2006-38: DEVELOPMENT OF AN INSTRUMENTATION AND EXPERIMENTAL METHODS COURSE AND LABORATORY FOR A BSE PROGRAM

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Development of an Instrumentation and Experimental Methods Course and Laboratory for a BSE Program

Background

Engineering students need educational experiences in instrumenting experiments, acquiring data, analyzing data, drawing conclusions, and reporting results with some statistical confidence in any engineering educational program. Specialized courses with laboratory components are commonly offered that are tailored to a specific engineering discipline or concentration, but general courses in instrumentation and experimental methods can serve more general programs. The University of Tennessee at Martin's ABET-accredited general engineering program offers a Bachelor of Science in Engineering (BSE) Degree with concentrations in mechanical, electrical, civil, and industrial engineering, and has one broad, required general-purpose instrumentation course for students of all four concentrations. This ENGR 317 course, titled "Instrumentation and Experimental Methods", has been developed and taught for the last three years, and is comprised of a lecture and a laboratory component. Students receive instruction in basic measurement terminology and concepts, computer-based data acquisition, and applied statistical analysis of experimental data. A broad survey of sensors and transducers is woven into the course, along with eight laboratory experiences, ranging in complexity from simple verification of analog voltages with a computer-based data acquisition system to verifying predicted thin-walled pressure vessel pressures with strain gage techniques.

The objectives of this paper are to relate the developed course and lab to the UT Martin engineering program curriculum and expected educational outcomes, to describe the developed course and lab content, to present some student feedback, and to note logistical issues regarding present and future offerings of the course.

Efforts of other engineering educators from the literature

In recent years, general objectives that were encountered at a 2002 ABET workshop for engineering educational laboratories have been listed and discussed[1], and instrumentation courses and laboratories have been documented for programs in mechanical engineering[2,3], civil engineering[4], and electrical engineering[5]. Instrumentation courses are also of interest to electrical engineering non-majors[6], agricultural and biological engineering programs[7], students of mechatronics[8], and interdisciplinary programs[9]. A program minor in computer-based instrumentation has been reported[10], and the complex issue of updating and maintaining data acquisition hardware and software systems has been reported from an aerospace engineering program[11]. Engineering technology programs also encounter issues of instrumentation[12,13,14]. One report was found of how efforts to update and expand instrumentation and experimental methods courses and laboratories paid off in the process of implementing a mechanical engineering program by being crucial to ABET accreditation[15]. LabVIEW software is frequently used for computer data acquisition[2,3,4,5,7,8,10,11,12,13,14,15], but there are alternatives reported[2,6,9,11]. Small budgets have reportedly yielded good results[9, 12]. Many kinds and levels of programs apparently have courses and/or laboratories addressing instrumentation, experimental methods, and related issues. This paper is meant to describe the implementation of, and some preliminary results for, the instrumentation and experimental methods course and laboratory developed for the UT Martin engineering program. The lab is Matlab-based, not LabVIEW-based, and the material is being taught to students having concentrations mechanical, electrical, civil, and industrial engineering, which is not unique, but certainly is a challenge in that it must be broad.

