AC 2005-223: DEVELOPMENT OF A STANDARDIZED LABORATORY EXAM FOR A MATERIALS AND MANUFACTURING COURSE

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Development of a Standardized Laboratory Exam for a Materials and Manufacturing Course

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Abstract

Many courses have a laboratory component. Some fraction of the courses have laboratory as part of the course while the remaining fraction have it as a separate course that need not be taken with the lecture portion of a course. Mechanical Engineering at Texas A&M University has a junior level materials and manufacturing course that includes the laboratory as part of the course. Over the years, faculty have wondered whether or not students learn in laboratory what the faculty envision is important and significant. For the past several years, we have worked on developing a laboratory test that assesses what the students have learned. This paper will discuss the development of the questions and examine the student responses. These will be compared with the course objectives and ABET program objectives a through k.

Introduction

Laboratory activities have been an integral part of the education process for a long time. It is the opinion of faculty that hands-on-activities enhance the learning process. Very few persons would like to have their blood drawn from a phlebotomist who had never practiced, but had only read the book.

Typically, engineering courses have the laboratory as either an integral part of the class or a separate free standing course that may or may not be taken with the lecture portion of the class. In mechanical engineering at Texas A&M University, we have a four-credit junior materials and manufacturing course that includes laboratory as part of the course. This course has recently been developed and we have reported on the development of the course at conferences.[1, 2, 3] A question that has bothered the faculty is whether or not the students have grasped the concepts we hope to have them develop from doing the laboratory activities. One of the ways of doing this is to use a standardized test that enables the students to be compared on a year to year basis. This paper will describe the development of the test and compare the results to course objectives and ABET outcomes.

A comparison of the laboratory activities for the past two semesters is shown in Table 1. Generally the fall semesters have fewer activities because of the Thanksgiving holidays. We have often started on the first week of classes to maximize the number of activities. As the table illustrates, there are several weeks of doubled up activities. The laboratory counts as 25% of the course grade. Each section of between 16 to 20 students has a faculty member and a TA assigned to the class. In addition, there is a technician and a laboratory supervisor available for helping, and in fact, they direct the welding, casting, and machining laboratories. At the end of the semester each faculty member gives the course instructor a grade for each of the students in his/her section.

Table 1. Comparison of laboratory activities for spring and fall semesters 2004.

Weeks	Spring 04	Fall 04
1	Introduction & Metrology	TA Training
2	Welding	Introduction & Metrology
3	Tensile Test & Hardness	Tensile Test & Hardness
4	Impact and Fatigue	Welding
5	Rapid Prototyping and Planning	Impact and Design and Planning
6	Heat Treatment of Steel and Aging of Aluminum	Heat Treatment of Steel and Aging of Aluminum
7	Cold work and Annealing	Injection Molding and Tensile Testing
8	Casting	Cold Work and Annealing
9	Injection Molding and Tensile Testing	Machining
10	Machining	Machining
11	Machining	Machining
12	Machining	Casting
13	Micromachining	Testing of Link and Weld Specimen
14	Oral Presentation	
	Laboratory Final Exam, 19April2004	Laboratory Final Exam, 11-22-04, 7 pm room 102 Zach

Reporting activities are mixtures of individual reports, business letters and team reports. The faculty decides this before the start of each semester. There has been at least one individual formal laboratory report and business letter required each semester.

In combination with faculty desires to have more student involvement and to help satisfy ABET Program Outcome b, the students are responsible for developing three experiments: heat treatment of steel, precipitation hardening of Al, and the design of a link for rapid prototyping, casting, and testing. The laboratory has many activities and for the fall, the faculty decided to eliminate the fatigue test. Both the welding and the machining activities are done using Engineering Technologies facilities. In particular, the machining activity has been added within the past three years and for the past three semesters, each student has made a hammer.

Development of Test

The development of the test has taken place over a period of five or six years. Initially, the test required students to remember details such as the ASTM standard for tensile testing. However, faculty realized that we had the opportunity to develop a test that would help us understand whether or not students have learned the concepts the faculty were anticipating they would. Table 2 list the topics covered in the examination, the number of questions under each particular topic, and whether the question is considered a concept or knowledge question. The number of questions for each topic is related to the faculties opinion of the importance of each topic and the faculties backgrounds.

Table 2. The number of questions and the topics covered.

Topic Covered	No. of Questions	Knowledge	Concept
Report writing	1	1	0
Tensile test	6	2	4
Hardness	4	2	2
Impact test	2	1	1
Injection molding and strain rate effects on polymers	4	2	2
Aging of aluminum	5	0	5
Heat treatment of steel	4	3	1
Machining	2	0	2
Manufacturing (Design, casting, and rapid prototyping)	5	2	3
Welding	2	2	0
Cold work and annealing	5	0	5
Evaluation of exam	2		

Thirteen of the 40 questions are included in the appendix. Nine of the questions are considered concept questions, while the remaining four are thought to be knowledge questions. They are marked with C for concept and K for knowledge. The examination is given in the evening as part of the lecture portion of class. We also use that time to ask students questions about which laboratory activities were especially worthwhile and which could use improvement.

