AC 2008-414: ALTERNATIVE STUDENT PERFORMANCE EVALUATIONS IN MECHANICAL MEASUREMENT COURSES

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Alternative Student Performance Evaluations in Mechanical Measurement Courses

Abstract

Courses that introduce experimentation, mechanical measurements and instrumentation have always been a fundamental part of a mechanical engineering technology program. Over the past few years, many papers have been written to document the drastic evolution of these courses. Most of the changes have been driven by advances in virtual instrumentation and data acquisition. Other developments resulted from critiquing student outcomes, which was brought about from current accreditation procedures.

One area which has not been addressed in the literature is assessing student knowledge in these courses. While the content and pedagogy of mechanical measurement courses has evolved, the grading has not. Grades are primarily determined from knowledge-based, problem-oriented tests and laboratory reports. While these are valuable assessment measures, they focus on a theoretical understanding, and the ability to analyze and communicate results. They do not directly address the ability of the student to design, configure and perform experiments. These items are the main focus of engineering technology programs.

This paper deals with methods to assess the abilities of the students in mechanical measurement courses. A review of common student outcomes and primarily used assessment methods will be presented. Yet, the focus will be on an alternative method, namely, practicum exams. This paper includes a statistical correlation of student performance at the University of X on primary and alternative measures. Additionally, student and instructor reactions to the methods at University of X will be offered.

Introduction

A course that introduces mechanical measurements, instrumentation and experimentation techniques has continually been an essential part of mechanical engineering and engineering technology programs. In many curricula, this course can single-handedly satisfy a program outcome required of the primary accreditation agency, ABET[6].

b. "Students must have the ability to conduct, analyze and interpret experimental and apply experimental results to improve processes"

The typical mechanical measurements course includes familiarization with a variety of sensors, while completing fundamental mechanical measurements[1, 7, 9]. The course allows students to gain experience with experimentation, along with expanding their understanding of mechanical phenomena presented in other courses.

The use of sensors, instrumentation and data acquisition systems in commercial products and manufacturing equipment has been rapidly growing over the last several years. "Smart" has been used to describe products from aircraft to automobiles to toasters[14]. Expertise with mechanical measurements is critical for technical professionals working with the design or implementation these systems.

Traditionally, product and manufacturing system design has been a common career area for mechanical engineering and engineering technology graduates. To follow suit with the growing use of sensors in these systems, mechanical programs have been strengthening their facilities and curriculum related to instrumentation[3, 11, 12]. Topics covered in mechanical measurements has been expanding to incorporate more digital data acquisition and electronic instrumentation topics[5, 10, 16]. With this growth of industry usage, these courses are even being introduced onto general engineering programs[8].

Inspired by accreditation changes beginning in 2000, a large amount of research and dialog has circulated regarding assessment of engineering education[13, 15, 17]. Increased attention has been paid to program outcomes, and their relationships to individual course outcomes. Quality assurance plans have been instituted that monitors the student performance relative to targets set for each specific course outcomes. The assessment results should be filtered upward to the program level, and outcomes. Course, or curricular, modifications can be made to address shortcomings.

In light of preparing a comprehensive assessment plan, a critical look was made on the methods of evaluating student competencies in a mechanical measurements course[2]. During the review, it appeared that an apparent hole exists. To address the issue, an alternative method of assessment was implemented, namely, a practicum exam. The remainder of this paper presents the outcomes from a typical course, the common assessment methods and details of the practicum exam.

Review of Mechanical Measurement Courses

A study was conducted that reviewed the outcomes and assessment criteria of several mechanical measurements courses. Course outlines, or syllabi, were obtained from 17 random institutions through an internet search, including both mechanical engineering and mechanical engineering technology programs. A list of the universities and programs is included in the appendix. All courses had a laboratory component; typically 2 hours of lecture and a 3 hour lab each week. Most stated that the students complete the lab exercises as teams.