Placement of course in UT Martin curriculum

The sophomore or junior year of study is typically where a first course in engineering experimentation is placed in four-year engineering curricula. At UT Martin, students typically have had basic coursework common to all concentrations by the start of their junior year: Graphics, English Composition I and II, Calculus I, II, and III, Differential Equations, Chemistry I, Physics I and II, Engineering Economy, Electronics I, Strength of Materials, Statics, and Dynamics. The junior year is when students begin to take coursework specific to their concentration of mechanical, electrical, civil, or industrial engineering, along with more core engineering coursework, which continues with Circuit Analysis I, Engineering Probability and Statistics, Thermodynamics, Engineering Materials, and Fluid Mechanics. By this point in the curriculum, many of these required core curriculum courses have included laboratory components: Chemistry I, Physics I and II, Electronics I, Circuit Analysis I, and Engineering Materials. Other "upper division" courses have laboratory components, including Elementary Surveying, Concrete Design, and Geotechnical Engineering for the civil concentration, Electronics II, Circuit Analysis II, and Microprocessors for the electrical concentration, Vibrations, Kinematics and Dynamics, and Machine Design for the mechanical concentration, and Automated Productions Systems for the mechanical and industrial concentrations. The ENGR 317 Instrumentation and Experimental Methods course described in this paper is intended to be taken in the junior year, is the highest level common course in the program with a laboratory component, and is intended to help prepare students to specify, design, instrument, take data, and otherwise conduct their own experiments in much of their upper division coursework, labs, and required senior capstone design projects. The prerequisites for the ENGR 317 course are: ENGR 311 Engineering Probability and Statistics, and ENGR 232 Circuit Analysis I. ENGR 315 Engineering Analysis I (differential equations) is a co-requisite for ENGR 317. Thus, students are expected to be familiar with electrical circuit principles, statistical distributions and considerations, and dynamical system response prior to or in parallel with taking this course. The UT Martin Undergraduate and Graduate Catalog describes the course thusly:

> **ENGR 317 Instrumentation and Experimental Methods (3)** - Introduction to experimental methods, design of experiments, and analysis and interpretation of experimental data. Topics include accuracy and precision, Fourier series and FFT, expected time response of zeroth-order, first-order, and second-order measurement systems, applied statistics and uncertainty analysis, analog and digital signals and AD/DA conversion, and introduction to basic transducers and instruments for measuring voltage, current, temperature, pressure, flow, and strain. Two lecture hours and one three-hour lab.

This is a very broad-based course and the lab component emphasizes applying concepts learned in the lecture and homework components to practical engineering measurements.

Relation to program educational outcomes

UT Martin's ABET-accredited BSE program has *program-level expected educational outcomes* which map roughly into the well-known ABET a-k criteria. The ENGR 317 course syllabus lists the following thirteen expected educational outcomes as ones that the course is intended to directly reinforce in the UT Martin program ("At the time of graduation, graduates will have an ability to"):

- Use standard software such as word processors, spreadsheets, and presentation systems.
- Use commercially available software to model and perform analyses of components and systems.
- Formulate and perform basic engineering analyses.
- Recognize discrepancies in analysis and test results.
- Visualize components and their interaction in a system.
- Interpret, use, and apply standard industry terminology.
- Make decisions necessary to ensure safety.
- Behave in a professional and ethical manner in personal and business affairs.
- Work as an effective contributor in a team environment.
- Prepare written documentation and make oral presentations that effectively explain project progress or results.
- Present hand-written technical information in a clear and orderly manner.
- Manage time and commitments with minimal supervision.
- Design and conduct experiments, as well as analyze and interpret data.

For completeness, the seven outcomes not listed as being directly reinforced by the course follow:

- Pass the Fundamentals of Engineering Exam
- Prepare and Interpret schematics and engineering drawings
- Perform basic engineering economic assessments
- Possess real-world experience obtained through internships and co-op programs
- Possess a broad education necessary to understand the impact of engineering solutions in a global and societal context
- Possess a knowledge of contemporary issues
- Possess a knowledge of the need for, and an ability to engage in life-long learning

These seven outcomes are addressed by other aspects and courses in the UT Martin program.

The ENGR 317 course thus reinforces thirteen of twenty identified expected outcomes of the UT Martin engineering program.

