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A Common Instrumentation Course for Electronics/Electrical and Other Majors

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Abstract

The design and contents of instrumentation courses in four-year colleges often reflect the stature of current instrumentation technology, background of the instructor, and the specific instrumentation need of an engineering industry. The syllabus in the instrumentation course, therefore, is largely shaped by individual taste and need and lacks cohesiveness in instruction to appeal to a large spectrum of engineering disciplines.

This paper provides an insight into the design of course contents and instructional approach for an instrumentation course to meet the need of a large spectrum of engineering and technology disciplines. Difficulties encountered in developing a cohesive and integrated course, faculty experiences in classroom and laboratory, student evaluations of the instructors, and course are described. The course that we envisioned captures emerging trends in electronics, mechanics, manufacturing, process, and other industry applications with emphasis on analog and digital electronics, microprocessor interface, specifications of data acquisition board for automated data acquisition and analysis, and graphical display of measured data. Issues related to the design of experiments, statistical representation of data, curve fit, identification of critical design parameters of an instrument, and robust design of an instrument are covered. This course-offer recommends a common lecture but different laboratory and project assignments to benefit electronics and mechanical engineering technology majors. Team teaching experiences, mental and technical preparedness of the course instructor, scope and nature of laboratory assignments, and student learning preferences are described in this paper.

1. Introduction

Engineers work often with a variety of instruments in industry. In real world engineering, productivity in manufacturing plants, control of temperature and humidity in air conditioning units, and regulation of pressure and volume of fluid media in process industries depend on appropriate selection and use of transducers, signal collection, analysis, and interpretation of data to ensure safety of equipment and efficiency of operation. Some specialized industries, including semiconductor manufacturing, require fast, miniaturized sensors to acquire large volumes of data. Also, research and exploratory investigation in science and engineering requires innovative methods of developing and applying new sensors to quantify and explain phenomena. Common measurements in engineering industries and other scientific applications to a large extent consist of pressure, temperature, velocity, and flow, and the sensors for acquiring such measurements are mostly analog. However, developments in electronics, especially integrated circuits, and the emergence of digital technology through computers and microprocessors enabled the design of miniaturized high-speed sensors to digitize the data, and this, in turn, resulted in large volume data collection, analysis, development of fast algorithms, and user-specific display formats.

The training and instruction in instrumentation, especially at the baccalaureate level, should reflect emerging trends in digital technology and new applications; they should aim to provide broader perspective of measurement principles and instrumentation to benefit a large section of students in engineering and technology. Validity and accuracy of measurements, operating principles of transducers, transducer applications, microprocessor interface, signal analysis, interpretation, and data presentation for easy decision and control are to become the core elements of instruction and training. The contents of courses and hands-on learning experiences through laboratory assignments in instrumentation should appeal to a broad spectrum of engineering and technology students.

2. Present Instructional Methods and Need for Change

Many institutions offer courses in instrumentation, but their design seems to follow two separate tracks: 1) The course for electronics/electrical engineering is often designed to emphasize signal conditioning, programming, and instrument control. These students have no opportunity to appreciate real world applications in mechanical instrumentation and lack broad perspective of the importance of instrumentation applications. The scope of these courses is often narrow. 2) Courses intended for non-electrical students emphasize transducers and applications in mechanical industries and emphasize older technology. Analog instrumentation has a larger share of the course coverage. New developments, especially digital hardware, miniaturization of devices through integrated circuits, and developments in virtual instrumentation software are often neglected.

Both approaches have drawbacks and need revision. Also, the ability of data scanners and acquisition boards to capture the dynamic content of signals is a significant advantage, and it should be included in the design of courses. With less emphasis on instrumentation applications and problem solving skills, the electrical/electronic engineers require retraining in industrial instrumentation. These engineers need to understand the importance and significance of measurements in the context of the operation of mechanical equipment in industry. Courses in mechanical instrumentation designed for mechanical and non-electronic/electrical students emphasize applications of analog instrumentation with no coverage on digital instrumentation and microprocessor interface. In a broader sense, non-electrical students are at a disadvantage from the current practice of instrumentation instructional methods.

It is customary to assign faculty to teach two distinctly separate tracks of instrumentation, and in this arrangement, the electronic faculty assigned to teach electrical/electronic students and mechanical faculty for mechanical and other engineering students portray individual tastes and traits corresponding to the instructors' experiences. Course coverage reflects the instructors' preferences and interests in individual topics with bias on electronic or mechanical instrumentation. This arrangement, as natural as it seems, has severe drawbacks.

