a return appearance, and three new categories (Dividing work evenly and fairly; Procrastination; and Personal Relationships) of responses replacing the previous ones. It’s unclear whether the issues mentioned in the surveys after the first project were still present but were deemed less significant, though it seems likely that the longer-term nature and increased complexity of the second project contributed to the development of different challenges with teaming. The four categories, with student-cited examples, are discussed below.

Dividing work evenly and fairly

As perhaps might be expected, given the increased workload of the second project, more students mentioned issues relating to the equitable division of work as influencing their attitudes toward teamwork. One student described the benefits of how his/her team divided both the building of and the reporting out on their design, saying that by dividing the building portion of the project evenly among the team members, it was much easier to evenly divide up the reporting, as well, since “it naturally forced the people that worked on that specific task to have to do the reporting portion due to their knowledge on the subject.” Not all teams were so successful, however; another student expressed frustration that his/her team had been unable to divide up the work successfully, and therefore ended up only making progress when everyone was present (which was difficult due to conflicting schedules). How the work was distributed was also a source of conflict: one student complained that his/her attempts to volunteer for certain aspects of the project were ignored, and that instead his/her tasks were assigned by teammates.

Procrastination

Many students expressed frustration at finding themselves or their teams waiting until the last few days before a deadline to make any real progress on project deliverables; one team found themselves in this situation despite having committed to starting the final project report and oral presentation a week early. Another student said that he/she had learned through this experience that procrastination can hurt a team’s chances of getting a good grade, while still another was

frustrated that the lack of motivation on the part of several team members to get started on main aspects of the project meant that the entire team failed to move ahead at a reasonable pace.

Communication

Several students recognized the importance of communication to their positive team experience, making general statements about the value of communication or how well their teams had communicated over the course of the project. Other teams, however, seemed to have more trouble with this aspect of teamwork, with students reporting that some opinions were ignored during team discussions, or that the team's ability to communicate effectively was inconsistent, as in this example: "There was communication throughout the competition, but then when things were pretty important, such as during times when we were practicing, communication lacked. It was frustrating at times when the communication skills of some team members were rough."

Personal relationships

Unsurprisingly, how well (or poorly) team members got along with each other also affected their overall attitudes toward teaming. Many students recounted positive experiences with the other members of their second teams, stating that they enjoyed their company and even spent time together socially as a team. Others complained generally of the disruptive nature of "more boisterous individual personalities," or seemed to relate well to all members of their teams but one; in several instances, one member of a team was called out as having sullied the overall experience by being difficult to work with, or, in one case, by "[trying] to take control when everyone else didn't agree with him/her." However, one student whose team experienced this sort of personality conflict described the experience as an opportunity to learn, stating that because "this group faced personality conflicts that I got to witness[, it] allowed me to gain experience with polar opposite teams while working in this class."

Conclusions

With twice as many unsolicited descriptions of negative perceptions of teamwork as positive perceptions, the pre-teaming survey suggests that many students hope, rather than believe, they will have better team experiences in college than in the past. The quantitative data shows a fairly wide spread of ratings on perceived fun, frustration, and learning with teamwork.

Midway through the class, after the first DBT project, perceived fun and learning has decreased from pre-teaming expectations. This is perhaps not unexpected as the first DBT project is a new experience, is short, is very intense, and sometimes uses less-than-ideal teams. We use it a little as a "wake up call" to college expectations, and the resulting stress of this is reflected in the quantitative scores and the qualitative responses. The open-ended comments focus mainly on the actions of "other students," rather than the student's own self. Interestingly, perceived frustration has dropped, which may indicate that methods such as the teaming sketch are effective at helping students avoid or correct team situations that lead to frustration.

In the final survey, after the second DBT project, there is somewhat of an improvement in perceived fun and learning, and frustration remains more or less the same from the midterm point. Of course, this improvement in student attitude toward teamwork may be partially attributed to the second project being generally more exciting than the first, but we hope that it is also due to

the skills we have given the students over the course of the semester. Many of the students' comments are more introspective than in the midterm survey. There are positive comments about opportunities to learn from difficult situations and negative comments about students' own procrastination. These types of comments, and others similar to them, reflect a maturing student that looks to themselves to improve their own skills in order to improve future teamwork experiences. This is the positive attitude toward teamwork we hope to instill in our students.

We plan to continue gathering data on students' perceived fun, frustration, and learning to understand what factors influence students' perceptions of these three aspects of teamwork. Our initial thoughts are that perceived fun is largely influenced by the DBT project used. If it is an interesting and challenging, yet do-able, project, the students will have fun with it. Perceived frustration is likely a function of communication, trust, and understanding between team members. Clear communication, trust in others' abilities, and understanding towards others' differences and commitments will reduce frustration. Perceived learning is likely also influenced by the DBT project but also by the student's general attitude toward teamwork. The DBT project should have enough breadth to interest students heading towards an array of engineering disciplines but still offer a large amount of potential learning to the motivated student. A positive attitude toward teaming allows the student to be open towards learning both technical and social skills. It may be, then, that increasing fun and decreasing frustration leads to a more positive attitude toward teamwork, which in turn may increase learning and reinforce a positive attitude.

Future work includes revising the survey to specifically ask about the effectiveness of each teaching method to determine which are the most effective or have the greatest return on effort invested. Other variables of interest are the students' prior team experience in K-12, the students' team experience in their other first year classes, and the effects of the DBT learning curve in going from the first cycle to the second cycle.

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