Experiential Engineers:
Developing an Integrated Mechanical Engineering Laboratory

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Abstract

The Department of Mechanical Engineering-Engineering Mechanics at Michigan Technological University has developed a required undergraduate laboratory that is a practical and relevant component of an engineer's education. The purpose is to provide a combined mechanical engineering experience that reinforces the traditional elements of a curriculum. Solid Mechanics, Dynamics, and Heat Transfer are integrated through individual experiments and a combined systems experiment at the conclusion of the course. Faculty is directly involved teaching the lecture component of the course and one lab section weekly. Graduate students work closely with these faculty members and teach the balance of the weekly labs. Progress in educational outcomes has been noticed in the second semester of senior design. Students now have knowledge and hands-on experience of experimental techniques to incorporate and utilize in the development and testing stages of their capstone design project.

Introduction

The Department of Mechanical Engineering-Engineering Mechanics initiated a full curriculum review that coincided with Michigan Technological University's conversion from a quarter-based to a semester-based academic calendar. The curriculum review began in the fall of 1998 with the conversion to semesters scheduled for fall of 2000. The department's forty-five faculty were challenged to begin the process with a clean piece of paper and were committed to creating a curriculum that would prepare students for the next century. During the first year of a two-year review the Mechanical Engineering faculty investigated curricula at institutions that had recently made major revisions, were NSF supported coalition schools, and a mixture of other peer and benchmark mechanical engineering programs across the nation. One important component of the first year review was identifying the need for more experimental laboratory experiences in the revised degree program. In addition to the traditional course specific laboratories, either as discovery or co-requisite, the desire to create a modern, state-of-the-art, laboratory environment existed. The review process also identified that the experience needed to be integrated with prior coursework and labs and have relevance in future coursework and projects.

The laboratory components required in the quarter-based degree were traditional, independent, experiences with no integration of topics and no systems-based experiments. Mechanical engineering students were not exposed to Solid Mechanics and Heat Transfer experimentation techniques and were required to complete their Dynamic Systems lab as a part of the Dynamic Systems/Vibrations course. An independent Thermodynamics laboratory in the quarter curriculum has been modified to an independent energy laboratory covering Thermodynamics and Fluid Mechanics experiments in the new semester curriculum.

A specific integrated two-credit course with a strong laboratory component was created at the junior year to compliment the newly developed mechanical engineering curriculum. The mechanical engineering areas of Solid Mechanics, Dynamics, and Heat Transfer would be introduced and reinforced by individual experiments and a combined systems experiment. This paper details the course format, laboratory integration and discusses specific experiments and equipment.

Laboratory Goal and Components

Students who successfully complete the course will have obtained laboratory skills in the measurement and analysis of static and dynamic phenomenon related to typical mechanical engineering topics. They will have had a reinforcement of concepts presented in Dynamics, Mechanics of Materials, Thermal Sciences, and Dynamics Systems through appropriate laboratory experiments and/or demonstrations. Students work in assigned teams producing written reports that present the mechanics of the experiment as well as conclusions drawn from the measured data.

The two-credit course format is a one-hour lecture on Monday by a faculty member covering the week's topic followed by a three-hour lab. The laboratory meeting begins with a short briefing that reviews the material presented in the lecture and the hands-on lab session follows, concluding with a short de-briefing summarizing the experience. Written reports are required for most of the labs and are prepared outside of class time. A quiz is administered after the completion of each three-week block. The textbook utilized in the course is *Introduction to Engineering Experimentation*[1] along with a set of course notes written by the developers of the course. Grading is composed of thirteen lab reports for sixty percent, four quizzes for twenty percent and a final exam that accounts for twenty percent of the total grade.

Experiments and Equipment

Exposure to each area in small groups facilitates the learning process and allows for easy rotation through the three technical components.

The weekly syllabus, detailed in Table 1, for the three student sections is scheduled so that students rotate through the area specific experiments in small groups. The system experiment is also conducted in small teams however each faculty member facilitates the same experiment simultaneously.

Table 1: MEEM3000 Course Syllabus

MEEM3000 Mechanical Engineering Laboratory			
Week	**Thermal Sciences**	**Solid Mechanics**	**Dynamics Systems**
1	Measurement Systems		
2	No Class/Campus Break		
3	Digital Data Acquisition		

4	Transducers and Calibration		
5	Thermal Sciences 1	Mechanics 1	Dynamics 1
6	Thermal Sciences 2	Mechanics 2	Dynamics 2
7	Thermal Sciences 3	Mechanics 3	Dynamics 3
8	Dynamics 1	Thermal Sciences 1	Mechanics 1
9	Dynamics 2	Thermal Sciences 2	Mechanics 2
10	Dynamics 3	Thermal Sciences 3	Mechanics 3
11	Mechanics 1	Dynamics 1	Thermal Sciences 1
12	Mechanics 2	Dynamics 2	Thermal Sciences 2
13	Mechanics 3	Dynamics 3	Thermal Sciences 3
14	Systems Experiment		
15			

During the first three weeks of the course all students participate in laboratories introducing the basic concepts of measurement systems, digital data acquisition, and transducers and calibration. Fifteen stations are available which consist of a networked PC, a Digital Data Acquisition system, an Oscilloscope, signal conditioning, and transducers. Figure 1 shows a typical lab setup.

