AC 2008-2368: A STUDY OF STUDENT RETENTION USING RAPID TESTING AND REPETITIVE TESTING: PRELIMINARY CLASSROOM RESULTS FROM AN FE REVIEW COURSE

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A Study of Student Retention using Rapid and Repetitive Testing: Preliminary Classroom Results from an FE Review Course

Summary

In this study, we have attempted to improve our students' retention of subject matter using a strategy of rapid and repeated testing. The study was done during the fall 2007 semester in a 1-credit, semester-long, review course for the FE exam. Retention was measured by comparing student performance on quizzes to their performance on the same topic-specific questions on intermediate quizzes and on the final exam.

Retention results were also compared to results for one topic that was taught without any intermediate testing. This topic was used as a control. The topic was taught to the same students and by the same instructor, but the topic was covered in a different course. Learning on the control topic was evaluated as part of a normal hour exam using a timed FE style instrument. Retention was measured for the control topic as part of the final exam. However, no intermediate testing was done. Our results showed significantly increased retention in eight of the nine subject areas reviewed with rapid, repeated testing.

As part or our work, we are developing review courses to help prepare our students to pass the discipline-specific Fundamentals of Engineering (FE) exam. The review course specifically designed for chemical engineering majors. During the fall semester, the course covers the general topics and we place emphasis on the topics where chemical engineers normally have a strong background: chemistry, mathematics, thermodynamics, materials, fluids, probability and statistics, circuits and computers. Statics and engineering mechanics were not covered. Recent research indicates that rapid, repeated testing could have a significant effect on long term retention.

In our course, nine of the morning FE exam topics are reviewed in two to four class periods. Class time allocated to each topic depended on the topic's weight on the FE exam and on our students' background. Following each topic, students were given a timed, FE-style, 10 question quiz that was graded immediately and a copy of the solution was posted. Student grades were posted to their Blackboard accounts. The quizzes contained a retesting component in addition to the questions covering the most recent topic. By the end of the course, each quiz contained additional questions covering the five most recently reviewed topics. Students are made aware of the retest topics and that the retest questions were being selected in areas where class performance was weak. Students were also given a 2-hour, timed, FE-style final exam covering all and only the FE topics reviewed.

Background

There are many review courses and review materials that are now available in the U.S. to help students prepare for and pass the Fundamentals of Engineering exam. Students take the FE exam to become an engineer-in-training. The FE is the first of two examinations that must be passed to become a licensed professional engineer.

Although many universities have review courses outside of the curriculum, only a few have required courses in their curriculum. We have placed two 1-credit review courses in our program to help with outcomes assessment for our program, to help our students prepare for the FE exam and to cover a few topics that might have been overlooked. Most review courses and materials treat all branches of engineering students as a homogeneous group having similar backgrounds and skill sets. Chemical engineering majors have taken an FE general topics review course on our campus for many years. The course has been taught or coordinated by an instructor with a strong background in mechanics. The course always places a high emphasis on mechanics and structures. The course is often team taught with "volunteer" lecturers in specific topic areas. Our general review also emphasizes fluid statics and the mechanical engineering part of thermodynamics while minimizing chemistry. As a result, chemical engineering students failed to gain enough confidence from the common course.

Many chemical engineering programs assist their students is some way to prepare for the Fundamentals of Engineering examination. Some programs offer no assistance because experience has shown that their students are able to succeed on their own. At a minority institution, course instructors face an additional cultural hurdle because many students have developed the feeling that "minority students don't do well on standardized tests." These institutions have an additional problem that comes from their mission to serve students that have average abilities. Their students do not want to attempt an examination where they are expected to fail. These institutions might greatly benefit from our approach of leading them through a course that demands they succeed. In addition, lower-tier schools could also benefit if their FE exam track record is at or below the national average.

Similarly, all courses could benefit from the implementation of rapid, repeated testing if history has shown that students have had difficulty with mastering an individual topic or concept.

Our Approach

In a recent review of the research conducted on the effect of rapid and repeated testing, Glenn[1] cited several studies that indicated that rapid testing and repeated testing could have a significantly positive effect on long term retention. We decided to test this concept in our FE review course because it has a diversity of topics. The review course provided us the opportunity to improve student performance and to evaluate a new tool for improving retention.

In our course, we covered nine of the 11 topics evaluated morning session of the FE exam. Two to four class periods were spent on each of the topics, depending on its weight on the FE exam. Within a week of completing a topic review, students were given a timed, FE-style, 15-question quiz. The quizzes were graded and a hard copy of the solution was posted on the same day. Student grades were posted to their Blackboard accounts. Each of the quizzes, except the first, contained a retesting component in addition to the 15 questions covering the most recent topic. Thus, a quiz could contain up to five additional questions covering five previously tested subjects. A sample, topic-specific quiz is shown in Table 1. Since Math is the most weighted FE topic, it was split into two sub-topics. Math 1 was covered following chemistry so the Math 1 quiz had 15 Math 1 questions and 1 Chemistry retest questions. The Math 2 quiz had 15 Math 2 questions, one retest question from Chemistry and 1 retest question from Math 1. Quizzes for the remaining topics were constructed similarly.

