Assessment Practices for Team-Based Learning in Sophomore-Level Courses

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Abstract

Team-Based Learning (TBL) is a form of student-centered active learning in which students study new conceptual material before it is treated in the classroom, and then subsequently spend significant classroom time working in groups on problems and applications of the conceptual material. TBL provides opportunities for students to learn course content better and deeper than in the traditional lecture-based setting, and to develop various transferable professional skills, such as self-directed independent learning, problem-solving, and teamwork skills. Because of these features, TBL has been used as the principal teaching and learning strategy in our sophomore-level electric circuit theory sequence for the past four semesters. The purpose of this paper is to describe the various instruments that are currently being used to assess learning of both the technical course content and various professional skills in TBL-taught courses. Of particular interest are those continuous assessment practices used to assess learning of the professional skills. Grading rubrics used with the continuous assessment practices will be described as well.

Introduction

Educational research has shown that student-centered active learning can produce much deeper conceptual learning than can traditional lecturing [1], and that when active learning is conducted in an extensively group-based learning environment, such as in problem-based learning, project-based learning [2], or team-based learning [3], students also develop various professional functioning knowledge skills, such as problem-solving, written and oral communication, independent learning, team work, etc [4].

In order to develop self-directed independent learning and some professional problem-solving and teamwork skills early in the curriculum, we have, for the past four semesters, been adapting and using TBL in the required two-course electric circuit theory sequence, which is usually taken in the sophomore year. Circuit theory was chosen for this initiative because it is one of the earliest courses taken by our students, so by learning some problem-solving and teamwork skills in circuit theory, students can be expected to use and develop them (at instructors' discretion) in all subsequent ECE courses throughout the program. TBL was chosen for this effort over project-based learning and problem-based learning for several reasons. In project-based learning, heavy emphasis is placed on the application of previously acquired knowledge, rather than its acquisition [2]. Thus, it is well-matched to upper-level design, i.e., capstone, courses. In both TBL and problem-based learning, on the other hand, the emphasis is on both the acquisition of fundamental concepts and their application in relatively simple applications (as compared to the projects of project-based learning). The difference between the two strategies lies primarily in how new content knowledge is acquired.

In problem-based learning [5, 6], teams of students are confronted with open-ended realistic problems and are required to develop solutions by following a prescribed multi-step problem-solving scheme; instructors function as tutors who also follow a prescribed scheme of tutorial behavior. It is important to understand that the problems to be solved are assigned without any prior instruction by the instructor, so that the problems themselves dictate what conceptual content knowledge has to be learned (independently and interdependently by the students) in order to solve the problem. The phrase “The problem drives the learning” is often used in descriptions of problem-based learning [4, 7]. Because the problems themselves, and not any prior instruction, hint at and ultimately determine what content knowledge is to be learned (in order to solve the problems), the problems must be designed with extreme care, in order to make sure that the course learning outcomes and content are all adequately addressed. However, even when problems are designed with such care, student teams often find ways of solving them without having to learn and use the intended content knowledge. Thus, there is the danger that some important items of course content will not be learned. Avoiding these so-called knowledge gaps is one of the biggest challenges to properly using problem-based learning [8, 9].

In team-based learning [3], on the other hand, students are told what specific content material needs to be learned (at an introductory level) independently in order to be successful in the subsequent classroom-based group work. They take a readiness test and are given a subsequent brief corrective lecture over the important content before beginning the in-depth group work. Thus, there is much less risk of creating knowledge gaps when using team-based learning. This is the principal reason why team-based learning and not problem-based learning, was chosen for the initiative described here.

In the following sections we briefly describe the basic, or textbook, TBL learning strategy and the modifications that we have made to make it more effective in the sophomore-level circuit theory sequence. Then, we describe the instruments currently used to assess student learning of both the technical course content and the professional skills associated with TBL. Those instruments have evolved from efforts to increase student engagement with the TBL strategy using feedback from students on course evaluation surveys. Currently, technical content learning is assessed using formative examinations throughout the course and a summative final examination. Student learning of the TBL process is assessed continuously throughout the course using several instruments, including a preparation notebook, frequent unannounced readiness quizzes, instructor observation, and peer assessment. Grading rubrics used with the continuous assessment tools will be described also. Finally, we discuss briefly how all the collected assessment information should be used in a criterion-referenced grading scheme to determine an actual final grade for the course.

