AC 2010-454: ORGANIZATION OF TEAMS FOR GROUP HOMEWORKS AND PROJECTS

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Abstract

This paper describes the organization of student teams in engineering courses developed over several years of the author's experience at multiple institutions. Students are assigned into groups of 3-4 students each for working on the homework. Homework problems are selected from a source other than the assigned textbook, since it has been found that as many as one-third of the students have access to the solution manual. All students in a group receive the same grade on the homework, and only turn in one copy of the assignment for the group. In order to help insure the full participation of all members of the group, on the day the homework is due, a quiz is given in class, in which one of the problems from the homework is randomly selected for the quiz problem, without any change to the problem. Selection of the students on teams follows best practices of grouping students from under-represented groups together. After that, students are grouped based on common interests gleaned from a survey given on the first day of class. In the group projects students are allowed to set their own responsibilities within the team. Typically one person will be in charge of the team budget, one person will conduct experimental testing, one person will be responsible for numerical modeling, etc. For the group projects each team is given an allocation of "Monopoly Money" that they use for purchasing supplies and paying for faculty and staff time to help them on their projects. At the end of the semester group project students give an evaluation of the performance of their teammates. Surveys were also given to students to assess the effectiveness of the team homework in helping them learn the material relative to working alone.

Introduction

The author has experience teaching both a state school with large enrollments in engineering with resulting large section sizes for required classes (as large as 100) and a private school where the section sizes are kept smaller (20-40 for required lectures). While at the private school it is expected that the instructor assign and grade homework on a regular basis in the undergraduate courses, at the public school, collecting homework was optional due to the large number of students. The author tried several strategies, including not collecting homework and giving students a list of "suggested" problems with the answers, collecting problems at random to grade, and assigning students to do group homework. Collecting and grading a large number of problems from all students at the state school was never attempted due to the large amount of work this would entail, when the majority of the instructor's time is to be spent on research. Repeatedly, when polled the students asked to have homework collected and graded, as they felt they needed the external motivation to help them study and keep up with the course material to be successful in the course. In response to students' requests to collect more homework balanced with the instructor's need to minimize grading time, a system of group homework has been developed over years of teaching. The methodology developed here was done for a junior-level fluid mechanics course, but should be generally applicable to most engineering courses.

To summarize, several different strategies for course organization and collecting homework have been tried:

- Individual Homework

- Group Homework
- Group Homework + Group Design Project

Note that while the use of student graders/teaching assistants does reduce instructor workload, the benefits are limited, as the instructor still has to work solutions, meet with graders, and collate results. In large sections, multiple graders will be needed, so uniformity of grading is also a concern. The team homework paradigm presented here can of course be done with graders, and the author has in fact done so.

It is highly recommend that an instructor **never** assign and grade homework from the end of chapter problems in the assigned textbook. During one semester, the author discovered that at least 30% of the class had access to the solution manual for the textbook. The discovery was made because there was an error in the solution manual, which was dutifully copied by the students. Apparently, one student had obtained access to the electronic copy of the solution manual, and burned multiple copies on CD, which the students were sharing with each other. It is not clear how the original solution manual was obtained, but author has heard a story about a professor at another university selling solutions manuals online through eBay. While it would be nice if all our students were perfectly ethical, it really is not reasonable to expect them not to look at the solution manual when it is freely and readily available, and it is unfair to grade the problems when part of the class already has access to the solutions and the other part does not. Since that time the author has picked homework problems from a textbook other than the assigned textbook (and of course not telling the students the source of the new problems). Textbook publishers are quite willing to send copies of alternative titles to instructors, so there is no shortage of sources for questions, and a different book can be used each semester. On one of his course evaluations the author did get the comment "there is no point in buying the textbook since you do not even use the end-of-chapter problems".

Literature Review

There is a large body of literature on teaming in general, though much less on the specific application of group work in engineering education. There is some disagreement in the literature on how teams should be constituted and the proper role of group work in classes, though the literature does seem to be unanimous that teamwork assignments do improve student learning, and of course an ability to work on multidisciplinary teams is one of ABET's required learning outcomes. The references cited below are not meant to give an exhaustive literature review, but show a sampling of the work done, with particular relevance to the current work.