Another reason for developing a common course on instrumentation is administrative. Strapped for funding, and also in an attempt to evolve a common engineering curriculum, administrations seek to combine seemingly similar courses. Instrumentation courses fit into that category, and the courses can be designed, modified, and adopted for instruction of electrical, electronic, and non-electrical majors. This administrative decision is also based on the hypothesis that the developments in electronics and computers, a new and specialized need for unique transducers, and instrumentation in all science and engineering fields require such common course instruction and training of students in all disciplines of engineering and technology.

A common course in instrumentation will meet the interests of all students and prepare them to appreciate the importance of instrumentation applications in a variety of industries. It creates a balanced perspective in the minds of students to solve instrumentation problems in the real world. The learning experiences through such courses will give students confidence to design instrumentation systems starting from scratch and not depend on the assembly of off-the-shelf devices. The course will incorporate emerging trends in instrumentation and develop problem-solving skills in students. Faculty members, therefore, are compelled to visit the course contents often and come up with new ways of instruction in the changing environment to benefit electronic/electrical and non-electronic majors.

3. Common Instrumentation Course Instruction: a Case Study

The Department of Engineering Technology at the University of Arkansas at Little Rock (UALR) has offered two courses in the past: one on mechanical instrumentation and the second on sensors and data acquisition for electronics majors. Sensors and data acquisition courses had emphasis on programming and projects but lacked applications. The courses on mechanical instrumentation emphasized analog devices and considerable coverage on stress and strain measurement and analysis. Use of digital hardware and computers and software for data processing was not included. In an attempt to achieve integrated knowledge, the faculty decided to offer a common instrumentation course for electronic and mechanical engineering technology majors. The planned course contents included operational amplifiers; filters; analog to digital and digital to analog conversion of signals; introduction to digital electronics; data sampling and selection of data acquisition boards; transducers for strain, temperature, displacement, pressure, and bridge circuits; and graphical user interface software. Due to the nature of topics, three instructors each with good background in electronic circuitry, digital electronics, and transducers and mechanical applications taught the course. A laboratory was common to both majors, and most of the laboratory assignments were done using Lab View, creating virtual instruments to analyze temperature and strain.

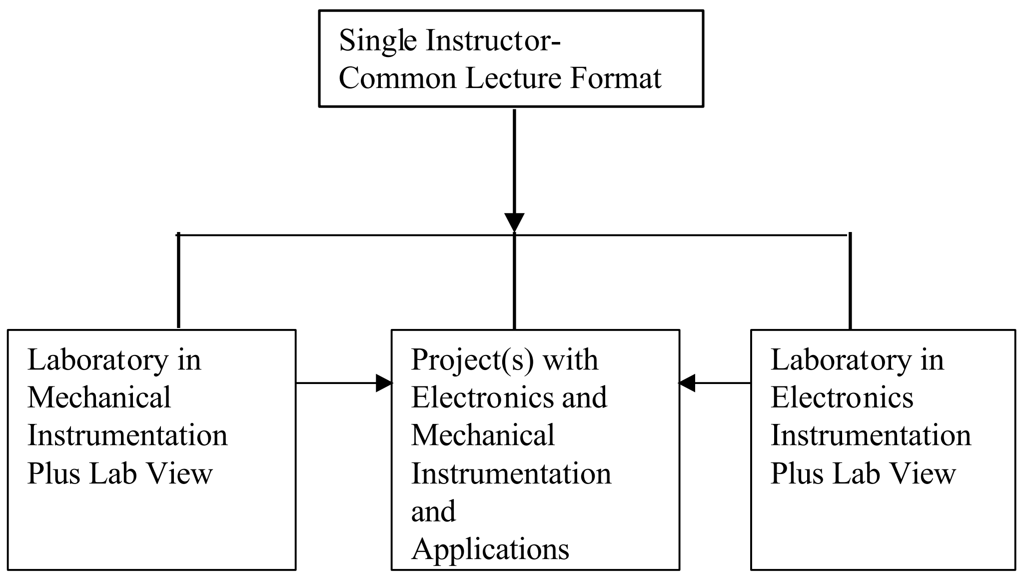
Student learning and performance were evaluated through two semester exams and one comprehensive final examination, several quizzes, and laboratory assignments. The enrollment in the class is evenly split between electronics and mechanical majors. Mechanical students had electronic circuits and a brief exposure to digital electronics, but the electronics majors had two to three courses in electronics in addition to C programming. Analysis of student performances from examinations and quizzes indicated that the electronics student group although had prior knowledge of analog and digital electronics, their performance was not markedly different from the other group. End of the semester student evaluations revealed several pitfalls with this instructional approach. Some student comments included: "It is difficult to get used to three instructors' styles of teaching"; "What do electronics signal conditioning and digital electronics have to do with mechanical instrumentation?"; "Do not combine electronics and mechanical majors"; "What use is this knowledge if we do not see hardware?"; "Why Lab View, it is simply a click and chuck exercise"; "Lab View is difficult to grasp"; "Text book is not the right type"; "Did not like test input from different instructors"; "Course unorganized"; "Laboratory unorganized"; and "Have realistic labs!"

