Improving Retention in a Thermodynamics Curriculum

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Abstract

Much attention is now being paid to assessment of learning in engineering technology. Current techniques usually focus on the individual course to see if desired outcomes have been met. These methods typically ignore the question of whether the student has retained the information and can recall it at a later date. The establishment of a prerequisite for a given course assumes retention based on the student's grade in the prerequisite course. To test the validity of this assumption, the faculty of the Mechanical Engineering Technology Department (MET) at Indiana University - Purdue University, Indianapolis (IUPUI), instituted, in the fall of 1999, a review test for students beginning a Thermodynamics II course. The test was made up of six questions on basic differential and integral calculus and four questions on basic thermodynamics. These represented the course's two prerequisites and all questions were multiple choice. The average scores for the students over an eight semester period were 46.6% for the mathematics and 38.3% for the thermodynamics, with a 43.3% overall. Clearly, retention has been limited.

In the fall of 2001 the MET Department instituted a comprehensive examination, also multiple choice, in its senior capstone design course covering twelve core subjects, including thermodynamics. While the results of this test have also shown limited retention (the average overall score is 47%), the students did much better on the four thermodynamics questions repeated from the test in Thermodynamics II (67% average). The marked improvement suggests retention can be enhanced by retesting subject material through the student's course of study for the BS degree.

I. Introduction

The Mechanical Engineering Technology program at IUPUI has, since its initial eligibility, been accredited by the TAC/ABET accreditation agency. This body requires the MET program to maintain outcome-based assessment processes for all of its courses[1]. Such processes have normally been developed within a particular course, with little emphasis on linkage to a course from its prerequisite. In other words, how much knowledge was retained in the prerequisite which the student passed that could be applied to the next course in a sequence. In 1999, this department initiated a test for prerequisite knowledge in its second thermodynamics course, MET 320, Applied Thermodynamics. Such an extension of assessment techniques has been shown to be an effective device for establishing the appropriate level at which instruction should begin in the follow-on course[2].

The early results of this test of prerequisites were disappointing as regards retention. Those results have been previously reported[3] and have prompted a review of material from the first thermodynamics course in the second. An update of the test results through the latest semester will be given herein. As will be seen, no improvement has occurred even though the students are by now well aware in advance of their being tested.

The question has arisen as to how successful the testing of prerequisites and the review in Thermodynamics II have been in augmenting retention of thermodynamics concepts. This has been evaluated as part of a comprehensive examination in mechanical engineering technology instituted in 2001 in our capstone design course, MET 414. This comprehensive examination is given as part of the curriculum, three-quarters along in the semester, and represents a portion of the course grade. It covers 12 subject areas, one of which is thermodynamics. Each subject is tested with ten multiple choice questions. For thermodynamics, four of those questions are the same as those on the prerequisite test. By comparing the results of these four questions on the comprehensive exam with those of the prerequisite exam, some conclusions can be drawn as regards retention.

II. Methodology

The test for prerequisites in the second thermodynamics course is given on the first day of class of the semester. It is in a multiple choice format of four possible answers. There are six questions on basic calculus (one of the prerequisites is the first calculus course), and four questions on basic thermodynamics. The questions, unchanged since inception of the test, are shown in Figure 1. Most would agree that these questions are not particularly difficult. Students are asked to answer the questions anonymously in ten minutes without using their textbooks. The test papers are collected and scored by the instructor. Answers and scores are given to the students during the next class meeting. The students are encouraged to review the material; the same textbook is now used for both thermodynamics courses. Once they learn the results of the test, the students are quite accepting of spending the first third of the second thermodynamics course in review of material from the first course.

The comprehensive examination was instituted in the capstone design course in 2001. It too is in a multiple choice format of four possible answers. The ten thermodynamics questions are shown in Figure 2. Note that the first four questions are identical to the four in the test of prerequisites. The ten questions are not grouped together but are scattered among those of the other 11 subjects for mechanical engineering technology majors (the department has other programs): statics, dynamics, computer graphics, strength of materials, machine elements, fluid mechanics, fluid power, material science, economics, manufacturing, and introduction to computers. Each subject's ten questions have been prepared by the faculty member responsible for the course. Scoring is by an electronic scanner. Results are given to the students as soon as possible as it becomes a part of their course grade.

Circle the correct answer of those following each question.