The course syllabus also describes some *specific capabilities* with which the course is designed to equip students, or which the course is designed to enhance for students, depending on their prior coursework and/or experiences. They are prefaced and listed in the course syllabus as follows:

"Upon completion of this course, the student should be able to":

- Describe the role and importance of engineering experimentation.
- Apply concepts and terminology such as accuracy, precision, calibration, linearity, sensitivity, correlation, uncertainty analysis, sampling rate, Fourier transform, spectral analysis, analog to digital conversion, transducer, error, and signal conditioning.
- Place appropriate emphasis on units of measurement and the "sanity checking" of results.
- Make reasonable efforts to account for sources of experimental error.
- Discuss and apply the fundamental concepts and components of a computerized data acquisition system.
- Cite examples of appropriate transducers for a given measurement application and describe their theory of operation.
- Perform elementary experimental data gathering and analysis, draw and justify reasonable conclusions, and report the results.
- Design, conduct, and report the results of an elementary engineering experiment, given only a specific system and system quality or quantity to be investigated and the tools and methods used previously in the course.

Text selection and topics treated

It was determined that the text selected for this first broad course in instrumentation and experimentation should conform to the following criteria as much as possible:

- be broad-scoped and written for junior-level engineering students
- be broken down into relatively short chapters
- treat computer data acquisition systems
- treat statistical aspects of experimentation beyond that taught in a traditional probability and statistics course
- treat uncertainty analysis
- include a broad survey of transducers
- include a mix of SI and US customary units
- have plenty of worked example problems
- have plenty of end of chapter exercises, with some back of the book answers
- have a rich vocabulary and glossary
- be a relatively recent work
- be relatively inexpensive

After reviewing several texts, it was decided that the initial edition of *Introduction to Engineering Experimentation,* by Wheeler and Ganji, was a good selection for the primary course textbook. The second edition is now required as the textbook for the course. Other works are used as references for the course, and the instructor refers to them as appropriate. These include *Statistical Design and Analysis of Engineering Experiments,* by Lipson and Sheth, *Experimental Methods for Engineers*, by Holman, Omega Engineering handbooks, and *The Mayfield Handbook of Technical & Scientific Writing*, by Perlman, Paradis, and Barrett.

The following topics are treated in the course lecture:

- Basic measurement concepts and definitions
- Amplification and filtration of electrical signals
- Computer DAQ Systems
- Sampling rate theory and Fourier transform
- Significant figures and rounding
- Uncertainty Analysis
- Strain gages and Wheatstone bridges
- Transducers for mechanical measurement (position, velocity, acceleration, and force)
- Analysis of variance (ANOVA)

These are essentially chapters 1-5, 7, and 8 of Wheeler and Ganji, which are supplemented by the lab experiences, which were developed by the author/instructor. Report writing is emphasized in the lab section, and report formatting and grading issues are discussed in a later section of this paper.

Course content delivery, student deliverables, and exams

The lecture portion of the course meets twice a week for 50 minutes, during which a conventional lecture is delivered which parallels the text and laboratory sessions. PowerPoint notes augment the lectures and example problems are worked in class as appropriate. End-of-chapter problems are assigned as homework approximately on a weekly basis, and there are two exams and a comprehensive final exam which draw from the lecture, homework, and laboratories. All student deliverables are individual efforts, except for lab reports, which are team efforts. At the end of the semester, the teams each complete a peer evaluation form for their team members, and the instructor uses the results to modify the individual team members' individual lab grade component with a "peer evaluation factor", which can range from zero to greater than unity. Table 1 shows how the student deliverables are weighted for grading purposes.

Table 1. Weighting of Student Deliverables

Student Deliverable	Weighting
Homework	10 %
8 Laboratory reports	25% (times peer evaluation factor)
Exam I	20 %
Exam II	20 %
Final Exam (comprehensive.)	25%

UT Martin does not have a graduate school of engineering, and thus the instructor performs all lecturing, laboratory sessions, and grading for the course. Occasionally, student workers who have completed the course are available to help set up lab equipment, but ultimately the students in the course interact exclusively with a full-time faculty member, since there are no graduate students by definition. This is the norm at UT Martin, where the emphasis is solidly on undergraduate engineering education.