Textbook team-based learning

TBL is a teaching and learning strategy in which students study new material independently before coming to class, and then spend most of their class time working in groups on increasingly challenging assignments aimed at deepening their understanding of the subject matter they initially studied independently [3]. Groups or teams of four students each are formed carefully by the instructor, making the groups as heterogeneous as possible with respect to talent, ethnicity, and gender. [3, 10, 11]. Course content is subdivided into approximately six major units, each of which consumes approximately two-to-three weeks of course time. For each of those units, a three-phase sequence of activities occurs.

Phase 1 is the Preparation phase, in which students complete the reading assignments for the entire two-to-three week unit. This is done independently, outside the classroom, and before the associated content is formally addressed in the classroom. The idea is for students to obtain “a good introduction to the information and ideas on the topic,” and not “an in-depth mastery.” In the first class session following the allotted preparation time, the preparation phase culminates in the Readiness Assurance Process, which consists of a short objective readiness test on the assigned reading. The test is taken by each student individually, submitted to the instructor, and then taken again by each of the student teams working together. Scores from both tests are recorded and contribute toward final grades. Finally, the instructor optionally lectures briefly, to the entire class, on material that students had trouble with on the readiness test.

Phase 2 is the Application phase, which lasts for the remainder of the two-to-three week period allotted to that content unit. During this phase students work in teams on increasingly challenging applications and problems related to the material they read and studied in Phase 1. The Application phase has two purposes: to help students achieve the depth of conceptual understanding required by the instructor, and to help them develop teamwork and problem-solving skills. During group work, the instructor acts as a tutor, with two principal tasks: to facilitate conceptual learning by asking guiding questions (and not simply supplying answers) and doing occasional just-in-time lecturing; and to observe and assess learning of group work skills, i.e., preparation for class and problem-solving using good interpersonal team skills.

Phase 3 is the Unit Assessment phase, which consists simply of a summative exam over the material covered during the two-to-three week period in question. The score on this exam determines the student’s grade for that portion of the course.

TBL for sophomore-level circuit theory

While using TBL in the sophomore-level electric circuit theory sequence for four semesters, four significant and beneficial changes to the textbook process described above have evolved. The first two are derived from current ideas on teaching and learning generally [4], and the second two are practical changes derived from the four semesters’ experience.

First, Consistent with the idea of expressing course content in terms of constructively aligned intended learning outcomes (ILOs) [4], which are statements of what students should know and be able to do at the end of the course, each of the above-mentioned TBL-defined multi-week major units of course content is expressed as a course ILO. Thus, each of the circuit theory courses in question has six content-related, or technical, ILOs. In addition, each course has the following seventh ILO, which addresses student learning of the TBL process: “Upon completion of the course, students should be able to produce a record of preparation for and participation in good group work." This ILO makes it possible to hold students accountable for learning and using the TBL strategy.

Second, having expressed major units of course content as ILOs (end-of-course knowledge and abilities) (the first change), it was logical and further consistent with current ideas on teaching and learning [4] to make the unit assessment exams of Phase 3 formative, rather than summative, and to add a summative comprehensive final exam at the end of the course. The principal purpose of the formative unit assessment exams is to provide feedback to help improve student learning in anticipation of the grade-determining summative final exam. This change created two practical difficulties, which required a change in how the scores from the formative and summative assessment exams are used to determine final grades. Those difficulties and the resulting change will be discussed in the following section on assessment.