Brickel et al.[1] studied groups of students that were arranged based on five different strategies – heterogeneous and homogenous GPA, heterogeneous and homogenous interests, and self-selected groups. The authors found that the method of group selection had only small effects on graded performance (with self-selected groups scoring the lowest), but had significant effects on the students' perceived quality of experience. While the self-selected teams may be more social than the other teams, "This type of group may actually encourage discontent about all aspects of the course (including the instructor)," and "Allowing students to select their own groups results in the poorest attitudes about the course, their instructors, the projects, their classmates, and other criteria."

Seat and Lord[2] note that while “complaints about the technical skills of engineers are rare…the quality of interpersonal, communication, and teaming skills… is of concern to both industry employers and educators.” These skills include “communication abilities, interpersonal interaction, conflict mediation, team performance, understanding of technical culture, and sensitivity toward diverse populations.” It is not surprising that the engineers more often have difficulty with the interpersonal skills rather than the technical skills, since, “An engineer’s critical skill is the ability to problem solve, and they tend to be field independent. Field independence theory suggests that problem solvers have an impersonal orientation, prefer non-social situations, and possess skills in cognitive analysis and structuring. The independent learner takes in information, internally assembles it into a pre-existing structure, and uses the information passed through the structure to solve a problem. Other characteristics of independent learners include poor interpersonal skills, exhibited by behaviors of withdrawal or isolation when in conflict. They are termed independent for a reason—they prefer to work by themselves to draw their own conclusions…engineers and scientists are often independent learners.” This reference also notes it is possible to successfully train engineering students in communication skills and group work.

Haag[3] notes that there is widespread interest in the retention and matriculation of female and minority engineering students. One effort to reform education with a goal of improving education to these groups is the NSF-supported Foundation Coalition. Some of the goals include “improvement of the interactions that affect the educational environment through teaming, … integration of subject matter within the curriculum, and the promotion of life long learning.” Some of the challenges in self and peer evaluations in group working include that “some students were reluctant to write critical comments about others fearing retaliation. Others were reluctant to reflect critically on their own attitude, behavior, and performance and have those comments voiced publicly during the focus group.” Haag also notes:

> “Although numerous studies have been done to assess the effect "gender ratio" has on a group and its members, the literature is inconsistent. Some researchers feel that increasing the proportion of females in a group will have a positive effect on its members. Others disagree and propose that an increase in female proportion in certain areas could have a detrimental effect. The Foundation Coalition female evaluation findings (including attitudes and implications), although more consistent with new research in other disciplines, are somewhat inconsistent with the paradigms and ideologies underlying current teaming practices in engineering education. We found that a higher proportion of females in teams did not have increased benefit, a finding consistent with current research in math, sociology, and psychology. Engineering teaming practice has been based on the assumption that an increase in female proportion helps.”

One concern is that when a minority student is placed alone in a group they feel like they are a token member, which has negative effects on group dynamics.[4] More recent research[5,6] disagrees with the point of view and argues that increasing the number of females (or other minorities) in a group will not have any beneficial effects. The Foundation Coalition also questioned female students after group work experiments and found that the women “1) were aware that they were being placed in a team in pairs, 2) were cognizant of research that prescribed at least two females per team, and 3) felt that faculty framed them according to their gender rather than their ability." The Foundation Coalition's literature also asserts that professors assign teams instead of letting students pick the teams and that it is preferable to avoid having a single representative of either gender or an underrepresented minority on a group. Team exercises should be designed that will require contributions from everyone and that could not likely be done by one of the team members on their own.

Felder and Brent[7] recommend to:

- Put students in teams of three or four people each. When students work in pairs, one of them tends to dominate, and in teams of five or more it becomes difficult to keep everyone involved.
- Collect one assignment per group.
- Try to form groups that are heterogeneous in ability level.
- Avoid groups in which women and minority students are outnumbered.[8,9]
- If at all possible, select the teams yourself. In one study, most students surveyed said that their worst group work experiences were with self-formed groups and their best ones were with instructor-formed groups.[10]
- Do not assign grades on a curve - The only way cooperative learning will work is if students are given every incentive to help one another.

This reference also notes the benefits of positive interdependence, individual accountability, face-to-face interactions, and the appropriate use of collaborative skills.

