# Adapting Team-Based Learning to Early Engineering Courses

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## Abstract

The purpose of this paper is to report progress made in adapting the learning strategy known as team-based learning for use in the required sophomore-level electric circuit theory sequence. The project is motivated by the desire to introduce students to self-directed independent learning and to learning in groups early in their programs, both of which concepts are, in theory, provided by team-based learning. Learning groups provide students with the opportunity to peer instruct, which has been shown to produce deeper conceptual learning than listening to a traditional lecture. Also, while observing the group learning, the instructor can identify and correct learning difficulties on the spot, which is usually not possible with the standard traditional lecturing method. Despite the potential benefits, several practical challenges have been encountered while attempting to implement the strategy. These include motivating students to study and learn new material outside of class and before encountering it in the classroom; and motivating them to engage in the formative/summative assessment processes used. The paper describes progress made over two semesters in overcoming these challenges. Although specifically adapted to the two-course electric circuit theory sequence, the results reported here can probably be applied to any sophomore level engineering course.

## Introduction

Copious research has shown that traditional lecturing is a very inefficient way to facilitate conceptual learning[1], and that student-centered active learning can result in a deeper understanding of the concepts in question[2]. Furthermore, when active learning is conducted in an extensively group-based learning environment, e.g., problem-based learning, project-based learning, or team-based learning, students develop various generic, professional functioning knowledge skills, such as problem-solving, written and oral communication, independent learning, team work, etc.

In our electrical engineering and computer engineering undergraduate programs, students complete a two-course senior design sequence using project-based learning, where, in addition to solving challenging design problems, they develop several of the generic skills. They also work in teams in the laboratory components of several earlier courses, but there is little formal instruction therein on how to behave in a group or how to conduct good team work. If some of those ideas were learned early in the program, they could be used all throughout the program, and thus the students would enter the senior design sequence with strong team skills and be able to focus on the technical aspects of the design projects. Also, they would graduate with the ability to work comfortably and successfully in teams.

In order to develop self-directed independent learning and good group skills early in the curriculum, we are using an adaptation of the learning strategy known as team-based learning (TBL) in the two-course electric circuit theory sequence, which is required of all students in either electrical or computer engineering, and which is usually taken in the sophomore year. The following sections of the paper describe how TBL has been adapted, implemented, and evaluated in the two courses over two semesters, the associated challenges, and changes that have been and are being made to improve matters.

## Basic Team-Based Learning[3]

Simply stated, TBL is a learning strategy that requires students to study new material independently before coming to class, and to spend most classroom time working in groups on challenging problems and questions aimed at deepening their understanding of the subject matter[3]. Thus, it basically reverses or "flips" the processes that traditionally occur inside and outside the classroom[4,5]. In TBL[3], course content is subdivided into approximately six two- to three-week-long major units; for each of those, TBL prescribes a three-phase sequence of activities[3], consisting of the following:

- Outside-the-classroom preparation and acquisition of new content knowledge, in which students independently read and study new material without significant prior lecturing by the instructor. The phase culminates with in-class readiness quizzes taken individually and by the teams, including an appeals process.

- Inside-the-classroom application of the new knowledge with formative feedback. For the remainder of the two- or three-week session, student teams work on increasingly challenging problems and questions. They follow a prescribed scheme of group work that stresses individual accountability to the process.

- The unit ends with a summative team project or exam, the score or grade of which contributes toward the students' final course grades.

## Adaptation and Implementation: Fall 2010

In our adaptation of TBL for use in the two-course electric circuit theory sequence in the Fall 2010 semester, each of the six technical-content-based learning outcomes of each course was treated as a major TBL unit. A seventh learning outcome required students to produce a record of preparation for class and participation in learning activities, particularly group work, during class. Associating group work with an assessed learning outcome, which would be factored into the final grade, was generally sufficient to motivate good group work behavior by most of the students. The preparation phase of each unit consisted of assigned readings of the new material for the unit, followed by a short readiness test, taken individually only, at the start of the first class of the multi-week session for that unit. Test scores contributed toward students' grades in the seventh learning outcome. The only materials used for the courses were the textbook (Electric Circuits by Nilsson and Riedel) for assigned readings and problems both for independent out-of-class study; and the on-line platform Blackboard for various communications.