Third, it was observed early in the initiative that most sophomore-level electric circuit theory students are unable to obtain "a good introduction to the information and ideas on the topic," when the required reading material in the Preparation phase consists of approximately one-sixth of the course content, or typically one or two complete chapters from the textbook, as is required in textbook TBL. This is probably because electric circuit theory (and most engineering course content) tends to be hierarchical, meaning that most topics build on previous ones, so that in order to understand a given topic it is essential to understand most of what came before it. It is very difficult for most students, working independently, to proceed very far into a body of new hierarchical material before becoming unable to obtain even an introductory level of comprehension. Thus, the readiness readings and assignments of Phase 1 are divided into several shorter segments, consisting of the new material to be applied in group work in the following class session or two, e.g., a section or two of a chapter in the textbook. As before, each readiness assignment culminates in a short readiness test, but now those tests, or quizzes, are given optionally at the instructor's discretion, and unannounced.

The fourth significant change to the textbook TBL process relates to what student teams are required to do during group work in the Application phase (Phase 2). As stated above, one of the purposes of the Application phase of TBL is to help students develop teamwork and problem-solving skills. While textbook TBL specifies development of problem-solving and interpersonal team skills (appropriate speaking, listening, and peer instructing), during group work [3], the strategy neglects to specify a problem-solving scheme, which would help students to better learn problem-solving skills. Thus, in our initiative, student teams are required to use good interpersonal team skills while following a simple problem solving sequence consisting of brief individual reflection on the problem in question, followed by team brainstorming and consideration of alternate solution approaches, followed by interdependent and iterative work on the agreed-upon solution approach.

Assessment of learning: technical content ILOs

Assessment of learning in the two electric circuit theory courses consists of assessing how well students achieve, by the end of the course, both the six technical-content-related ILOs and the seventh, TBL-process-related ILO. Currently used assessment instruments and the ways that they are used to motivate student engagement with the TBL process have evolved over the course of the four semesters, due in large part to the results of student course evaluation surveys that are conducted at the end of each course each semester.

Achievement of the first six ILOs is assessed using written formative and summative exams, as explained above in conjunction with the second change made to the basic TBL process. However, as also mentioned, that scheme creates two related practical difficulties. The first one is that many students will not take formative exams seriously or prepare well for them when the scores from the tests do not contribute numerically toward the final course grade. Impending tests (for which scores do count toward the final grade) or even graded assignments in other courses usually take precedence over formative exams. The second, related, practical difficulty is that many students object strongly to the heavy grade-determining weight attributed to the summative final exam and the test anxiety associated with such a final exam format.

In order to address both difficulties, i.e., increase engagement in the formative assessment process and alleviate anxiety associated with the heavily weighted summative final exam, a so-called 50-50 compromise is now used, by which, if a student's score on the final exam for a specific ILO is lower than the corresponding score on the earlier formative exam, the final grade for that ILO is determined by the average of the two scores. Otherwise, the score on the final exam alone is used to determine the grade. Student course evaluation surveys show that over 90% of students are satisfied with this assessment scheme for the content-related ILOs.

Continuous assessment of learning the TBL process

In both electric circuit theory courses, the seventh ILO is stated as follows: "Upon completion of the course, students should be able to produce a record of preparation for and participation in good group work." Assessment of achievement of this outcome is done continuously throughout the semester, using the following five instruments: attendance requirements, instructor observation while tutoring group work, peer assessment, readiness quizzes, and preparation notebooks. It will be evident that these instruments are also used to motivate students' engagement in both the preparation and participation aspects of this outcome. At semester's end, all this continuous assessment data is combined to determine students' grades in this ILO.

Class attendance is a serious issue in a TBL-based course because team members depend on each other to be prepared for and contribute productively during the group work exercises. Missing class negatively impacts other students' learning. Thus, attendance is mandatory in our TBL-based courses, and attendance records are used as part of the instructor observation assessment instrument discussed in the following paragraph.

While observing the discussions and group interaction during group work (tutoring), it is easy for the instructor to determine (by their participation in the discussion or lack thereof) whether individual students have prepared appropriately for class. It is also easy to observe how well the group follows the prescribed problem-solving scheme and uses good interpersonal team skills. The assessment rubric for instructor observation is a subjective evaluation, over the course of the semester, of each student's attendance, preparation for class and appropriate participation in group work.