The course outcomes of all outlines were strikingly similar. While the wording was varied, four primary pillars surfaced. These are:

1. Students will develop an understanding of the operational theory and apply appropriate sensors, instrumentation and computer acquisition systems to measure physical quantities; (*Instrumentation*)
2. Students will be able to devise an experiment, specify equipment and procedures, and implement the procedure; (*Experimentation*)
3. Students will understand how to analyze experimental work; (*Data Analysis*)
4. Students will be able to communicate their experimental results, conclusions, and the significance of the conclusions. (*Communication*)

All of the courses cited that grade determination would be based on laboratory reports and exams. Many of the courses also required homework and some form of a design project. The grade for the project was based on a formal is a report.

Possible Inconsistency between the Outcomes and Evaluation Methods

Critically reviewing the four outcomes identified above, attention was placed on a key word in outcome 1 being “apply”, and from outcome 2 being “implement”. These are both interpreted as having a working knowledge. The action words are consistent with “conduct” from the accreditation outcome b., listed in the introduction section.

It is noted that traditional homework and exams directly evaluate outcome 3, and partially assess outcome 1. Questions and problems can assess data analysis and understanding of sensors . However, they do not address the ability to set-up and conduct experiments. In other words, a working knowledge of the equipment is not assessed.

Laboratory reports directly assess outcomes 3 and 4, and indirectly assess outcomes 1 and 2. Working in a team, a single student may not gain sufficient proficiency in configuring sensors, instrumentation and a data acquisition system. They may be able to report on the set-up, but may not be able to perform the task themselves.

Design projects, if used, directly assess outcome 3 and 4, and partially address 1 and 2. Again, working knowledge is not verified with a report.

The author has encountered several students who poorly participate during equipment set-up and experimentation, yet submit excellent reports and perform well on exams. Additionally, some mechanical students often get confused wiring circuits, and avoid that task, deferring to their bench mate. A high final grade is awarded, yet ability to conduct testing is questioned. This awareness that course outcomes are not directly and completely assessed led the author to incorporate an alternative assessment, specifically practicum exams.

Practicum Exams

The practicum exams as incorporated in the mechanical measurements course at the University of X place a single student at a bench. The lab is equipped with 10 identical benches. The student is asked to configure and perform 3 or 4 basic and intermediate tests during a 45 minute period. All the necessary apparatus, and some decoys, are given in a box at each bench. Measurement results, and set-up sketches, serve as exam answers. In some cases, the students need to call the instructor to the bench to evaluate the set-up. Three of these practicum exams are given during a semester.

The goal for the practicum exam is to evaluate working knowledge. However, the questions/problems typically require the student to have an understanding of the underlying technical principles. For instance, prior to taking measurements, students must understand that electrical power consumed by a dc motor is the product of voltage and current.

Examples of Practicum Problems

The following lists several examples of practicum problems used by the author. They are separated into the major competency evaluated; mechanical setup, instrumentation setup, data acquisition programming.

Mechanical Set-up Problems:

- Using the calipers, measure and compute the moment of inertia of the bar consistent with the strain that would be sensed by the gage.
- Using the handheld force gage, determine the coefficient of friction of the steel block on the steel runner.
- Clamp the beam to the bench top. Place 3 lbs on the beam at a distance of 5 inches from the strain gage. Using the bench top meter, determine the experimental strain sensed at the gage (GF = 2.083).
- Measure the density of the steel slug, and compare to the handbook value.

