Team-based Learning in an Engineering Materials Course

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Abstract
To encourage teamwork, students in the traditional first course in Engineering Materials are divided into groups of five, with the group further broken down into two teams of two students and one “manager.” Each team of two works together to prepare a “Competency Assignment” which usually covers 3-4 chapters. In the typical class of 25 students, the five “managers” work together to prepare one Competency Assignment. Every three weeks (in a 15 week semester), an exam is given. Students can use their Competency Assignment while taking the exam. An additional twist, however, is that the managers take the exam together in another room, and although each manager submits his/her own exam, the managers can discuss the exam questions and answers with one another. Further, each manager must also grade the Competency Assignments from his/her teams (two assignments). The course instructor grades the Competency Assignment submitted by the managers and the exams submitted by all. Students have different teammates for each assignment and everyone gets to be a manager once.

Outcomes from this are:

1. Students are required to meet and interact with more of their classmates.
2. Students learn how to deal with teammates who have a different work ethic than they do.
3. Students learn that they must complete the assignment on time.
4. Students learn that they must understand the work in the competency assignment in order for it to be helpful during the exam.
5. Students prepare the Competency Assignment neatly because it will be judged by one of their peers.
6. Students who are the managers learn to discuss problems analytically while they take the exam (the managers are usually the last ones to finish the exam).
7. Students are more enthusiastic about the course.

I. Introduction
The traditional methods of engineering instruction at the university level typically involve lecturing, homework, quizzes and exams. Although commonly viewed as “not the best” educational method, it has persisted because of the ease with which large numbers of students may be accommodated - - universities generally have the mission to educate a vast number of students. If one measures the subject knowledge gained by students (as evidenced in quiz grades, exam grades, and graduation rates), this method can be deemed successful. Students seem to be acquiring the prerequisite knowledge - -or at least demonstrating that they have the knowledge.
Industry and its needs, however, are constantly changing. Indeed, the students themselves are changing! Those who have been involved in university education for a number of years are most keenly aware that today’s students are not the same as those seen a decade or two ago. Students are not content to passively listen to a professor lecture for fifty minutes. They want to be more actively involved in the learning process. They are being inundated with information and they need help in learning how to manage all of it. If a university wishes to be regarded as an institution positioned to provide leadership in education arena, it must be ready to respond to the needs of both its students and the industries that will eventually be employing them.

As someone who has taught Engineering Materials for a number of years, I began to observe that students were not responding well to the traditional lecture/exam method of conducting this course (Basically, this means that they were not doing the homework or studying for the exams). During the same period, I had the opportunity to do some summer consulting work at several of the large manufacturing firms in our area. I realized that our students needed more than knowledge of facts and problem-solving. They need to know how to learn a subject on their own and how to work with others. They need to be able to explain concepts to their peers and they need to be able to produce professional-looking documents utilizing word-processing and spreadsheets (In industry, the “secretary” is close to becoming an ”endangered species.”). They need to realize the importance of finishing a project on time.

Since the Engineering Materials course was obviously in need of a new approach, I decided to use the opportunity to have the students practice some of these skills that I had observed were needed in industry. This paper explains the variation, developed by this author, on the typical team-based learning method. The “lecture method” is partially maintained but is used only to explain certain concepts that students have difficulty grasping or to answer specific questions raised by a student. The remaining class time is used for “team-based learning,” where it is intended that students work together to help each other learn and understand various topics in the course.

II. Course Goals
Traditionally, each course sets goals for its students. In the past, goals have typically been concerned with the subject matter of the course, often requiring that a student acquire and retain specific types of information. Engineering courses have also required that students use this information analytically in various problem-solving scenarios. Generally accepted course-specific goals for the first course in Engineering Materials are:

- Have an understanding of the basic structures of metals, ceramics, polymers and composites;
- Know the various material properties important to engineers and how they are measured;
- Know how and what material properties can be controlled and improved;
- Be aware of typical applications and limitations of the various types of materials;
- Understand the design process in materials selection.

Although these goals are indeed necessary, today they are not sufficient. To be truly current, the course’s goals must also address university and industry needs. University-specific goals for its students include such things as:
• Reach a certain level of expertise in a particular knowledge area;
• Acquire analytical skills and reasoning ability;
• Develop the ability to be a self-learner;
• Recognize their responsibilities to society.

