

## Group homework: A new faculty member's experiences in an introductory engineering course

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### Introduction

As described recently<sup>1</sup>, most new engineering educators teach in the manner they were taught. Many recognize that more effective methods of instruction must exist; however, they often become overwhelmed with literature that is written in “a language that is foreign to them” and, lacking the time to decipher the jargon, end up continuing to use the same old teaching methods.<sup>1</sup> This paper provides new engineering educators with the rationale and basic knowledge required to begin incorporating cooperative learning (through group homework) into their classes. Cooperative learning is different from merely having students work in groups. Cooperative learning occurs when students *interactively* work together, and they are *accountable* both to do his/her share of the work and to understand everyone else's contribution.<sup>2</sup>

### Rationale

The decision to incorporate cooperative learning through group homework exercises was based on (1) evidence that indicates cooperative learning is more effective than traditional teaching techniques, (2) the importance of teamwork skills in industry, and (3) specific aspects of the course, including the difficulty of the course material, which requires a different approach to problem solving than that typically used by the students up to now.

Students taught cooperatively tend “to have better and longer information retention, higher grades, more highly developed critical thinking and problem-solving skills, more positive attitudes toward the subject and greater motivation to learn it, better interpersonal and communication skills, higher self-esteem, [and] lower levels of anxiety about academics.”<sup>2</sup> An extensive analysis<sup>3</sup> has shown that the effect on student achievement would “move a student from the 50<sup>th</sup> percentile to the 70<sup>th</sup> on a standardized test” and the “effect on students' persistence is enough to reduce attrition...by 22%”. However, poorly structured small-group instruction can also be significantly less effective than traditional lecturing.<sup>4,5</sup> Many theories been promoted to explain why cooperative learning is effective, including the ideas that (1) “it allows students to cognitively rehearse and relate course material into existing schema or conceptual frameworks, thus producing a deeper, contextualized level of understanding of content”.<sup>5</sup> By placing the students in a situation where they must communicate their problem-solving approaches to one another, they gain a better understanding of how they achieve the answer and they learn from one another. Ideally the structure of the cooperative learning exercise will help students to develop

teamwork and interpersonal skills. Thus, the instructor must dedicate time in and out of class to effectively set the stage for cooperative learning.

Virtually all engineers in industry work as a part of a team. Typically, communication and teamwork skills are not required in courses until near the end of the curriculum when students suddenly are required to work in groups to complete a design project. However, in surveys of industry representatives, communication and teamwork rank as among the top skills required for engineering graduates.<sup>2</sup> Because students need to learn these skills to be successful professionally, incorporating them early on in the curriculum can benefit students in the long term.

The introductory chemical engineering course (mass and energy balances) is a particularly difficult course for many students because it requires a change in thinking. Significant emphasis is placed on understanding and setting up problems as opposed to merely solving straightforward problems. Students need to learn how to take a text problem description, find the important pieces of information and convert that information to a set of independent equations before ever punching numbers into a calculator. Homework is the major vehicle for teaching these concepts, thus by focusing the cooperative learning exercises around the homework problems, it was hoped that the students' would spend more time focusing on the problem-solving *method*, since they would have to explain their thoughts to one another. When the author previously taught the course, the top 35% of the class formed an informal study group to work on problems together. In addition, R. Felder, a major proponent of cooperative learning, has taught a similar course that has incorporated cooperative learning.<sup>6,7</sup> Thus, with these three rationales, group homework was adopted in the fall 2000 offering of CM2110, Fundamentals of Chemical Engineering I.

### **Implementation and discussion**

Beginning on the first day of class, cooperative learning in the form of group homework was introduced along with the syllabus and other course policies. Because the literature<sup>2</sup> stresses the importance of setting the stage for cooperative learning, significant time during the first class period was spent discussing the benefits of working in groups (i.e., how studies have shown that this helps students learn the material and how this is a major skill that employers look for) so that the students would not think this was just an eccentric idea of the instructor. Despite this effort, a vocal part of the class remained skeptical as is often common when introducing new techniques in the classroom.<sup>8</sup> It was not until a recent alumnus visited the course and, in answer to a question about teamwork, said that she could not think of any projects at her employer that did not involve working in teams, that the majority of the class decided that team skills would truly be important in industry.

After outlining the benefits of group homework, the structure and logistics of the group homework was briefly introduced. As with most information provided on the first day, students could access this in written format via the web. In the future, it may be useful to provide paper copies in class so that any difficulties with campus computer systems will not hamper their access. The students were told that they would work in teams of four, turning in a single

assignment for the team that would be thoroughly graded. In their groups, they would each have a specific role that would rotate with each assignment. The *Coordinator* would keep everyone on task. The *Recorder* would prepare the single, final solution to be turned in. The *Monitor* would check to make sure that everyone understands the final solution, and the *Checker* would proof read the final solution before it is turned in. As part of the first assignment, the groups were to agree upon and write out a set of expectations that would guide their actions over the semester. Continuing through the semester, the groups were asked to assess how well they were functioning together. This structure has been shown<sup>2</sup> to promote *positive interdependence, individual accountability, face-to-face interaction, appropriate use of interpersonal and teamwork skills, and regular self-assessment of team functioning*, all important factors for the success of a cooperative learning activity.

Several times during the first several weeks, part of lecture was spent discussing team building and group dynamics to ensure that the students developed appropriate interdependence and individual accountability within their groups. Several methods were used to promote individual accountability. Students were encouraged to rough out a solution to the problems before meeting as a group. These solutions were occasionally collected (announced in advance) to force the students to prepare somewhat before meeting. Students were also told that they should only record the names of the team members who actually participated in solution of the assignment. Others would not get credit. In general, this worked well; however, some groups failed to work as a group, instead having one member individually do each homework assignment. This was partly due to mistakes made in forming the initial student groups.