The students in the two courses were formed, randomly, into teams of approximately four students each. They were instructed, during a full class period at the beginning of the semester, (with regular reminders throughout the semester) on what was expected of them during group work. Those expectations included: 1- following a simple problem-solving scheme, which included brief individual reflection, brief group brainstorming to decide a solution approach, and then interactive work with discussion until the problem is solved; and 2- using good interpersonal team skills, which included participating respectfully, helpfully, and fairly. Since the courses were sophomore-level circuits courses, the assigned group work projects could simply be increasingly challenging problems from the textbook.

During group work, the instructor acted as tutor, performing two principal tasks: observing and assessing (and reminding teams about) the prescribed process of group work; and facilitating technical learning, which involves providing formative feedback, teaching by asking guiding questions, and occasionally interrupting the process to do brief lecturing on some point of common difficulty. Occasionally the groups were required to submit their work as a report, one report per team, for formative assessment.

At the end of each multi-week session, students took a strictly formative assessment exam over the material (the learning outcome) covered during that session. In contrast with the summative assessment conducted at the end of each session in TBL as described above[3], this exam had no numerical impact on the students' final grades. Instead, it was used to provide feedback for improved student learning in anticipation of the grade-determining summative final exam to be taken at the end of the semester.

The seventh learning outcome, associated with preparation and participation, was assessed continuously via readiness tests, daily instructor observation, and a peer assessment survey given at approximately mid-semester. In the peer assessment the members of each group anonymously assessed each other's contributions to the group work process.

**Evaluation: Fall 2010**

Evaluation of the adapted TBL strategy as implemented in Fall 2010 was done using two instruments: continuous observation by the instructor throughout the semester, and a survey taken at the end of the semester to examine students' perceptions of the strategy and gather feedback for improvement. The most important positive observations made by the instructor concerned the group work. As the semester progressed and after several reminders about the group work process, most teams evolved into engaged learning units in which students discuss the problem in question, discuss solution approaches, and instruct each other. Also, while observing and tutoring group work, it was very easy for the instructor to see exactly what the learning difficulties were, and to take appropriate and immediate actions to correct them.

The two most important negative observations, which suggested changes to be made, concerned motivating students to prepare for class on a regular basis, and students' discomfort with the formative/summative assessment grading scheme. These concerns were echoed in the student surveys, taken of 62 students in both courses at the end of the semester. The principal results of the survey were as follows:

- Perception of learning: 45 students (73%) felt that they learned more with TBL than they would have if a traditional lecture approach had been used.

- Most noted the benefits of working on problems in groups in class with tutor (instructor) assistance. No attempt was made to determine whether the students actually had learned more with TBL than they would have otherwise, but the final mean grade point average (GPA) was 2.75 in Circuit Theory 1, which is higher than the typical GPA of 2.60 for that course, and 2.60 in Circuit Theory 2, which is equal to the typical GPA for that course.

- Satisfaction with group memberships: 58 students (94%) were pleased with their group. Many noted that they became better at working as a team as the semester progressed, just as promised in TBL theory[3]. The few unsatisfied students noted that their group had at least one student who was frequently either absent, late, or unprepared.

- Preparation and readiness testing: 48 students (77%) favored the readiness test concept, although several commented that some of the readiness tests were unfairly difficult, and 57 students (92%) agreed that readiness assignments, to be submitted regularly, not just at the beginning of a multi-week session, would be another good way to test readiness.

- Strictly formative assessment exams: 43 students (69%) took them at least moderately seriously, i.e., prepared for them; the others did not, mainly because the scores didn't contribute to the final grade. A frequent comment was that a graded assignment or test in another course always got priority. (In an educational culture, such as in the UK, where mid-semester summative assignments and exams are rare, more students would probably take the formative assessments more seriously.)

- Summative assessment and final grades: Only 20 students (32%) were comfortable with such heavy emphasis on the final exam. Many objected to the anxiety caused by such a system. (Again, this is reflective of our local educational culture, in which it is common for tests given throughout the semester to contribute significantly toward the final grade.)