Industry’s needs add even more to the mix. Typical goals indicated by industry are:

• Be technically competent;
• Have the ability to work with others in a team setting;
• Have good communication skills — verbal, written and computer;
• Be able to manage one’s time effectively and complete projects on schedule.

It can be recognized immediately that although the course-specific goals can be achieved through the traditional lecture/exam method, the university-specific and industry-specific goals cannot. This further reinforced my decision to modify the delivery method for the Engineering Materials course.

III. Team-based Learning Logistics

The traditional lecture/exam method of instruction can be described as “instructor-centered.” The instructor has the responsibility for managing the classroom, delivering course content, motivating the students to learn, and ultimately determining if the course has been successful in expanding a student’s knowledge and reasoning base. My variation to instruction is to make the course “student-centered” through the creation of student teams. Team members are required to assume more responsibility for the successful completion of the course — both for themselves individually and for other members of their team.

At the beginning of the course, students are told that this course will be conducted differently from the traditional lecture/exam courses. Lecturing will be minimized. It will be used only to explain those concepts which students traditionally have difficulty grasping or to answer specific questions raised by a student. Students will be required to work in teams on assignments. Further, they cannot choose their own team members and their team members will change with each assignment. They will be expected to use the textbook and any additional outside resources (typically Web sites) to complete the assignments, as the instructor will not explain everything in class. Sometimes they will find themselves “teaching” other members of their team — and sometimes other team members will be teaching them! They will be able to begin work with their team members during the class periods when the instructor is not lecturing and are encouraged to meet with team members outside of class. They will need to assume most of the responsibility for their own success in the course.

The usual class in Engineering Materials consists of twenty-five students. On the first day of class, students are divided into groups of five, with the group further divided into two teams of two students (each) and one “manager.” Each team of two works together to prepare a “Competency Assignment” which covers 3 – 4 textbook chapters. Additionally, the five “managers” work together on the same Competency Assignment.
Since the assignments are somewhat extensive, the team members and managers need to decide the best approach to completing the assignment in a timely manner. They need to decide if the work should be divided between team members or whether each member should do every question and then all compare answers with one another. They begin to realize that they have a responsibility to a colleague. They also may need to deal with a situation where one member does not do his/her share of the work.

Every three weeks (in a 15 week semester), an exam is given. Students can use their Competency Assignment while taking the exam. An additional twist, however, is that the managers take the exam together in another room, and although each manager submits his/her own exam, the managers can discuss the exam questions and answers with one another. They also can use their Competency Assignment. The managers can all have the same answers on their exams or they can choose to answer a question differently from the others.

When students turn in their completed exam, they must also submit a Competency Assignment. Each team (of 2 students) submits only one copy. The students thus must have agreed on who will be responsible for the submitted copy. The group of managers (5 students) submits one copy of the Competency Assignment.

Each manager must grade the Competency Assignments from his/her teams (two assignments/manager). The course instructor grades the one Competency Assignment submitted by the managers and also grades all exams.

Every third week a new Competency Assignment is given and new groups are formed, followed by an exam. In all, student teams must work together to complete five Competency Assignments and must take five exams. Everyone gets to be a manager (and thus take the exam in a “group setting”) once.

IV. Course Organization
The Engineering Materials course is a three semester-credit-hour course, meaning it meets three times a week (fifty minute periods) for fifteen weeks. Typical class size is 25 students per section. The textbook used in the course is Materials Science and Engineering – An Introduction, 5th Edition by William Callister, Jr.

The course also has a website utilizing Blackboard 5 (Guests are allowed to visit my website. The website can be accessed through the university server. The URL is www6.ltu.edu. At the opening page, choose “Course Catalogue,” then choose “Preview.” In the “Search for a course” box, type “shamamy.” In the next screen, click on the “Preview” button for the Engineering Materials course.).

Students receive a syllabus on the first day. The syllabus contains the grading system, the schedule for topics covered, report due dates and exam dates. The syllabus and all other course documents are posted on the website. Students can access the website on the first day of class.