Figure 1 Data Acquisition Equipment

Figure 2 Convective Heat Transfer Experiment

The Thermal Sciences portion consists of two heat transfer and one fluid mechanics experiment. The three experiments are:

- Determination of convective heat transfer coefficient with air in cross-flow over solids of different shapes
- Determination of natural convective heat transfer coefficient, and the emissivities of two different surfaces, one oxidized and another highly polished
- Development of the fan characteristics employing dimensionless variables.

The experiments in Solid Mechanics reinforce the concepts of basic strength of materials. The students learn how to perform simple torsion and tensile tests of elastic materials. In addition they study the relationships between moment and bending strain, location of the neutral axis, contact loading stress and the use of foil-type strain gages. The beam bending experiment is shown in Figure 3.

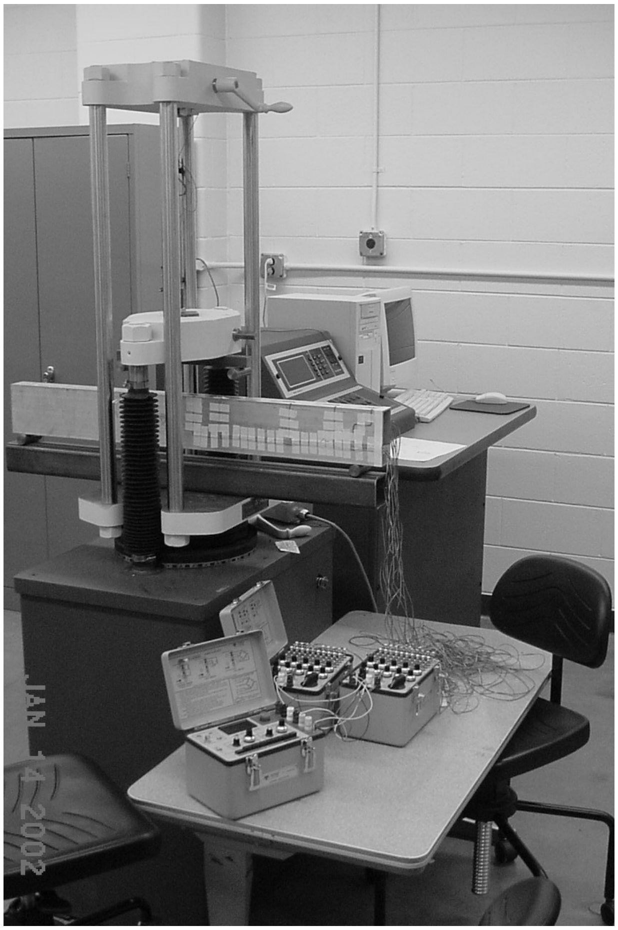

Figure 3 Solid Mechanics Experiment – Bending Strain

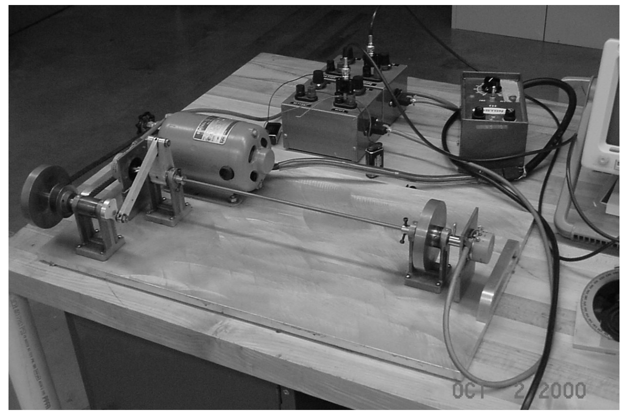

Figure 4 Forced Vibration Experiment – Torsional System

The three experiments in Dynamic systems cover the topics of free vibration, forced vibration, and fatigue. The goal of the free vibration experiment is to capture the response of a structure in such a manner that the data can be used to gain knowledge of the dynamic characteristics (mass, stiffness, and damping) of the structure. The forced vibration experiment, shown in Figure 4, uses a torsional system that can be driven at various frequencies both above and below resonance. The effects of undesirable dynamic behavior are predicted and measured. The fatigue experiment uses calibrated angular position and strain measurement systems to determine the alternating shear stress in a flawed torsional shaft under dynamic excitation. Using this information the fatigue life of the shaft is predicted and verified.