Further discussions among instructors pointed to making significant changes to the course instruction. We agreed to use one instructor for lecture course contents, to emphasize the use of hardware, and to introduce Lab View gradually. The experience was frustrating to instructors and students, and the reasons for dislike for the integration among students were: lack of preparedness with mechanical students to grasp electronics; lack of hardware to demonstrate hands-on exercises; non-availability of a single instructor who can cover all aspects of instrumentation- electronics, mechanical, and industry applications, with confidence; heavy dependence on the use of software; and lack of opportunity for electronics majors to exercise programming skills. Moreover, students knew of the precedence in having two separate courses on instrumentation. One single factor, as we realized, for this lukewarm reception of the course by students is the non-use of hardware to make measurements and analysis interesting.

4. Proposed Instructional Strategy

From the experience and lessons learned in last spring, the faculty decided to revise course contents and offer it in the following format: common lecture by a single instructor, two separate laboratory groups, and common projects. This arrangement will hopefully provide an opportunity for electronics students to exercise their programming skills through individualized laboratory assignments, and mechanical students to expose to mechanical instrumentation applications similar to those in industry. The combined group project(s) with both mechanical and electrical elements will enable both groups of students to communicate, help each other with ideas, and solve instrumentation problems. Moreover, this new and upcoming mechanical student groups will have hands-on knowledge and skills in digital electronics, and the revised format, we hope, will work well.

In addition to formal lecture and lab, we intend to invite guest lecturers to speak on the nature of an instrumentation engineer's work in industry. We plan to take students on a visit to a process industry to show the types of transducers, applications of sensors, data acquisition, and analysis systems. The new method of course offering is shown in a sketch below.



A single instructor with an electronics background and who has previous experience in teaching non-electronics majors will deliver the course content in lecture format for the combined group of students. Two faculty members, one with an electronics background and the other with a mechanical background, will run the laboratory sessions in separate sections with different emphasis to benefit individual groups. Lab View sessions will be common to both students.

The strategy to adopt two different laboratory sessions and a common lecture format is to provide a balanced perspective for all majors on instrumentation practices and yet provide an opportunity to take up challenging, individual hands-on, laboratory assignments to match the students' abilities in each discipline.

To achieve broad perspective on instrumentation principles, the course will cover the following topics:

Measurement principles-- measurement quantities, statistical parameters of data, and curve-fit methods and regression analysis.

RMS value of signals, transducer impedance matching, signal amplification through op-amps, signal conditioning, sources of noise and noise reduction, filtering, and signal transmission (4-20 mA) through current carrier circuits.

Principles of operation of different transducers and 4 arm ac and dc bridges; transducers to measure temperature, pressure, humidity, displacement, velocity, acceleration, strain, force, and torque; principles of shaft encoders, stepper motors, Hall effect sensors, semiconductor sensors, and optical sensors.

Applications of transducers in industry.

Analog to digital conversion and representation of data with numbering schemes, data sampling, rate of sampling and errors, specifying data acquisition card.

Introduction to transducer-microprocessor interface, signal analysis, FFT and DFT, and signal correlation.

Data display--graphical user interface software such as Lab View. Using Lab View to create virtual instruments to generate, analyze, and display measured data with set points for process and instrument control.

Projects with elements of mechanical and electronic instrumentation to select transducers, specify signal conditioning boards, identify methods to control noise, measure data, use of data acquisition board, interface data with computer, and analyze and display data.

5. Conclusions

This paper describes the present status of an instrumentation course offering to two groups of majors in engineering and technology. Keeping hands-on learning and practical applications in industry as goals, a combined course with analog and digital electronics and use of graphical user interface software was offered. Lessons learned from this first attempt were analyzed, and the course was further modified to emphasize realistic laboratory assignments. Plant tours and lectures by guest lecturers will emphasize the importance of integrated knowledge on industrial instrumentation and enhance students' interests in instrumentation. A new feature of this course design is to have a common lecture for both groups but have separate laboratory assignments to further enhance their interests in instrumentation. Group projects are proposed, providing opportunities for all students to work together and share their learning experiences and work toward completion of a project.