Lab component

The laboratory component is designed to reinforce material covered in the lecture portion of the course. A suite of eight laboratory experiences has been developed. Students work in teams with a nominal size of four, and lab section enrollment is typically limited to 16 students. Four stations are set up for most experiments. Each lab experience includes a detailed procedure handout for the students, who follow the procedure as a team and analyze and report the results in a team-based report, using a handout-specified formatting guide. The eight laboratory topics treated are described here:

Lab#1 – Analog Input: *DC Voltage Measurement and Introduction to Computerized Data Acquisition Systems* - Known voltages of power supplies and dry cell batteries are measured with a computerized DAQ system, which is a Windows PC instrumented with a National Instruments general purpose DAQ board and programmed with the Matlab DAQ toolbox.

Lab#2 – Analog Output: *Analog Signal Generation and Measurement Using Computerized DAQ System, Signal Generator, and Digital Oscilloscope* - Sinusoidal voltages are output from the computer DAQ system and from benchtop signal generators and observed on digital oscilloscopes.

Lab#3 – Sampling of Continuous Signals: *Digital Sampling of Continuous Signals* - Sinusoidal voltages generated with function generators are sampled with the DAQ system. Varying the sampling rate illustrates the effects of aliasing and the need for sampling rate theorem and related considerations. Alias frequencies are predicted, generated, and confirmed using a folding diagram.

Lab#4 – Linear Motion, FFT, and Filtering: *Measuring Linear Periodic Motion and Analyzing the Results with Fast Fourier Transform Methods* - A linear shake table is commanded with known multi-frequency sinusoidal signals using frequency generators and the table position is measured with an LVDT and sampled with the computer DAQ system. The sampled position data are analyzed with an FFT algorithm and the commanded input frequencies are confirmed, along with any deliberate alias frequencies.

Lab#5 – Temperature: *Measuring Temperature with Semiconductor Sensors, Thermocouple Probes, and Mercury Thermometers* - Known temperatures of room temperature, ice water, and boiling water are verified with mercury thermometers, thermocouple probes, and semiconductor sensors. Measurements from each instrument are compared to the known values and to each other. First order system response of the semiconductor sensor is sampled with the computer DAQ system. Time constant of sensor is determined and compared to manufacturer's published value.

Lab#6 – Accelerometer and LVDT: *Estimating the Sensitivity of an Accelerometer* - A shake table is driven with a sinusoidal position command using a frequency generator. The table position and acceleration are measured with an LVDT and an accelerometer, respectively, and sampled with the computer DAQ system. The LVDT sensitivity is known, but the accelerometer sensitivity is not known. The accelerometer sensitivity is determined by using the known position vs. time data and the relations between position, velocity, and acceleration amplitudes for sinusoidal motion. The estimated accelerometer sensitivity is compared to the manufacturer's published value.

Lab#7 – Strain Gages: *Using Strain Gages with Cantilevered Beams-Strains, Forces, Deflections, and Uncertainty Analysis of the Results* - Predicted strains and deflections of cantilevered beams end-loaded with known weights are compared to measured strains and deflections using pre-mounted strain gages and instrumentation amplifiers employing quarter-bridge circuits. Simple uncertainty analysis propagation, using the Kline-McClintock equation, is performed.

Lab#8 – Student-Designed Lab: *Determining the Internal Pressure of a Can of Soda with Strain Gages and Analysis of Variance of Results* - Given no formal procedure handout, students determine how (and proceed) to instrument a common can of soda with a single strain gage in a quarter-bridge circuit in order to determine the internal pressure. Students must review thin-wall pressure vessel relations and material properties and verify the results with known values of pressure from the internet and/or canning facilities. Multiple brands of soda are analyzed and a single factor ANOVA is performed to determine if soda brand has any effect on internal pressure. A demonstration of mounting strain gages is given by the instructor.

Reports are due the week following the lab sessions. The instructor is usually able to provide feedback within a week after submission, and makes every effort to do so.

Table 2 shows how the labs are related to the earlier-listed course topics.