Forming successful groups turned out to be the most difficult part of the implementation. Most researchers indicate that it is best for the instructor to form the teams.<sup>5,9</sup> This recommendation was followed, but several mistakes were made. The first mistake was placing too much importance on getting the students into groups on the first day. Instead of collecting information about the students to form teams of heterogeneous ability with common interests and open blocks of time as recommended by at least one author,<sup>2</sup> the initial groups were formed by having the students count off, based on where they were seated. This resulted in groups which consisted of 2-3 people who were friends, and 1-2 outsiders who were not well integrated into the group. Fiechtner and Davis<sup>9</sup> indicate this is a common problem when students groups are clustered around friends. In addition, this caused women and minority students to be isolated in groups, which has been shown to negatively impact their participation in the group.<sup>2,7</sup>

After the first exam, all the groups were reformed using a random computer program, which ensured that no one was in a group with people from their previous group. These groups were generally more successful; however, some problems resulted from forming new groups after only 4 weeks, as opposed to having groups for the whole term. Some students were resentful that they were no longer in groups with their friends. In addition, students were forced back to the first stage (forming) of group development. For groups having trouble dealing with conflict and establishing norms in order to become a productive, “performing” team, this reduced the benefits that they received from working in the group.<sup>2</sup>

Following the second exam, as part of each group member's evaluation of the group, the students were given the option of being reorganized if anyone in the group wanted out. Of 22 groups, less than half of them wanted reorganized. Some groups only needed reorganized because they had shrunk in size due to people dropping the course. On the evaluation following the third exam, only 2 groups wanted to be reformed. By the end of the course, most groups indicated that all team members were contributing comparably to the final solutions whereas on previous evaluations many teams had one member who failed to participate fully.

For the first 10 weeks of the semester, homework was assigned each class period (Monday, Wednesday, Friday) to promote regular work on course material. Each assignment was generally short, consisting of only a few problems. In the final five weeks of the semester, homework was only assigned and collected weekly with the hope that students would have developed the discipline to work steadily on the assignments instead of waiting until the last minute. This did not prove to be the case. Despite repeated warnings in class, most groups did not allow sufficient time to complete the first longer, full week assignment.

Data from this implementation does not demonstrate whether the use of group homework improved the learning and retention of the course material. This has been described elsewhere.<sup>2-5,7</sup> However, anecdotal evidence indicates that overall this was effective. Both mid-term and end-of-term surveys indicate that two thirds of the students found team homework to enhance their learning of the material, while one sixth thought that it made learning the material more difficult. In written comments, several students indicated that group homework was one aspect of the course to keep. One student indicated that eliminating the requirement for group homework was the number one thing that could be done to improve the course. Grade distribution for the students were on par with what the instructor had seen when teaching the course previously. Insufficient experience with the course, plus a change from quarters to semesters precludes a more conclusive analysis.

The largest negative of the implementation also resulted from the end-term surveys in which the instructor was not rated as highly as in other classes taught by the instructor. A myriad of external factors most likely contributed to this (changing to semesters, computer problems, etc.); however, evidence exists that when first attempting new teaching techniques, course evaluations usually suffer initially.<sup>1</sup> As described elsewhere, "cooperative learning tends to be the hardest student-centered method to sell initially, especially to high academic achievers and strong introverts."<sup>8</sup> As an incentive for strong students who have reservations about having to work with others, the instructor can stress how they will benefit through *cognitive rehearsal*, the idea that "students, like professors, learn best what they teach."<sup>10</sup>

## Conclusion

In conclusion, this paper has presented a summary of the major benefits that have been reported for using cooperative learning and provided a discussion of its implementation in a sophomore engineering course. Although not designed to be a rigorous study of the benefits of cooperative learning by itself, results indicate that, overall, most students felt as though team homework helped to enhance their learning.

From the standpoint of implementation, this paper emphasizes several issues that must be carefully considered by anyone desiring to try out team homework. First, it is important to discuss with the class the reason for this innovation. In particular, it is helpful to have a neutral third party indicate the importance of teamwork in industry. Second, it is crucial that adequate time be spent creating solid groups initially. This was one of the biggest shortcomings as it was implemented by the author. In the future, a questionnaire will be distributed on the first day of class which asks the students to identify time availability, minority status, grades in key freshman courses (calculus and chemistry) and whether the student lives on or off campus. Using this information to form groups should lead to groups that will be more effective and have fewer problems.<sup>2,5,8</sup> Thus, although it is straightforward to have students work in groups to do homework assignments, significant upfront effort is required to provide the appropriate skills and motivation to the students and to create teams that will have the highest likelihood of success.

The most positive aspect of the group homework was that students thought deeply about problem solving. More time during class and during office hours and class time were spent discussing the more interesting aspects of problems solving instead of just how to get started. This occurred primarily because the students would meet to work on the problems in their groups where they could discuss the problems in detail and encourage one another to persevere. Overall, team homework seems worth further investigation and incorporation into engineering classes.

### **For more information**

In addition to the references cited in this paper, several additional sources of information concerning cooperative learning are available including a comprehensive annotated bibliography put together by the National Institute for Science Education.<sup>4</sup> Several workshops are held regularly which provide additional information on a wide variety of innovative teaching techniques. These include the National Effective Teaching Institute<sup>11</sup> sponsored by ASEE and the Engineering Education Scholars Workshops<sup>12</sup> and Stanford New Century Scholars Workshop<sup>13</sup> sponsored by NSF.

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