1. The integral of x dx is:

1	2x	x^2	$x^2/2$

2. The integral of (1/x) dx is:

x	2x	ln x	x^2

3. The integral of $6x^2$ dx is:

$2x^3$	$6x^3$	6x	$3x^2$

4. The derivative of $2x^2$ is:

2x dx	4x dx	$4x^3$ dx	x^3 dx

5. The derivative of 2 ln x is:

2x dx	(2/x) dx	(1/x) dx	2 ln x dx

6. The integral of x^2 dx from x=1 to x=3 is:

26/3	-26/3	26	none of these

7. Which of the following is a statement of the first law of thermodynamics?

$Q = mc(\Delta T)$	$W = \int p\, dV$	$Q - W = \Delta U$	all of these

8. Which of the following is the definition of enthalpy?

Q/T	Q - W	$mc_p\Delta T$	U + pV

9. The typical electric power plant relies on which energy conversion cycle?

Brayton	Otto	Rankine	Diesel

10. Which of the following expresses the second law of thermodynamics?

a) Work cannot be completely converted into heat.
b) Heat cannot be completely converted into work.
c) Energy can be neither created nor destroyed in a system.
d) The rate of mass flowing into a system equals the mass flow rate leaving.

Figure 1. Test of Prerequisites in Thermodynamics II

1. Which of the following is a statement of the first law of thermodynamics?
(a) $Q = mc(\Delta T)$ (b) $W = \int p\, dV$ (c) $Q - W = \Delta U$ (d) all of these

2. Which of the following is the definition of enthalpy?
(a) Q/T (b) Q - W (c) $mc_p\Delta T$ (d) U + pV

3. The typical electric power plant relies on which energy conversion cycle?
(a) Brayton (b) Otto (c) Rankine (d) Diesel

4. Which of the following expresses the second law of thermodynamics?
(a) Work cannot be completely converted into heat.
(b) Heat cannot be completely converted into work.
(c) Energy can be neither created nor destroyed in a system.
(d) The rate of mass flowing into a system equals the mass flow rate leaving.

5. What is the efficiency of a Carnot cycle operating between 950 F and 500 F?
(a) 31.9 % (b) 47.4 % (c) 52.6 % (d) 68.1 %

6. Ten pounds of air expand from 300 to 900 cubic feet in volume at a constant pressure of 20 psia. How much work is done by the air?
(a) 2221 Btu (b) 2221 ft.-lbs. (c) 22,210 Btu (d) 1,220 Btu

7. In an air standard Otto cycle, the compression ratio is 10. Maximum and minimum temperatures are 2000 K and 300 K. What is the efficiency of this cycle?
(a) 39.8 % (b) 60.2 % (c) 72.2 % (d) 85.0 %

8. In an ideal vapor compression refrigeration cycle, the process through the expansion valve is characterized by which of the following processes?
(a) constant pressure (b) constant volume (c) constant entropy
(d) constant enthalpy

9. Four pounds of water at 100 F are mixed with six pounds of water at 60 F. If the specific heat of water is 1.0 Btu/lb-degree, find the total change of entropy, in Btu/degree, for this process.
(a) + 0.0066 (b) + 0.0808 (c) + 0.1818 (d) zero

10. The inside surface of a cylindrical steel pipe is at 200 F; the outside at 60 F. The pipe's thermal conductivity is 26 Btu/hr-ft-F. Find the rate of heat conduction in Btu/hr through the pipe's wall per foot of pipe length if the pipe is 6 inches OD by 0.5 inch thick.
(a) 7,280 (b) 87,360 (c) 125,442 (d) 262,849

Figure 2. Thermodynamics Questions on Comprehensive Exam

The test results were evaluated to see how the scores for the thermodynamics questions on the comprehensive examination compare to those of the other subjects on this exam and how the scores of the four original thermodynamics questions compare between the prerequisite exam and the comprehensive exam.

III. Results and Discussion

The scores for the ten thermodynamics questions as well as the overall scores for the comprehensive examination by semester are given in Table 1. These results are of the same order of magnitude as those for the thermodynamics prerequisite test (Table 2). However if one breaks out the four thermodynamics questions asked on both tests, the results are far better. As shown in Table 3, the average score for the four repeated questions on the comprehensive exam was 67 percent, whereas the score for the remaining six thermodynamics questions was 27 percent. Of these six questions, the scores were lowest for those requiring calculations; number nine in particular was considered the most challenging and resulted in the lowest score. One can conclude that the repetition of exam questions concerning concepts contributes to greater retention of the subject matter of the questions.