Table 2. Relation of Laboratory Experiences to Course Topics
p => primary topic of lab
s => secondary topic of lab

Course Topic	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8
Basic measurement concepts and definitions	p	p	p	s	p	s	s	s
Amplification / filtration of electrical signals				p	p	p	p	s
Computer DAQ Systems	p	p	p	s	p	p	p	p
Sampling rate theory and Fourier transform			p	p	s	s		
Significant figures and rounding	s	s	s	s	s	s	s	s
Uncertainty Analysis							p	s
Strain gages and Wheatstone bridges							p	p
Transducers for mechanical measurement				p	p	p	p	s
Analysis of variance (ANOVA)								p

A 'p' means a topic is a primary topic for a lab experience, and an 's' means a topic is secondary to a lab experience. The labs generally build on the prior labs and course material, and lab four and labs six through eight are overall more involved than labs one, two, three, and five. The latter levels of complexity and number of topics brought together by the labs are meant to expose the students to some of the scenarios and considerations they may encounter in industry.

The flavor of the course

As a course intended for mixed sections of students concentrating in mechanical, electrical, civil, and industrial engineering, the course is necessarily very broad-based. Students experience the multi-disciplinary nature of modern data acquisition systems in that they see how electrical, mechanical, mathematical, and computational elements combine to perform measurement of physical phenomena. Furthermore, the students are required to do detailed report writing, and thus see the importance of communicating the results of their activities. Students are constantly encouraged to *judge results*, that is, to report on how well the theory predicts the outcomes of the lab activities. One of the more difficult aspects of teaching this course for the author/instructor is just that, because many students have not had much experience with judging results by their junior year. The lab reports are graded for form, content, and style, and spelling, grammar, and phrasing are emphasized. The first five to six reports are termed "informal" reports, in which mainly a bulleted list of report features provided in the lab procedure handout, such as cover sheet, plots, data sheets, specific questions to be answered, and a brief narration of the experience and results comprise the reports. The grading of informal reports does not follow a strictly points-based grading system, but rather an "overall effort" assessment, with feedback comments, negative and positive, as appropriate. For the last two to three labs, a formal report format handout is to be followed by the students, which is weighted numerically as follows for grading purposes:

- 8% Title page
- 10 % Abstract
- 10% Introduction
- 15% Results
- 30% Discussion
- 12% Conclusions
- 5% References
- 10% Appendices

The handout also includes general descriptions and guidelines for the different sections of the report.

The believability of results, in the labs, homework, and exams, is emphasized. This so-called "sanity checking" of results is intended to reinforce in students the notion that they should be able to judge results for quality, estimate outcomes in advance given sufficient information, and, of course, always check the units of a result. In the course, a numerically correct answer without the proper units is counted as wrong. Thus, the students are encouraged to think in ways other than just "getting the right answer". The labs are mostly verification-based, and so the emphasis is on process just as much as on outcome. Anecdotally, the civil concentration majors do not seem very enthusiastic about the course until near the end, when strain gages are covered and used in two labs. When students see cantilevered beam theory and thin-wall pressure vessel equations verified by measurements, they manage to find some enthusiasm. The author/instructor frequently sees marked improvements in student writing after all eight lab reports are executed by the student teams. Instructor feedback is provided on each report, to be incorporated into the next report by the students.

Some student feedback

At the end of the Spring, 2005 offering of the course, a questionnaire was completed by the students that solicited their comments on the laboratory experiences. Specifically, it was asked which lab "…helped them the most to understand any particular topic…", which lab "…was the most interesting…", and which lab "…was the most fun…", with elaborations for each, if desired. The numerical results are shown in Table 3.