Instrumentation Set-up Problems:

- Use the power supply to apply 5 V through the resistor labeled "RD". Use the bench-top multi-meter to measure the amperage draw. Record the value, and roughly draw your circuit below.
- Use the power supply to apply 5 V as an excitation to the appropriate colored wires of the linear displacement transducer. Extend the transducer to 3 inches, and use the bench-top multi-meter to determine the voltage of the transducer signal.
- Use the themistor and the bench top multimeter to measure the temperature of the room. The constants for this thermistor are $a = 0.0009354$, $b = 0.0002211$, and $c = 1.275\text{x}10^{-7}$.
- Apply 4.5 volts to the motor. Determine the power being drawn by the motor.
- Using the power supply, the transistor the mystery resistors (labeled) and the small dc motor, create the circuit in Figure 1.
  a) Use the bench-top multi-meter to determine the voltage across the motor.
  b) Use the bench-top multi-meter to determine the current through the motor.

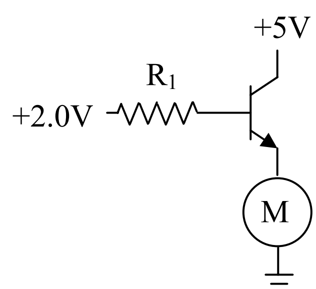

Figure 1: Motor drive circuit.

- Clamp the beam to the bench top. Place 3 lbs on the beam at a distance of 5 inches from the strain gage. Using the power supply, bench top meter, and dummy resistors, determine the experimental strain sensed at the gage (GF = 2.083).

Data Acquisition Programming Problems:

- Create a LabVIEW program to read the “unknown voltage” from the power supply on the circuit trainer into channel 5. Configure the channel to read 0 to 10V. Record the value below.
- Create a new LabVIEW program that accomplishes the following tasks:
    a) Drives a motor using a voltage read from the front panel and placed in a while loop.
    b) Accepts a tachometer output from the motor. Set your DAQ to ±6V, 2000 samples per second, and 500 samples.
    c) Calculates the rpm, using the pulses per revolution as an input from the front panel.
    d) Determines the difference from the rpm determined in the prior acquisition.
    e) Turns on a light on the front panel if the rpm is either above or below specified limits (on the front panel).
    f) Shuts the lights off when the stop button on the while loop is pressed.
- With the two resistors labeled R1 and R2
    a) Use the bench-top multi-meter to determine their resistance.
    b) Use the two resistors to create a voltage divider. Apply the 5 V (from the power supply) across the voltage divider circuit. Create a LabVIEW program to read the voltage across the smaller resistor.
    c) When configuring the acquisition channel in LabVIEW, specify the input range you used, and indicate why.
    d) Use a statistics function to measure the noise range of a random 1000 sample points from the voltage signal.
- Send the signal from the Function Generator portion of your BNC board into any analog input channel. Configure LabVIEW to acquire 10000 points of a ±0.5V signal at 10k hz.
    a) Create a waveform graph, and sketch the first 0.04 seconds of your acquired signal.
    b) Use the axis labels to determine voltage and time values of a few points that define one cycle. Label the values on your sketch.
    c) From these measurements, determine the period and peak-to-peak amplitude of the signal.

Student Perception Survey

A survey was administered to multiple sections of the course to gauge the student’s perception of the assessment tools. There were 38 responses to the survey. The responses where solicited on a standard Likert scale (4: strongly agree, 3: agree, 2: neutral, 1: disagree, 0: strongly disagree). The quantitative results are given in table 1.

The findings from the perception survey confirmed the author’s expectation. A summary of these findings include:

- Students cited that problem based exams adequately assessed their knowledge of the measurement theory and functioning of a sensor, but did not assess their ability to perform experiments.

- Students indicated that practicum based exams assessed their ability to perform experiments. They also stated that the practicum exams assessed their understanding of the theory.
- Students feel that laboratory reports did a better job assessing the effort placed in a course than mastery of the course material.
- Students were most consistent (lower standard deviation) in their belief that the problem oriented exams fairly assessed their understanding of theory. Additionally, they were consistent in believing that practicum exams fairly assessed their working knowledge.