A recommendation is given to promote individual accountability. The simplest way to do this is to give primarily individual tests; another is the technique mentioned above of selecting an individual team member to present or explain the team's results. Further, instruct the students not to put someone's name on the solution set if they did not participate in generating the set. Felder and Brent[7] also allow teams to fire non-cooperative team members if every other option has failed, and these fired team members must then find another team willing to take them. The student ratings of group homework were consistently and overwhelmingly positive, with the percentage of students rating the group work as helpful typically in the mid 80s. They also note many research studies show that students who learn cooperatively get higher grades than students who try to learn the same material individually.

Smith[11] states, "Cooperative learning is the instructional use of small groups so that students work together to maximize their own and each others' learning[12,13]. Carefully structured cooperative learning involves people working in teams to accomplish a common goal, under conditions that involve both positive interdependence (all members must cooperate to complete the task) and individual   group accountability (each member is accountable for the complete final outcome)." The longer the group is together, the better for the group productivity. Smith notes five essential elements are of cooperative learning:

- Positive Interdependence: Students must believe that they are linked with others in a way that one cannot succeed unless the other members of the group succeed (and vice versa).
- Face-to-Face Promotive Interaction: Once a professor establishes positive interdependence, he or she must ensure that students interact to help each other accomplish the task and promote each other's success.

- Individual Accountability/Personal Responsibility: The purpose of cooperative learning groups is to make each member a stronger individual in his or her own right. To ensure that each member is strengthened, students are held individually accountable to do their share of the work. Common ways to structure individual accountability include giving an individual exam to each student, randomly calling on individual students to present their group's answer, and giving an individual oral exam while monitoring group work.
- Teamwork Skills: Students must have and use the needed leadership, decision-making, trust-building, communication, and conflict-management skills. Many students have never worked cooperatively in learning situations and, therefore, lack the needed teamwork skills for doing so effectively.
- Group Processing: Groups need to describe what member actions are helpful and unhelpful and make decisions about what to continue or change.

Smith also recommends that grading not be curved, and he defines "Problem-based learning" as the process of working toward the understanding or resolution of a problem, in contrast to subject-based learning[14]. Problem-based learning is suitable for engineering because it helps students develop skills and confidence for dealing with problems they have never encountered before. This is important, since few professional engineers are paid to solve problems that come from the end of chapter problems in a textbook. Finally, Smith remarks:

> "During the past 90 years, nearly 600 experimental and over 100 correlational studies have been conducted comparing the effectiveness of cooperative, competitive, and individualistic efforts. These studies have been conducted by a wide variety of researchers in different decades with different age subjects, in different subject areas, and in different settings. More is known about the efficacy of cooperative learning than about lecturing, the fifty-minute class period, the use of instructional technology, or almost any other aspect of education. Cooperation among students typically results in (a) higher achievement and greater productivity, (b) more caring, supportive, and committed relationships, and (c) greater psychological health, social competence, and self-esteem. A summary of the studies conducted at the higher education level may be found in Johnson, Johnson, & Smith[12,13]. Cooperative learning researchers and practitioners have shown that positive peer relationships are essential to success in college. Isolation and alienation are the best predictors of failure. Two major reasons for dropping out of college are failure to establish a social network of friends and classmates, and failure to become academically involved in classes[15]. Working together with fellow students, solving problems together, and talking through material together has other benefits as well."

Organization of Teams

In an elective course, the instructor tried letting the students pick their own teams. This resulted in a few teams of 3-4 students, a large number of students working in pairs, and a few leftover individual students. This wide distribution of number of students per team did not meet the goal of providing a uniform experience and opportunity for each student, and it proved difficult to force the leftover students to come together into a team. Since that time the instructor has selected the student teams himself. As much as possible students are grouped into teams of 4 people each, with a last team of 5 or one or two teams of 3 used to round out the course enrollment. Since students do occasionally drop the course, starting with groups of 4 helps insure that there are almost always at least 3 participating members on a team. It has been my practice to create all-female groups when possible (particularly at the state school with large class sizes). Students are assigned in groups after filling out a survey. The survey asks for:

- Hometown
- Favorite Sports Team
- Other interests

These factors, along with demographic information, are used to group the students. GPA is not used.