Table 3. Results of Questionnaire

Item	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	None	Totals
Most helpful lab	0	0	3	1	3	0	10	10	0	27
Most interesting lab	0	0	1	5	4	0	8	11	0	29
Most fun lab	1	0	0	2	2	0	1	21	1	28
Totals	1	0	4	8	9	0	18	43	1	84

Of 30 students, 29 returned questionnaires, for a potential total of 87 responses. Three responses were not counted, as it was not possible to put them into any one bin. Also, there were several responses that appeared to be for both labs 7 and 8, which were very similar exercises involving strain gages. The author/instructor put them into categories to the best of his ability. The lab 7 and lab 8 combined count total is accurate, however. The strain gage labs seemed to garner the most positive responses from the students in terms of helpfulness in understanding the material, interest level, and fun. Lab 8, where students actually mount strain gages and determine an unknown quantity, was by far the most popular in terms of fun. Other labs were deemed helpful, namely 3, 4, and 5, which were also deemed interesting by some students. Interestingly, lab 6 received no votes in any category, nor did lab 2. Lab 1 was deemed most fun by one student because "…the report was so simple." One student did not "…recall any 317 lab being fun."

While table 3 shows the admittedly limited results of only one semester's offering of the course and lab, the distribution of the responses in table 3 is interesting in that labs 7 and 8, when considered together, garnered more votes for effectiveness in helping students to understand a particular topic than the other six labs combined. A similar pattern is seen for the category of lab interest level. The author/instructor speculates that this may be because students of all four concentrations must take the required strength of materials (solid mechanics) course, not all students may have mastered that material, and that course does not have a lab component. The number of mechanical concentration students for this section was 14, and there were 4 electricals, 11 civils, and 1 industrial concentration student in this section. Mechanical and Civil concentration students, taken together, were the majority in the section and that might also give insight into the results of table 3. Mechanical and Civil concentration students could reasonably be expected to be more interested in measuring beam deflections, for example.

The seemingly dominant popularity of lab 8 in terms of "fun factor" might be related to students measuring something familiar to them (soda can pressure) with the new tools that they have been exposed to in the course and lab.

The author/instructor realizes that an in-depth long-term (over several semesters) survey of students would be necessary to draw any statistically meaningful conclusions about the lab's effectiveness in helping students learn. Determining whether section concentration demographics correlate to students' "reported preferred lab learning experience" is an example of a hypothesis worth testing. Clearly much more can be done in this area of assessment for the course and lab.

A few more selected student comments follow.

Most helpful labs – selected students' comments

- "Sampling rate testing because it helped understand (sic) how to properly sample signals. Communications and this went well together the first half of the semester."
- "Lab 8, finding the pressure of a coke can. It was something interesting not boring. When things aren't boring it's just easier to pay attention and learn."
- "Lab 7&8 - The strain gages. Actually seeing the gages work, then applying equations for the gages and materials equations and getting a similar result help tie the classes together."
- "The temperature lab helped me understand the importance of this class because we were able to see how different measuring tools take different measurements of the same measurand. The very first day of class you spoke of the temp of the classroom. You said it was not just 72 degrees but 72 degrees plus or minus a few degrees."
- "Temperature lab. Thermocouple, thermometer. Made practical use of MATLAB for dynamic plots."

Most interesting labs – selected students' comments

- "Lab 8 – It allowed us to actually mount our own strain gages and be completely responsible for our own results."
- "Making the strain gages was the most interesting because I was able to see the effects of my own doing. It was cool to see my strain gage work properly."
- "…cantilever beam/strain gage – Its topic coincided more with my major (sic) and I liked having more than one circumstance to evaluate and compare."
- "The most interesting lab was lab 4 which dealt with Fast Fourier Transform methods for frequency analysis. This will prove to be helpful when I take vibrations in the fall."
- "Shake table. Because it was cool to see the frequencies entered come through the mechanical devices."

- “Temperature lab – saw practical use of the dreaded MATLAB program.”

Most fun lab – selected students’ comments

- “Coke can/strain gage. It was more hands-on, instead of staring at a computer screen and letting it do all the work.”

- “Lab 8 – Because of the practicality of it. It was fun to see if we were good enough to determine the actual pressure inside the cans.”

- “The labs with the DAQ systems. I like letting the computer do the hard work.”