Systems experiments are also included as the final portion of the course. These experiments require the use of many of the laboratory skills and concepts that were presented throughout the course. A pump and piping system requires the students to establish pump characteristics and the effects of pipe geometry, size, and material on friction factor, Figure 5. The washing machine experiment requires the students to measure the operating response of a washing machine using multiple sensors simultaneously, Figure 6. The measured data is observed in both the time and frequency domains. The students are asked to determine what this data says about the operating characteristics of the machine.

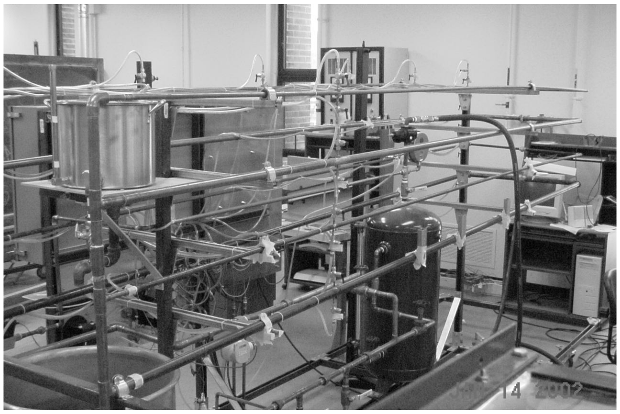

Figure 5 Pump and Piping System Experiment

Figure 6 Washing Machine Systems Experiment

Implementation

Each semester three lecture and nine laboratories sections are scheduled to accommodate approximately 270 mechanical engineering juniors annually. Lecture sections have a capacity of 45 students and each lab has a capacity of 15 students. Three weeks of common lecture material is followed by three weeks of laboratories in each core area. Students rotate through the three core areas to insure exposure to each mechanical engineering subject and all participating faculty. Faculty involved in the lecture is responsible for the first weekly lab and graduate teaching assistants cover the remaining lab sections. Faculty representation from each of the focus areas provides continuity and focus on integration and relevance from previous and future coursework.

Conclusions

Students have mixed opinions when asked to evaluate the new integrated lab during the chair's exit interview. They feel that the course is a lot of work for only two credits but they comment that it is a worthwhile experience. Educational outcomes progress has been noticed in the second semester senior design requirement. Students now have knowledge and hands-on experience of experimental techniques and they incorporate and utilize them in the development and testing stages of their capstone design project. Students are requesting laboratory equipment from this course to perform experiments and performance measurements on their senior design projects.

This course specifically addresses ABET Program Outcomes and Assessment (Criterion 3)[2] a, b, f, g, i and k; outlined in the following table.

Table 2: ABET Educational Outcomes

Criterion 3. Program Outcomes and Assessment
✓(a) an ability to apply knowledge of mathematics, science, and engineering
✓(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
✓(f) an understanding of professional and ethical responsibility
✓(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
✓(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
✓(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Both faculty and students have positively accepted faculty's weekly involvement in the laboratory lecture and lab section. The students appreciated the dedication of the faculty in the lab and the ability to approach the faculty in an experimental environment at the undergraduate level. The faculty has the opportunity to work closely with the students in a non-classroom setting and is better able to address topics in the lecture and voids in the overall course structure.

Bibliography

1. Wheeler, A.J., Ganji, A.R., *Introduction to Engineering Experimentation,* Prentice Hall 1996.
2. 2001-2002 Criteria for Accrediting Engineering Programs – Engineering Criteria 2000.

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Chuck Van Karsen has been a member of the Michigan Tech Department of Mechanical Engineering - Engineering Mechanics since August 1987. Prior to that he had a twelve-year career as a practicing engineer in the Machine Tool, Automotive, and Software industries. He specializes in Experimental Vibro-Acoustics, NVH, and Structural Dynamics. His research efforts have concentrated on experimental noise and vibration methods related to automotive systems and subsystems, large home appliances, machine tools, and off-highway equipment. Chuck regularly presents seminars and short courses on Experimental Modal Analysis, Digital Signal Processing, Acoustic Measurements and Sound Quality, and Source-Path-Receiver methods. At Michigan Tech, Chuck teaches Mechanical Vibrations, Experimental Vibro-Acoustics, Analytical and Experimental Modal Analysis, Mechanical Engineering Laboratory, and Controls. He holds B.S. and M.S. degrees in Mechanical Engineering from the University of Cincinnati.

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