Another instrument that provides a subjective assessment of student learning of the two principal components of TBL is peer assessment. Late in the semester, the members of each group complete a confidential survey that allows them to assess the other members of their group for preparation for and participation in group work. The results of the peer assessment usually support the results of instructor observation, but not always; occasionally they reveal group dynamical issues not previously evident to the instructor.

The other two continuous assessment instruments, readiness quizzes and preparation notebooks, provide objective data for assessment of student engagement in the Preparation phase, i.e., how well students have done the pre-class readings and other readiness assignments. Readiness quizzes, mentioned above in connection with the shortened readiness cycle, are given at the instructor's discretion, and unannounced, to avoid burdening the instructor with excessive grading work. The principal purpose of the readiness quiz is to "motivate" students to engage in the Preparation phase of the TBL strategy by doing the pre-class readings. Thus, the quiz has become an assessment of effort with a grading rubric consisting of the question "Did the student do the readiness assignment, and, if so, with how much effort?" and three possible answers: i) A, yes, and appropriate effort is evidenced by responses to quiz questions; ii) C, yes, but very little effort is evidenced by responses to quiz questions; F, no evidence shown of any real effort. Results from student course evaluation surveys suggest that a readiness quiz be given approximately every one-to-two weeks.

Use of preparation notebooks is an extension of the notion of reflective journals that are appropriate to courses in history, literature, education, etc. [4]. In our electric circuit theory courses students are required to summarize readiness readings and do readiness assignments in their preparation notebooks. The notebooks are occasionally collected and, like the readiness quizzes, assessed for effort. The grading rubric for the preparation notebooks consists of the question "How much effort did the student put into summarizing or outlining readiness readings and completing readiness assignments?" and five possible answers: i) Excellent (A), Readings are thoroughly outlined or summarized, and most assigned problems are worked to completion; ii) Good (B), Most readings are outlined or summarized, and many assigned problems are worked to completion; iii) Fair (C), A few readings are summarized, and some assignments are completed. Minimum passing effort; iv) Poor (D), Little, if any summary work, and very few assignments completed. Below passing standard; v) Failure (F), Little or no evidence of reading or working assigned problems before class. Feedback from student course evaluation surveys suggest that notebooks be collected approximately once every four weeks.

Determining final grades: criterion-referenced grading

Assessment data for the technical content learning outcomes (exams) and for the preparation and participation learning outcome (various continuous assessment instruments) have to be weighted and combined in some way in order to determine a final course grade. If the course has a laboratory component, that has to be included as well. It is important to recall that team-based learning requires students to collaborate with each other during group work so that everyone learns as much as possible. However, collaboration is inconsistent with a grading scheme in which students compete with each other for grades, as they do with norm-referenced grading, wherein a certain percentage of the students receive the grade of A, and so on. Such a scheme is a disincentive to collaboration and good group work, and should not be used. Criterion-referenced grading should be used instead. With criterion-referenced grading, each student's achievement (scores on exams and continuous assessments) of learning outcomes is measured against an absolute standard, i.e., how well the student can do what the learning outcomes require, regardless of how well other students can do it. Students are not in a competition with each other for grades, so everyone or no one can receive a good grade. Thus, criterion-referenced grading encourages collaboration, so it is consistent with the team-based learning strategy.

Conclusion

In summary, technical content-related learning outcomes are assessed using test questions and problems in a system of formative exams throughout the semester and a summative final exam. Final grades for the content-related learning outcomes are determined using the above-described 50-50 compromise.

The learning outcome related to the preparation and participation aspects of TBL is assessed continuously throughout the semester using attendance, instructor observation, peer assessment, readiness quizzes, and preparation notebooks. This group of assessment instruments has evolved over the past four semesters with helpful input from student course evaluation surveys. These instruments make it possible to gather ample data for this outcome, making it possible to attempt to do too much. Thus, they should be used judiciously, i.e., enough to fairly assess achievement of the outcome without overly burdening the instructor with assessment data work.

Finally, assessment data must be used in a criterion-referenced grading scheme that encourages collaboration and good group work.

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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.