- “The last two labs.”

- “Beam deflection, makes strengths finally understandable.”

- “Vibrations experiment with two freq. generators. This was fun to change the movement of the shake table. We could make it dance.”

The author/instructor notes that the questionnaire lacked any direct solicitation for which labs were the least helpful, least interesting, or least fun. These will likely be included on future questionnaires and the results could be used to help improve the lab offerings, procedures, and related items. These results are for the only lab questionnaire conducted to date for the course. Such comments are heartening to the author/instructor and also illustrate that hands-on labs can still have relevance in 21st century engineering education.

The author/instructor further notes that team-based hands-on laboratories can present good opportunities for active and collaborative learning. The student comments alone would seem to suggest that, and most engineering educators would likely concur that the topics treated by such a course may be transmitted more readily and more effectively to more students with a lab component than without one.

The active learning aspects of the laboratory experiences in this course include:

- Students gathering, setting up, and operating equipment (the labs are not turnkey)
- Students modifying computer code to acquire and process data
- Students researching and confirming instrument sensitivities and accuracies
- Students revisiting other courses’ material (formulae, terminology) to perform analyses
- Students observing the lecture material “in action” in the lab
- Students relating the lab experiences to the lecture material when writing the lab reports

The collaborative aspects of the laboratory experiences in this course include:

- Conducting labs and submitting reports as teams
- Rotation and reporting of individual team member roles for each laboratory exercise (i.e. data taker, equipment operator, editor, responsibility for draft section(s) of report, etc.)

- Bringing any team conflicts to the instructor's attention only after failing to resolve such issues as a team
- Individual team member accountability addressed by the peer evaluation conducted at the end of the course
- Self-governance of teams

Benefits to downstream courses in curriculum

Faculty have commented on how much better students write in various courses and labs after completing ENGR 317, but equally important is that successful completion of the ENGR 317 course benefits students in that they are able to apply the technical material and writing skills taught in the course to their required senior year capstone design projects, in which they must submit a report and presentation on their projects. Some of the instrumentation tasks for such senior capstone projects are accomplished with skills (and occasionally with equipment) that students learn in ENGR 317. Examples of these are:

- Vibration testing and modal analysis of a quarter-scale structure
- On-board vehicle and engine speed mapping for a Mini-Baja vehicle
- Characterization of existing machine dynamics in support of an industrial plant redesign
- Remote communication development for an IEEE Autonomous Robot competition entry

Future of the Course

The Spring, 2006 semester is the first time that three sections of the lab are being offered, owing to the increased enrollments the UT Martin program has been experiencing. More faculty are to assist in this third lab section offering, and thus coordination will be necessary with regards to lab exercises, grading, and the like, as there will be a single lecture section taught by the author. Two items that need to be addressed are adding more lecture sections, with attendant staffing coverage, and acquiring more lab equipment such that the nominal student team size can be reduced from four to three, or even two. The demand for this course has historically been such that it likely needs to be taught every semester, instead of annually as it is now.

Conclusions

This paper has described a broad-based course and laboratory in Instrumentation and Experimental Methods that have been developed at UT Martin and taught for the past three years. Serving as a common course for students concentrating in mechanical, electrical, civil, and industrial engineering, the course and laboratory are intended to educate students in the important areas of instrumentation and experimental methods of engineering, and thus help support the described program educational expected outcomes, which are related to program accreditation. In the described course and lab, students acquire educational experience in instrumenting experiments, acquiring data, analyzing data, drawing conclusions, and reporting results with some statistical confidence. Admittedly limited initial student feedback seems to indicate the general benefit of the lab component to the students. It has been noted that increased enrollments may necessitate more frequent course offerings, and more lab sections have already been offered.

Acknowledgements

The author expresses gratitude to Dr. Rich Helgeson and Dr. Robert LeMaster, both of the UT Martin Department of Engineering, for their helpful suggestions for the development of the ENGR 317 course and laboratory described in this paper.

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