The instructors maintained a database of student success on each retest question. Students were made aware that the retest questions would be part of their ultimate quiz grade for each topic and that the retest questions would be selected in areas where the class performance was low. Students were graded in the course based on their quiz grades (75%) and on their final exam score (25%). For course grading purposes, the quiz grades for each topic included the initial quiz and all of the retest questions. The 2-hour, FE-style, timed, final exam covered all, and only, the FE subjects reviewed. We measured student retention by comparing student performance on a topic quiz during to student performance on the final exam in each subject area.

To have a control group for comparison purposes, we included and evaluated one of the FE topics, engineering economics. Engineering economics is taught in our design class during the same semester as the FE review. The control group had the same instructor and the same students. The topic, however, was taught rather than reviewed. In the design class, students were tested on engineering economics as part of a regular exam and as part of the normal final exam. They were not subjected to any mini quizzes. However, their knowledge was partially evaluated using the same instrument used in the review course. Students in process design were given a timed, FE-style, 15-question engineering economics quiz as the first part of exam 1. To measure retention in engineering economics, the control group was also given a timed, FE-style, 15-question engineering economics quiz as the first part of the final exam.

Our FE review course was based on current FE specifications[2]. The morning session of the FE exam has 120 questions covering 11 subject areas, according to the National Council of Examiners for Engineering and Surveying, NCEES. NCEES maintains, administers and grades all FE exams. It also publishes the FE exam specifications and the list of sub-topics included on each exam. We have developed and implemented a review course for chemical engineering majors. The objective of our course is to provide the student with an opportunity to review the general engineering topics that are included on the AM part of the FE exam. On completion of this course, we expect that the student will be able to:

- Demonstrate the expected problem solving and analysis skills necessary for them to perform as an entry-level engineer. (measured by ABET outcomes a to k)
- Pass the AM session of the Fundamentals of Engineering Exam as measured by passing the quizzes with an average score of 70%. (as measured by quizzes and the FE exam)

Our course topics were specifically selected for chemical engineering majors. The course emphasizes topics where chemical engineers have a strong background: chemistry, mathematics including probability and statistics, materials, fluids, computers and thermodynamics. We have de-emphasized, but not eliminated, magnetism, and electrical circuits. We eliminated any review of statics and engineering mechanics. Although the review is a 1-credit, semester course, it meets for three hours each week. The course topic syllabus, topic order and review time devoted to each topic are shown in Table 1.

Topic	Class Periods
Chemistry	5
Mathematics Part 1	4
Mathematics Part 2	4
Thermodynamics	4
Material Properties	3
Computers	3
Fluid Mechanics	4
Eng. Prob. & Statistics	4
Electricity & Magnetism 1	4
Quizzes	9

Our course is based on the most recent FE specifications[2] latest edition of the FE Review Manual[3]. We have also made use of the course materials that the text author and publisher[3] have so generously made available to instructors.

Our Results

The following data were taken for our control group. Our students performed well above the National Average for FE performance when they were tested immediately following their learning experiences. However, their performance dropped significantly when they were retested during the final examination.

Topic	Quiz Average	Final Exam Ave.	% Retention	National Average* [4]
Engineering Economics	**68.2**	**53.1**	**77.8**	**55**

* For Universities in the Comprehensive MS Category

All of our performance results are summarized in the table shown below. For eight of the nine review topics, our students' retention was significantly above that of the control

group. This improvement is retention can be attributed to continued reviewing and testing on sub-topics where class performance was poor.

Since topic retest scores are based on one question, the results for the individual retests are difficult to interpret. They do, however, provide some indication of the percentage of the class that was willing to prepare for the retest. Our results indicate that student retention in 8 of 9 topics is significantly higher with retesting (94%) compared to the control without retesting (77%).

Student retention in the remaining topic, Electricity & Magnetism, was poor. We felt that the poor performance on the Electricity & Magnetism questions on the final exam was caused by the fact that no retesting was done and by the time factor. The Electricity & Magnetism questions were at the end of the final exam. An informal survey of students, done at the beginning of the next semester, supported the notion that many students were pressed for time.

Electricity & Magnetism was retested as part of the first quiz given in the following semester as part of the chemical engineering topics review. Student performance on each FE topic was discussed and compared with national averages for each topic. The retest was done without any further discussion or review. The class averaged 63% on the retest. That score indicated 100% retention and further supports the notion that retesting improves retention. No general comparisons are made here to national averages for each topic. However, the average of initial quiz scores was close to the national average. They differ by less that 3%.