Depending on the course, homework is assigned either weekly or bi-weekly. Each group turns in one copy of the homework, and all four members in the group receive the same grade for the homework. This of course reduces the grading workload by 75%, and it is easy to setup an EXCEL worksheet in which the scores for each group need only to be entered once, and it is linked to the individual students' grades.

Of course, once some of the less motivated students discover that they will receive the same grade as their teammates regardless of how much they contribute, this creates a potential for slackers. Two strategies have been implemented to minimize this problem. First, on the day the homework is due, a short quiz will be given. The quiz is taken word-for-word from one of the homework problems and the students do not know which problem will be selected until the quiz is given. This helps to motivate all the students to want to know how to work all of the problems in each assignment. Second, it is made clear to the students at the beginning of the semester that if they do not fully participate in the group homework, their individual homework grade can be lowered relative to their teammates. This penalty is typically 25% of the homework grade, but in the extreme case of someone who never solves any of the problems in their group a score of 0 will be given for the homework. Students are told to write down only the names of the team members who participated in solving the problems on the cover of their homework assignment. Merely showing up for the group meeting without having done any work beforehand and wanting to see all the answers does not count as participating.

On the quizzes, two different strategies have been employed – 1. To create a problem that is "similar" to one of the homework problems. 2. To use a problem that is word-for-word identical to one of the homework problems. The second choice was found to work better. Quizzes are given on the same day that the group homework is due. All students in a given team receive the same homework grade, but each individual student receives an individual quiz grade. In addition, the instructor makes it clear that he reserves the right to lower a student's homework grade if he does not participate in the group homework and/or project. In the last semester using the glider design project, students were given the opportunity to evaluate their group mates. The results are below.

Survey Results

Note some questions refer to homework and some to the semester-long glider project and some to both.

1 Relative to traditional courses with individual homework and assignments, the ME 308 setup of group homework followed by individual quizzes a) Caused me to learn more than I would have by working alone b) Caused me to learn about the same as I would working alone c) Caused me to learn less than I would have working alone

a – 63%, b – 32.6 %, c – 4.3%

2 I would prefer to take more classes with the group homework followed by individual quizzes with problems taken directly from the homework arrangement used in ME 308 a) agree b) disagree

a - 73.9%, b – 26.1%

Students were also asked to rate the quality of the contributions of their teammates based on the following scale.

1 - Minimal/Non-contributor - Contributions were minimal and could easily have been done by another member of team. Would not have noticed if he was not part of the team.

2 - Marginal - Below average. Less than expected amount of effort, but still managed to contribute something useful to the group effort.

3 - Acceptable - Did what was asked of him. Made significant contributions to the project. I would have no problem working with this person again in the future.

4 - Exceptional - The person went above and beyond the call of duty to make the project a success. May also have taken a leadership role.

The overall class average was 3.46/4.0, and as can be seen in the table below, most students rated their teammates very highly.

Peer evaluations – rating scale

Bin	*Frequency*
1.0 - 1.5	1
1.5 - 2.5	2
2.5 - 3.5	10
3.5 - 4.0	19

Design Projects

Starting four semesters ago, the author decided to add a group design project to the course. Two different design projects have been used – a model Rocket Design Project[16] and a new design-build-fly Glider Project. When these semester-long projects are employed, the same teams are used for the group project and the homework. The rocket project was conducted by the author for 3 semesters, and was also used by other professors at the same institution in another laboratory course. While the rocket project is a worthwhile project that covers many different skills (data acquisition and analysis, numerical methods, modeling, teamwork, and design), it is not truly an open-ended design project, as all successful rockets will have basically the same design (weight in nose, large fins in back). To create a more open-ended design project, the glider project was implemented in which students build a foam glider, with the only constraints being in the amount of foam provided. The first run of the project was a success, as each team developed separate designs, and as seen in the survey results, the students enjoyed the project while learning engineering skills.

Conclusions

Anecdotally, the author has noticed a marked improvement of students' understanding and mastery of the course material since he implemented the group homework strategy. While some students may not like being forced into groups they did not choose, the group homework setting forces them to explain the material both in written form and in oral discussions with their teammates, which serves to enhance understanding. The students who seem to resist working in groups the most tend to be the students with the highest GPA's, which is not surprising, since they have already mastered how to be successful in the traditional university class structure of individual work, and are now being force to adapt to a new paradigm.

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