If all 40 questions are considered then the number of concept questions would be 25 and the number of knowledge questions would be 15. The percentage of knowledge questions increases from about 30% in the 13 demonstration questions to 38% for all 40 questions. Table 2 provides the number of concept and knowledge questions for each of the 40 questions.[4]

Results

The average tests results are compared in Table 3 for the past two semesters. During spring 04 the test contained 45 questions, while the fall exam contained only 40 questions. Since, the fatigue test was dropped; those questions were eliminated from the exam. For all of the students, the % correct is shown in Figure 1for the spring and fall data.

Table 3. Data comparison for spring and fall 2004.

	Fall 04		Spring 04	
	No. of Ques. Correct	% Correct	No. of Ques. Correct	% Correct
Average	22.19	55.48	25.91	57.56
Maximum	32.00	80.00	37.00	82.00
Minimum	13.00	32.50	17.00	38.00
Standard Deviation	3.49	8.73	3.98	8.83
No. of Students		93		90

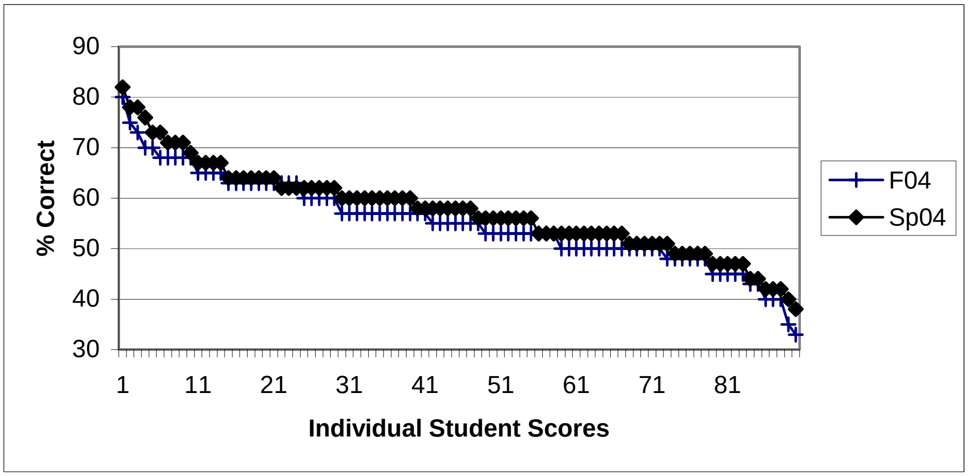

Figure 1. A comparison of fall 04 and spring 04 data for the laboratory final exam. The % correct is given on the y-axis, while individuals are represented on the x-axis.

The agreement between the spring and fall data is very good. The data in Figure 1 is plotted as percentages, so that the different number of questions is not relevant.

Discussion

Both the fall and spring courses have 90+ students. Even though the tests differ by five questions the averages, maxima, minima, and standard deviation are very similar. Frankly, it was disappointing the initial time that we gave the test to have such a low average. We expected the average to be in the 70's. However, the second time the test was given an average in the 50's was not surprising. Similar results have been shown for the Materials Concept Inventory developed by Krause, et. al.[5]

For the fall test, if 70% is considered acceptable and this is the percentage that the department used for ABET, then 13 of the 40 questions were acceptably passed. Of those questions, four were considered knowledge questions while the remaining nine were considered concept questions. The above questions and their answers are shown in the Appendix. The ones marked C are concept questions and the ones marked K are knowledge questions.

Two areas that were surprising were the aging of aluminum and the heat treatment of steel. There were nine questions asked and none were greater than 70%. If the passing percentage is dropped to 60%, then three of the nine questions were passed. However, there were a couple of areas where the students performed adequately. The tensile test and manufacturing and design had 3 of 5 questions above 70%, while machining had 2 out of 2 questions above 70%.

The laboratory portion of the class satisfies ABET Program Outcomes (PO) a, b. d, g, and k. The laboratory final examination contributes ABET PO a, b, and k. These are shown in Table 4.

Table 4. ABET program outcomes and course outcomes for laboratory portion of course.

	Outcomes
ABET a	an ability to apply knowledge of mathematics, science, and engineering
ABET b	an ability to design and conduct experiments as well as to analyze and interpret data
ABET k	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
Course 3	The student should be able to describe, in detail, select and use mechanical property tests, and determine failure modes
Course 7	The laboratory experience will provide the students an opportunity to independently determine characteristics of materials and processes, and plan experiments.
Course 8	Students should be able to use engineering metrology and instruments to measure and evaluate dimensions.

