Tests Given Throughout a Course as Formative Assessment Can Improve Student Learning

Robert M. O'Connell
Electrical and Computer Engineering Department
University of Missouri
Columbia, MO 65211

Abstract

Research has shown that formative assessment can have a significant positive impact on student learning. Furthermore, tests administered throughout a course can be used effectively for formative assessment. However, such tests are often used for both summative and formative purposes, which is erroneous because formative assessments work best when students can take risks and make errors without fear of penalty. In order to provide useful feedback, it is imperative that the instructor knows the students' misconceptions and knowledge gaps. Tests that have a summative component discourage students from taking such risks and thus hinder the formative feedback opportunity. This paper clarifies the differences between testing for formative and summative purposes and presents data from five recent offerings of a course in electric circuit theory that illustrate that when tests are used for strictly formative purposes, they can significantly enhance student learning, as shown by student performance on summative final examinations.

Keywords

Formative assessment; feedback; examinations; student learning.

Introduction

The purpose of this paper is to present and discuss the results of a study to quantify the benefits of properly used formative tests given throughout the duration of a course. For convenience, the term "midterm exams" is used to describe these tests, and they include all tests and exams given during the semester or quarter during which the course is taught, excluding the final, summative exam. Formative tests or assessments are, by definition, used to provide feedback to both instructors and students in order to enhance student learning and produce greater achievement of learning outcomes[1-3] as demonstrated on the summative final assessment or exam, which is used to help determine a grade. It is not used for feedback to improve student learning. Although the most common form of summative assessment is the final examination, some instructors structure their courses in units, and do a summative assessment after each unit. In that model, each unit of the course is essentially a self-contained mini-course.

Midterm exams are frequently used for both summative and formative purposes. For example, in a course having two midterm exams and a final exam, the midterms may each be used to determine ten to twenty percent of the final grade (while the final exam, laboratory scores, homework, and other items determine the remainder of the grade). This is the summative component of assessment. At the same time, the results of the midterm exams are also often used

to provide feedback that helps students improve their learning in preparation for the final exam. This is the formative component of assessment.

There are pedagogical difficulties associated with using midterm exams for both formative and summative assessment. First, learning outcomes are usually expressed in terms of what students should know and be able to do at the end of the course. By assigning permanent credit to midterm exams, the instructor either rewards the student prematurely (if he or she does well on the exam) or penalizes him or her unfairly (if they do poorly), because the learning outcome statement explicitly gives them until the end of the course to demonstrate achievement of the outcome. In many countries outside the U.S., there are no midterm exams, only the summative final exam. This practice is consistent with the learning outcome statement. Secondly and perhaps more importantly, formative assessments work best when students can take risks and make errors without fear of embarrassment and/or penalty[1]. For the instructor to provide useful feedback, it is necessary to understand the students' misconceptions and gaps in knowledge. Midterm exams with a summative component discourage students from taking such risks and thus demonstrating what they don't know and understand, thereby hindering the described feedback opportunity.

These difficulties posed the question as to whether and to what extent midterm exams, used properly for formative purposes, would be effective at improving student learning, as measured by student performance on summative final exams. Thus, as part of the process of adapting the teaching and learning strategy known as team-based learning (TBL) to basic electrical engineering courses[4–6], an important change to the basic process[7] has been to use strictly formative midterm exams. In the following sections, the manner of using formative and summative exams in those TBL-based courses will be described; and formative and summative assessment data from the five most recent offerings of a required course in electric circuit theory will be presented and discussed. In all five cases, the student scores were significantly higher on those portions of final exams that corresponded to earlier midterm exams; and that in those instances where formative midterm exams were not used for certain (the final two) learning outcomes, the scores on the summative final exam were significantly lower than those portions of the exam for which there had been an earlier formative midterm exam.

Methodology

The course in question is a required sophomore-level course in electric circuit theory, which has six intended learning outcomes (ILOs)[1]. Briefly, they are that by the end of the course, students should be able to analyze linear circuits containing operational amplifiers and transformers (ILOs 1 and 2); analyze RLC circuits in the time-and complex frequency domains (ILOs 3 and 4); and determine the impulse and frequency responses of simple passive and active filters (ILOs 5 and 6). In the five most recent offerings of the course (Spring 2013 through Spring 2015, inclusively), achievement of the first two ILOs was assessed formatively with a midterm exam approximately one-third of the way through the semester, and similarly for the third and fourth ILOs approximately two thirds of the way through the semester. Ideally, a third formative midterm exam should also be administered for the final two ILOs, but that would occur at the end of the course, just a few days before the comprehensive summative final exam. This usually places an excessive labor burden on the instructor, so in the five course offerings used in this study, the third midterm exam was not administered. This omission actually provided additional, useful information, as will be explained.

Prior to Spring 2013, midterm exams in the course were used formatively in the strictest sense. That is, the exams were graded to provide instructional feedback, returned to the students, and reviewed in class carefully, thus providing both instructor and students with the immediate opportunity to correct misconceptions and improve student learning in preparation for the course grade- determining final exam. Scores from the midterm exams had no bearing on final grades. That practice encountered two practical problems, which were identified in student course evaluation surveys[4–6]. The first was that many students would simply not take the midterm exams seriously or prepare well for them, because their scores didn't contribute toward the final course grade. Impending tests or even graded assignments in other courses (where scores contributed to the final grade) often took precedence over the strictly formative midterm exams in the circuit theory course. The second problem, also identified in course evaluation surveys, was that many students objected to the heavy grade-determining emphasis attributed to the summative final exam and the test anxiety associated with such a format.