We have been teaching chemical engineering-specific FE review courses for the past 2 years. During that time, we have taught the test to help chemical engineering majors! Although many educators despise the idea of teaching to a test, it has been working for us. Our objectives are to increase the number of seniors that take the FE exam and to increase the pass-rate of our graduates. NCEES[2] reports that 55% of engineering graduates take the FE exam. We suspect, however, the percentage of chemical engineering graduates taking the FE is much lower. Our goals are to get over half of our graduates to take the exam and for them to perform above the national average. About half of our graduates have taken or plan to take the exam during the two-year period. For the April 2007 exam, our pass rate was less than 100%. On average, our graduates scored within 3 points of the FE passing score, which was estimated by the authors' to be 133 points out of 240 points. For the October 2007 exam, our pass rate was 100%, but few students took the exam.

Topic	**Initial Quiz Ave.**	**Retest 1**	**Retest 2**	**Retest 3**	**Retest 4**	**Retest 5**	**Final Exam Ave.**	**Retention**
	%	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Chem.	69	59	83	89	56	74	61	89
Math 1	76	83	44	94	100	47	75	98
Math 2	74	47	37	53	32	26	73	99
Thermo	61	26	53	53	27		67	110

Materials	66		61	44	94		59	89
Computers	64	89	57	37			56	89
Fluids	58		47				52	90
Prob. & Statistics	66	89					61	92
Electricity & Magnetism	63						47	75
Eng. Econ.	68						53	78

Conclusion

- Our results indicate that student retention can be significantly improved if they are rapidly and repeatedly tested on subject matter.

- Our results indicate that repeated testing is required to maintain student retention.

- Our results are too limited to recommend how much retesting is needed.
    - Based on the authors' experience and interaction with students, retesting 2-3 times might be optimum.
    - Students and authors feel that retesting five times might be counter productive.

- Single question quizzes might be just as effective as much longer tests, but individual performance is almost left to chance.

Bibliography

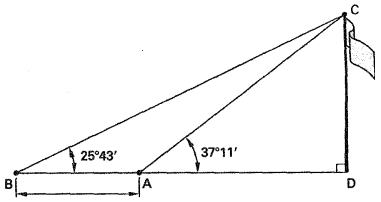
1. Glenn, David, "You will be tested on this", The Chronicle of Higher Education, Vol. 53 No. 40, June 8, 2007.
2. National Council of Examiners for Engineers and Surveyors (NCEES, www.ncees.org)
3. Lindeburg, M. R., "FE Review Manual – Rapid Preparation for the General Fundamentals of Engineering Exam", second edition, Professional Publications, 2006.
4. National Council of Examiners for Engineering and Surveying, NCEES, Data distributed at the 2007 ASEE annual meeting, Honolulu, HI, June 2007.

Table 2 Sample Topic-specific Quiz

Mathematics 2 Review Quiz (version A)

Math 1 Review Problem

The vertical angle to the top of a flagpole from point A on the ground is observed to be 37°11'. The observer walks 35 m directly away from point A and the flagpole to point B and finds the new angle to be 25°43'. The height of the flagpole is most nearly



(A) 32 m (B) 47 m (C) 85 m (D) 110 m

Chemistry Review Question

If 38 ml of an H_2SO_4 solution are required to neutralize 56.0 ml of a 1.5 N NaOH solution, the molarity of the solution is

(A) 0.96 M
(B) 1.11 M
(C) 2.22 M
(D) 4.85 M

Math 2 Quiz Problems (first 3 of 15 shown)

1. What is the polar form of the complex number $z = 3 + 4i$?

   (A) $z = 3 + 4i$ (B) $z = 5e^{-53.21i}$

   (C) $z = 5e^{-0.927i}$ (D) $z = \sqrt{27}e^{-0.927i}$

2. Rationalize the complex number, $\dfrac{4 + i5}{2 + i}$

   (A) $z = 2.6 + 0.8i$ (B) $z = 0.8 + 2.6i$

   (C) $z = -0.8 - 2.6i$ (D) $z = 2.6 - 0.8i$

3. The Laplace transform of the solution to the following equation with the given boundary conditions is

   $y'' + y - \sin 3t = 0 \qquad y'(0) = 0 \qquad y'(0) = 0$

   (A) $y(s) = \dfrac{3}{(s^2+1)(s^2+9)}$ (B) $f = y(s) = \dfrac{3}{(s^2+1)(s^2-9)}$

   (C) $y(s) = \dfrac{-3}{(s^2-1)(s^2+9)}$ (D) $y(s) = \dfrac{s}{(s^2+1)(s^2+9)}$