	Average	Std. Dev
1. The problem oriented exams adequately assessed my understanding of the theory.	3.27	0.66
2. The problem oriented exams adequately assessed my ability to perform the experiments.	2.42	0.82
3. The problem oriented exams adequately assessed my ability to program LabVIEW.	2.82	0.77
4. The practicum exams adequately assessed my understanding of the theory.	3.11	0.79
5. The practicum exams adequately assessed my ability to perform experiments.	3.37	0.62
6. The practicum exams adequately assessed my ability to program LabVIEW.	3.26	0.70
7. The reports adequately assessed the effort I placed into this course.	3.48	0.80
8. The reports adequately assessed my understanding of the material in this course.	3.10	0.77

Table 1: Results of Perception Survey

Analysis of Grades

The course grades for were analyzed to examine differences of student performance in the different assessment tools. Data for a single section of 20 students is given in table 2. Focusing on the practicum exams, it is noted that they had the lowest average score, and widest deviation.

	Exam Grade (%)			Practicum Grade (%)			Report Grade (%)			Final
	1	2	1	1	2	3	1	2	3	Grade (%)
Average	83.95	87.05	86.15	79.14	83.70	81.28	85.15	86.22	88.12	84.53
High	98	97	95	95	100	95	95	95	96	95.44
Low	58	74	60	55	60	45	60	60	65	63.53
Std Dev	9.57	6.26	8.83	12.2	9.71	13.16	8.83	8.83	8.02	9.323

Table 2: Student performance per assessment type

With the widest range scores consistently given in the practicum exams, student capabilities in ability to operate and perform tests are varied. This suggests that students who are successful at problem-oriented exams and laboratory reports are not able to successfully set-up instrumentation and conduct experiments. Data from this small sample confirms the premise of the paper, and justifies the use of practicum exams for assessment.

Instructor Reactions

Two different instructors have implemented the practicum exams. Both responded that these exams are time consuming to prepare and difficult to conduct. Grading for partial credit is also difficult, as it is challenging to monitor the progress on multiple stations. During the exam, the instructor can roam around room, making notes on the progress of each student. Yet, this process is not completely reliable.

Yet with these difficulties, both instructors are committed to this form of assessment. It directly completes a full assessment of course outcomes. Further, it is proposed that by merely announcing the practicum exams have increased student participation.

To help with preparation, a bank of exam problems is being developed (see above). Kits with necessary components for each problem have being assembled. To help with partial credit, preference is given to multiple step problems, and asking students to explain, or sketch, their set-up.

Conclusions

This paper deals the course outcomes for a mechanical measurements course, and assessing student performance. Specifically, it addresses the lack of evaluating a working knowledge of the students. Practicum exams are proposed as being a solution to the shortcoming. Statistical analysis of semester grades reveals that the practicum exams give the widest range of student capabilities. This hints that students are to succeed in problem-oriented exams and laboratory reports, but are not as successful at instrumentation set-up and conducting experiments. A survey corroborates the proposition, in that student agree that the practicum exams adequately assesses working knowledge. Faculty state that these exams are not easy to implement, but are necessary to evaluate working knowledge.

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Appendix

Course syllabi for mechanical measurements, or similarly named courses, were reviewed from the following institutions:

Pennsylvania State University: Mechanical Engineering Technology
Southern University: Mechanical Engineering
University of Minnesota: Mechanical Engineering
West Virginia University: Mechanical Engineering
Indiana University - Purdue University Indianapolis: Mech. Eng. Tech.
New Jersey Institute of Technology: Mechanical Engineering
Northeastern University: Mechanical Engineering Technology
Washington State University: Mechanical Engineering
University of Dayton: Mechanical Engineering Technology
Miami University: Mechanical Engineering Technology
University of Missouri: Mechanical Engineering Technology
Oklahoma State University: Mechanical Engineering technology
Worchester Polytechnic Institute: Mechanical Engineering Technology
University of Tennessee – Martin: General Engineering
Rose-Holman Institute of Technology: Mechanical Engineering
Iowa State University – Mechanical Engineering
Clemson University – Mechanical Engineering