The last two questions asked of the students were their opinions of the test. Twenty considered it about right, 50 thought it was too difficult, and 22 thought it was very difficult. With regard to the fairness of the exam, 4 considered it completely fair, 50 mostly fair, 25 mostly unfair and 2 thought it was completely unfair.

For grading purposes 20 points were added to each score and the laboratory final exam counted 10% of the 25% laboratory portion of the course grade.

Improvements

Eight of the questions had many more wrong answers than correct answers and these questions need to be re-evaluated or perhaps reworded. Clearly, the faculty need to a better job helping students develop an understanding of the aging of aluminum and the heat treatment of steel. As part of the means to improve students understanding in these areas, faculty are considering rearranging course content in our materials courses. This is complicated by the fact that one of the courses is a college wide course and changes have to be agreed upon by faculty of different departments. Within the laboratory itself, faculty are trying to be more intentional about the specific activity on heat treatment to insure student understanding.

Conclusions

A laboratory examination was developed and tested over two semesters. The results were similar with an average grade of about 55%. The tests were a mixture of concept and knowledge questions. More work needs to be done helping students learn concepts that faculty consider important for a materials and manufacturing course.

Acknowledgments

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Biographical Information

RICHARD B. GRIFFIN- Dr. Griffin is part of a materials group within mechanical engineering at Texas A&M University. He has been an active member of the Materials Division for more than 15 years. His research interests are education and corrosion.

K. T. HARTWIG- Dr. Hartwig is currently the leader of the materials group within mechanical engineering at Texas A&M University. He has been at A&M for 20 years. His current research interests are severe plastic deformation, applied superconductivity and technical writing.

Answer

Appendix

Reference and Reporting

1. Which section of a complete technical report should be viewed as a "mini-version" of the report?

K

   A. Table of Contents
   B. Abstract
   C. Introduction
   D. Results/Discussion
   E. Summary/Conclusions

Lab Tensile Testing - Metals

2. What is a typical value of Poisson's ratio for metals during elastic deformation?

K

   A. 0.00
   B. 0.10
   C. 0.33
   D. 0.50
   E. 1.00

3. All of the following can be determined from a tensile test **except**:

C

   A. Yield strength
   B. Ductility
   C. Tensile strength
   D. Flexural Strength
   E. Young's Modulus

4. What is the area under the complete stress-strain curve for a ductile metal?

C

   A. Hydrostatic pressure
   B. Energy to fracture
   C. Resilience of the metal
   D. Permanent deformation
   E. Biaxial stress state

Lab - Hardness

5. Which of the following is important when determining the location for a hardness test on a specimen?

C

   A. Specimen thickness
   B. Distance form edge of specimen
   C. Distance between indentation centers
   D. All of the above are important
   E. None of the above are important

6. The hardness test that is most suited for hard steels is:

K

   A. Brinell
   B. Rockwell B
   C. Rockwell Superficial B
   D. Tukon B
   E. Rockwell C

Lab - Impact

7. Which of the following will encourage brittle fracture in a carbon steel plate?

C

   A. Stress concentration
   B. Low temperature
   C. High strain rate
   D. All of the above
   E. A & B only

Lab TT Polymers

8. When thermoplastic linear amorphous polymers are stretched at a temperature 10°C above T_g to produce a given strain, and then the strain is held constant, the stress will:

C

   A. Decreases due to stress relaxation
   B. Remains constant
   C. Increases due to creep
   D. Increases due to stress relaxation

E. None of the above

Lab - CW/Annealing

9. The increase in hardness of a metal due to cold working is because of:

C

- A. An increase in dislocation density
- B. An increase in ductility
- C. An increase in modulus of elasticity
- D. An increase in grain size
- E. B & D

Lab- Manufacturing

10. What are advantages of rapid prototyping?

C

- A. No machining
- B. Quick turn around
- C. Parts customers may handle.
- D. Can be used for casting patterns
- E. All of the above

Lab- Welding

11. Consider a circumferential (girth) weld on a 24" diameter steel pipe. What is the name given to the welded region between the pipes?

K

- A. MIG welding zone
- B. TIG welding zone
- C. Liquid metal zone
- D. Heat affected zone
- E. Failure zone

Lab Machining

12. For a lathe, what does the maximum speed describe?

C

- A. Travel of the tool parallel to the workpiece.
- B. Motion of the tool perpendicular to the workpiece.
- C. Rotation of the workpiece at the surface.
- D. Rotation of the tool.
- E. Rotation of the tailstock.

13. For a lathe, what does the feed rate describe?

C

- A. Travel of the tool parallel to the workpiece.
- B. Motion of the tool perpendicular to the workpiece.
- C. Rotation of the workpiece at the surface.
- D. Rotation of the tool.
- E. Rotation of the tailstock.