Course grade (in percent) is determined by summing the points obtained in the areas shown below and dividing by 100:
- Group work/reports (5 areas @ 40 pts each) 200 points
- 5 Exams (5 areas @ 150 pts each) 750 points
- Attendance (2 pts per class attended) 50 points (max)

The “Group Work/Reports” are called “Competency Assignments.” Students are required to work in teams to complete these. The Competency Assignments typically cover 3-4 chapters and consist of short answer questions and numerical problems. Students are not given paper copies of the assignments. The Competency Assignments are posted on the course website and the students must download the assignment, save it as a document, and use a word-processor, equation writer and graphing program (Excel) to answer all questions. These assignments are usually quite extensive and vary from 5 to 10 pages in length when complete. Students have approximately 2 ½ weeks to complete each assignment. Because the students are working with an electronic assignment and answering the questions using a word-processing program, the completed assignments are extremely neat and professional looking. There is a strong incentive for the students to complete the extensive Competency Assignments as they are allowed as aids when taking the exams! There is also a strong incentive to complete the assignment neatly because it will be graded by one of their peers, i.e., the manager for their group.

Exams are scheduled for Wednesdays. On the Monday preceding each exam, a “Practice Exam” is given. This “Practice Exam” is the exam given in the preceding semester, thus making sure no students are at a disadvantage because they lacked access to this previous exam. Students are told that they need to have the Competency Assignment done so that it can be used for the Practice Exam. This serves as an impetus to complete the assignment before the date it is actually due. Most students complete the assignment in time to be used for the Practice Exam. The Practice Exam is not graded, but the answers are explained in the last 5-10 minutes of the class period.

Five exams are given. No exam grade is dropped. Students who have a legitimate reason for missing an exam are allowed to take a Make-up exam. Exam questions involve problem solving similar to problems solved in the Competency Assignment and Practice Exam. Short answer questions involve looking for certain information in the Competency Assignment or involve reasoning related to questions answered in the Competency Assignment. It was found that an easy way to make sure that a student really understands and knows the material is to make the exam long! If a student does not know the material, he/she will not have enough time to find the needed information in the Competency Assignment. Students are told repeatedly that they must be familiar with the information in the Competency Assignment because the exam will be long.

Students are encouraged to come to class by awarding them 2 points for every class attended, up to a maximum of 50 points. Most students pick up all 50 points. More importantly, however, is the fact that they set up a pattern of regularly coming to class at the beginning of the semester, see the value in attending class, and continue to regularly attend class even though they no longer earn points for it.

V. Outcomes
A number of positive outcomes have resulted from using this instructional approach:
1. Students have more opportunities to meet and work with other engineering students. This begins to lay the foundation for the teamwork skills needed in industry.

2. Students use the textbook as a learning tool, rather than completely relying on the instructor. They learn to explain and justify their assignment answers to their team member. They learn that they can always ask the instructor for help - - in class, outside of class, or electronically. Students thus are forced to be “self-learners.” They also begin to learn to verbally communicate with one another in an engineering sense.

3. Students quickly realize that the Competency Assignment is helpful during an exam only if they have been actively involved in its preparation. During the exam, a student cannot find the needed information in the Competency Assignment fast enough for it to be helpful unless he/she has actually done the assignment. They thus realize that although they have a team member, they themselves must also do their fair share of the work.

4. Students learn the importance of preparing their Competency Assignment neatly, using readily available computer tools, because it will be much easier for them to find needed information during exams, and also because it will be judged by one of their peers. The quality and overall appearance of the Competency Assignments is very high, which is particularly noteworthy because most students are second-semester freshmen.

5. Students, when they are “managers,” learn to discuss problems analytically with one another in a high-pressure situation, i.e., during an exam. Typically, they analyze many facets of a problem, trying to consider all possible scenarios. They also learn how to reconcile differences in answers quickly. This is usually a new type of experience for the students and it is analogous to what they eventually will be experiencing in industry.

6. Students are more enthusiastic about the course. Sections taught using this technique are more popular. Students complete the Competency Assignments (which actually are much more extensive than previous “homework”), attend class more regularly, and score better on the exams.

VI. Conclusion and Further Implications
This method using “team-based” learning has resulted in a more positive educational experience in the first-year Engineering Materials course. Students are more enthusiastic about the course. Course-specific goals are easily met. Additionally, university-specific goals and industry-specific needs, which really cannot be taught by the lecture method, are also incorporated into the learning experience by having the students practice these needed skills inadvertently. Thus students begin to assimilate these needed professional behavioral practices early in the educational process.

An obvious question arises - - can this system work with other courses as well? The answer is that each course must be considered individually. Courses similar to Engineering Materials (i.e., where principles must be understood, certain facts learned, and some calculation-based problem solving done) can probably easily adopt this system. Courses that tend to be 100% calculation-based problem solving would need a modified approach.

VII. References

Biographical Information
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