To solve both problems, a compromise was adopted, by which, if a student's score on the portion of the final exam corresponding to a specific ILO is higher than the corresponding score on the earlier formative midterm exam, the final grade for that learning outcome is determined solely by the final exam score. This is the original strategy. However, if the student's score on the portion of the final exam corresponding to a specific ILO is lower than the corresponding score on the earlier formative midterm exam, then the final grade for that outcome is determined by the average of the two scores. This is the change to the original strategy, a compromise that treats the midterm exam scores as a back-up of sorts in case of a "bad day" on the final exam or a portion thereof. The effectiveness of this compromise solution was illustrated in student course evaluation surveys[4–6], which showed that, before instituting the compromise, 69% of students in the TBL-taught courses studied seriously for the formative midterm exams and only 32% of them were comfortable with the heavy emphasis given to the summative final exam. Since introducing the compromise, over 90% of students in those courses now treat the formative midterm exams seriously and are comfortable with the final grade-determining policy. This compromise was used in all five course offerings analyzed and discussed here, and it provided additional useful information concerning the benefits of the formative midterm exams.

Results and Discussion

The relevant data are provided in Table I. The first two columns give the semester of the course offering and the number of students completing the course that semester. The fourth and fifth columns of the table show, respectively, the average scores on the midterm exam and the portion of the final exam corresponding to the pair of ILOs identified in the third column. (The data were combined in ILO pairs this way for simplicity.) The sixth column (Percent Change a) shows the percentage change in the scores given in Columns 4 and 5. Thus, for example, in the Spring 2013 offering of the course, the class average on the portion of the final exam corresponding to ILO pair 1,2 (0.762) was 26.2% higher than the class average on the earlier midterm exam on the same two outcomes (0.604). All ten percent change values in Column 5 are positive, with an average value of 25.1%, which suggests that the formative midterm exams helped to improve student learning.

That suggestion is further supported by the negative percentage change values given in the sixth column (Percent Change b) of Table I. As stated above and shown in Column 4, midterm exams

were not given for the ILO pair 5,6 during any of the course offerings in question. The average scores on the portion of the final exam for that ILO pair are shown in Column 5; these values are smaller than the mean value of the two portions of the same final exam for ILO pairs 1,2 and 3,4 by the percentage given in Column 7. In the Spring 2013 offering, for example, the average scores on the final exam for ILO pairs 1,2 and 3,4 were, respectively 0.762 and 0.750, with a mean value of 0.756. The average score on the same exam for ILO pair 5,6 was 0.667, which is 11.8% smaller than 0.756. Similar results were obtained for the other five offerings of the course, as shown in the table, with an average negative Percent Change b value of 15.8%.

A final indication of the successful formative aspect of the midterm exams is shown in the final column of Table I, which shows the numbers and percentages of students whose final exam scores were at least as high on the final exam as they were on the earlier, formative, test. In aggregate, 212 of 246 (or 86.2%) students' ILO 1,2 scores were higher (or equal) on the final exam than on the earlier test; and similarly for 185 of 246 (or 75.2%) ILO 3,4 scores. This information is an additional benefit of the compromise grading scheme described above.

Table I. Data from TBL-Taught Electric Circuit Theory

Semester	No. of Students	Course ILOs	Midterm Average	Final Exam Average	Percent Change a	Percent Change b	No./Percent improved
Spring '13	42	1,2	0.604	0.762	+26.2		31/73.8
		3,4	0.736	0.750	+1.9		22/52.4
		5,6	-------	0.667		−11.8	
Fall '13	52	1,2	0.619	0.874	+41.2		47/90.4
		3,4	0.619	0.793	+28.1		42/80.8
		5,6	-------	0.671		−19.5	
Spring '14	48	1,2	0.613	0.817	+33.3		42/87.5
		3,4	0.632	0.760	+20.3		37/77.1
		5,6	-------	0.662		−16.0	
Fall '14	45	1,2	0.601	0.777	+29.3		38/84.4
		3,4	0.603	0.678	+12.4		31/68.9
		5,6	-------	0.634		−12.9	
Spring '15	59	1,2	0.625	0.810	+29.6		54/91.5
		3,4	0.626	0.804	+28.4		53/89.8
		5,6	-------	0.656		−18.7	

Conclusion

In the five course offerings studied, final exam scores for ILOs 1 through 4 improved by an average of 25.1% over earlier midterm exam scores on the same ILOs; and final exam scores on ILOs 5 and 6, which had not been formatively assessed prior to the final exam, were an average of 15.8% lower than the mean value of the final exam scores on ILOs 1 through 4. Also, 86.2% and 75.2% of students' scores improved on the final exam for ILO pairs 1,2 and 3,4, respectively. These results suggest that midterm exams, used properly for formative assessment, can be effective at improving student learning, in response to initially-posed question. One area for

continuation of the project will be to examine why the improvement in scores for ILO pair 3,4 is consistently smaller than for ILO pair 1,2.

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Biographical Information

Robert M. 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. He is currently Associate Head of the ECE Department and Director of the Teaching Fellows Program.