The score for the four repeated questions was 43 percent better than the score for the full comprehensive test, whereas the score for the remaining six thermodynamic questions was 43 percent worse. One cannot make definitive statistical analyses of the scores since there was not a control group; i.e. one that took the comprehensive exam but not the prerequisite exam. Also the latter exam has historically been given anonymously so that one cannot assign a score to an individual student. Some validity may be attached to the comprehensive exam results by comparing the scores of the ten thermodynamics questions with those of the ten questions on fluid power. Both courses are taught by the author and the level of the fluid power course corresponds to that of the first thermodynamics course. The average score for the ten thermodynamics questions on the comprehensive exam was 43 percent, whereas that for the ten fluid power questions was 45 percent, a comparable result.

It can also be seen that for individual questions as well as the test as a whole, scores tend to be better in the spring semester than in the fall semester. This holds for both the prerequisite exam and the comprehensive test. The averages for the full comprehensive test are 41 percent in the fall semester and 53 percent in the spring. The scores for the thermodynamics prerequisite test average 39 percent in the fall compared to 41 percent in the spring. It appears that the longer vacation between spring and fall contributes to less retention than the shorter period between fall and spring.

To test the concept that a retest enhances retention, additional thermodynamics questions from the comprehensive examination will be added to the prerequisite test. In addition, prerequisite tests will be added to other advanced courses in the MET curriculum. We are also considering modifications to the prerequisite tests, namely giving them further along in the advanced course and scoring these tests as part of the students' grade in the course. The results of changes and additions to prerequisite testing will be presented in future papers.

Table 1. Test Scores for Comprehensive Exam

	Fall 01	Spr 02	Fall 02	Spr 03	Cumul
No. of Students	10	12	17	14	53
Thermo Q1 Score	0.70	0.67	0.65	0.64	0.66
Thermo Q2 Score	0.60	0.75	0.82	0.71	0.74
Thermo Q3 Score	0.70	0.75	0.82	0.79	0.77
Thermo Q4 Score	0.40	0.83	0.35	0.50	0.51
Thermo Q5 Score	0.30	0.50	0.06	0.21	0.25
Thermo Q6 Score	0.30	0.58	0.06	0.57	0.36
Thermo Q7 Score	0.10	0.58	0.41	0.14	0.32
Thermo Q8 Score	0.30	0.17	0.24	0.21	0.23
Thermo Q9 Score	0.00	0.08	0.12	0.07	0.08
Thermo Q10 Score	0.20	0.58	0.29	0.57	0.42
Full Test Score	0.39	0.55	0.42	0.51	0.47

Table 2. Scores for Test of Prerequisites

RESULTS BY SEMESTER AND SUBJECT				
Semester	No. Students	% correct Calculus Ques.	% correct Thermo. Ques.	% correct All Questions
Fall 1999	15	50.0	41.7	46.7
Spring 2000	10	56.7	40.0	50.0
Fall 2000	16	45.8	39.1	43.1
Spring 2001	14	51.2	44.6	48.6
Fall 2001	13	71.8	42.3	60.0
Spring 2002		NOT GIVEN		
Fall 2002	19	50.9	39.2	46.2
Spring 2003	14	59.5	39.3	51.4
Fall 2003	15	46.7	33.3	41.3
Totals	103	46.6	38.3	43.3

Table 3. Comparison of Scores on the Comprehensive Exam

	Fall 01	Spr 02	Fall 02	Spr 03	Cumul
No. of Students	10	12	17	14	53
Score of 4 Repeated Thermo Questions	0.60	0.75	0.66	0.66	0.67
Score of 6 New Thermo Questions	0.20	0.42	0.20	0.30	0.27
Full Test Score	0.39	0.55	0.42	0.51	0.47

IV. Conclusions

A test of prerequisites was instituted in a second thermodynamics course to evaluate retention of key topics. The results of these tests have been disappointing and prompted extensive review of basic thermodynamics in the second course. Subsequently a comprehensive examination was begun as part of the syllabus of our department's capstone design course that involved thermodynamics plus 11 other subjects. The results of these comprehensive exams, while also disappointing overall, did show significant improvement in the scores for the thermodynamics questions that were repeated from the prerequisite test. We have concluded that repetition of concept questions can help with overall retention and additional tests of prerequisites will be added to the syllabi of other advanced courses in MET. We believe that there is a natural loss of retention of material with time and that subsequent retesting of basic material can help to minimize such loss.

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