## Changes for Spring 2011 and Results

In order to improve the TBL strategy as implemented in the two electric circuits courses for the Spring 2011 semester, several changes were made. First, even though 94% of the students were satisfied with their randomly formed groups in the Fall, for the Spring it was decided to form the groups more carefully[3], by ensuring that each team had at least one strong student, determined using grade point averages; and by making the groups as diverse as possible with respect to ethnicity and gender. Second, in response to student input concerning preparation and readiness, readiness tests were supplemented with assigned problems from the textbook. However, when it was realized that many students were copying and submitting solutions from the solutions manual, the practice was terminated. And finally, in order to both increase engagement in the formative assessment process and to alleviate anxiety caused by the heavily weighted summative final examination, a 50-50 compromise was used, in which, if a student's score on the final exam for a specific learning outcome was lower than the corresponding score on the earlier formative exam, the final grade would be determined by the average of the two scores. Otherwise, the score on the final exam would determine the grade.

As at the end of the previous semester, a similar survey of students' perceptions was taken at the end of the Spring 2011 semester, with particular interest in evaluating the effects of the changes made for the Spring semester. The principal results of the survey, taken by 61 of the students in the two courses, are as follows:

- Perception of learning: 56 students (92%) felt that they learned more with TBL than they would have if a traditional lecture approach had been used. This is an improvement from 73% in the Fall. As in the Fall, no attempt was made to determine whether the students actually had learned more with TBL than they would have otherwise, but the final mean GPAs in the two courses were 2.92 in Circuit Theory 1 (compared to 2.75 in the Fall) and 3.13 in Circuit Theory 2 (compared to 2.60 in the Fall.) It might be noted that the group of students whose GPA was 3.13 in Circuit Theory 2 in the Spring was virtually the same group that had earned a GPA of 2.75 in Circuit Theory 1 the previous semester.

- Satisfaction with group assignments: 58 students (95%) were pleased with their group. This is virtually the same result as in the Fall (94%), and student comments echoed those in the Fall.

- Preparation and readiness testing: 38 students (62%) favored the readiness test concept, which is less than the 77% who favored it in the Fall. As mentioned, the attempt to assign textbook problems as readiness work was unsuccessful due to the ready availability of the solutions manual. Despite this problem, students echoed the sentiment from the Fall that readiness assignments are desirable. They also commented, interestingly, that if readiness tests are to be used, they should be in the form of short quizzes, and be given frequently.

- Revised formative and summative assessment exam schemes: 56 students (92%) treated the formative assessment exams at least moderately seriously, as compared to only 69% in the Fall, and 55 students (90%) were comfortable with the scheme used to determine their final grades, as compared to only 32% in the Fall. These large improvements are the results of the above-mentioned 50-50 compromise made for the spring, which essentially turns the formative assessments into a back-up in case of a poor performance on the summative final exam.

## Conclusions

After two semesters, many of the practical challenges of implementing TBL in the sophomore level circuit theory sequence have been resolved satisfactorily. The grading system consists of a series of continuous assessments for the learning outcome associated with preparation and participation, and formative and summative assessments for the six technical learning outcomes. Items used in the continuous assessment included readiness tests, instructor observation, and peer assessments. The formative midterm assessments are used primarily to provide feedback to the students so they can be better prepared for the summative final exam. The final grade for each of the six technical learning outcomes is determined by the score on the final exam unless it is lower than the corresponding score on the formative exam. In that case the average of the two assessment scores is used. The course grade is determined as the average of the grades for all seven learning outcomes. Criterion-referenced grading, rather than norm-referenced grading, is used to determine the final letter grade.

It still remains to find a better way to motivate students to engage in the preparation phase of the strategy, i.e., to motivate them to study and learn new material outside of class so they are prepared to use it in group work in the classroom. Current ideas for the next round of improvements include readiness problem assignments as tried in Spring 2011, except that the assignments be taken from other sources than the textbook, so that solutions won't be readily available; and the requirement for a preparation notebook[6], in which students summarize and outline their readings, and show the work on any problems that have been assigned.

Finally, although the adaptation and implementation of TBL as described here has been done specifically for the two-course electric circuit theory sequence in electrical and computer engineering, there is no apparent reason why the results cannot be applied to any sophomore level engineering course.

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## Biographical Information

**Robert O'Connell** received the B.E. degree in electrical engineering from Manhattan College and the M.S. and Ph.D. degrees in electrical engineering from the University of Illinois. He is a Professor of Electrical and Computer Engineering at the University of Missouri-Columbia and a registered Professional Engineer. He recently completed a Fulbright Fellowship in the School of Electrical Engineering Systems at the Dublin Institute of Technology in Dublin, Ireland, during which he studied modern teaching and learning methods for engineering education, including various forms of group-based learning.