TOWARD A NEW PARADIGM IN TEACHING EXPERIMENTAL DESIGN AND ANALYSIS

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Introduction

As suggested by current and proposed ABET guidelines, numerous engineering educators, and by our own advisory committee of practitioners, an expansion of laboratory experiences in the undergraduate curriculum is needed to better prepare Civil and Environmental Engineering students for professional practice. In particular for Civil and Environmental Engineers, this lab experience must satisfy complex needs: to expose students to large, often noisy, but very practical data sets, to give them hands-on access to state of the art methods in data acquisition and control and to educate them in the utility of non-destructive real time measurement techniques. Given the nature of civil and environmental work, field rather than strictly-lab-based experiences are crucial. This is a radical departure from conventional undergraduate pedagogy.

The creation of this type of lab class comes at an opportune time. Restructuring of the RPI undergraduate engineering curriculum as a whole is being discussed with a major emphasis being placed on new modes of learning (so called *inter-active learning*). Traditional disciplinary boundaries are being blurred.

We present in this paper a description and preliminary assessment of a new NSF sponsored undergraduate course in Civil and Environmental Engineering that *uses the campus as the laboratory* and introduces civil and environmental engineering students not only to conventional methods but also to real time non-destructive measurement techniques. Students are introduced to instruments as generic devices and an attempt is made to demystify the user interface. Access to, transfer and manipulation of data from remote sites is coupled with sensor calibration, deployment and maintenance and the use of statistical analysis.

In conjunction with the local office of the USGS, the NYS Dept. of Transportation and the innovative facilities of the RPI Technology Park, we are using this course as the first stage in the development of a comprehensive ongoing laboratory effort stressing information collection and management. This lab will serve, then, as a *practical* "capstone," preparing students for the new information-rich workplace.

As a companion course to the traditional senior capstone design class, this lab emphasizes the very necessary step of problem definition, as opposed to problem solution. By integrating traditional civil engineering concerns with environmental concerns, the class explicitly prepares the future civil/environmental engineer for the expanded role and inter-disciplinary vision professional practice now demands and focuses attention on the global and national need for improvements in infrastructure engineering.

Specifically, the Department views the collection and understanding of information about the response of natural and engineered systems to changes in environmental conditions as necessary and often neglected skills. By preparing students not only with traditional textbook and lab learning but with an appreciation for experimental practices used under field conditions, the department will insure that new generations of Rensselaer engineers will be literate in field-based methods, ready for the new demands of engineering practice, and leaders in the re-creation, refurbishment and renewal of the infrastructure.

Course Structure

We have divided the course into three main sections. Table 1 is a course outline. The structure intends to first introduce students to the generic concept of an instrument. It follows up with exposure to conventional and cutting edge instrumentation. And finally it forces the students to install and use the instrumentation in the field.

In the first section students are introduced to general concepts of instrumentation and measurement. Along with traditional lecture material (e.g. precision and accuracy, units etc.) common laboratory exercises are conducted on the construction of instruments and their calibration. We use a simple first exercise with the graphical programming data-acquisition and control software LABVIEW™ in which the students build a temperature probe and instrument interface on the computer and then connect the "virtual" instrument to several types of thermocouples (a crude two-wire home made version, then a Type J and finally a Type K thermocouple mounted in a pipe). As the students install analog to digital boards in the computers and wire the systems to breadboards, they are interactively learning concepts like gain, noise, signal to noise ratio, sampling rate, single versus multi-point data acquisition, data storage, and simple programming -- traditional weaknesses in Civil and Environmental curricula. Calibration efforts are stressed and students are asked to use several techniques including conventional thermometers (provided) and creative solutions (like human body temperature, and freezing and boiling points of water).

The next two labs introduce typical instrumentation that they will encounter in the field. In one lab they must learn to program conventional data loggers (Campbell Scientific) with a wide array of instruments such as soil temperature probes, barometric pressure and relative humidity sensors, rain gauges, solar pyranometers, and wind speed and direction sensors mounted in or near the laboratory. They must then collect the data from these sensors using data loggers accessed by short haul modems, radio modems, and cellular modems in both real time and at discrete intervals. The next week then takes the class to the field site (USGS at RPI Tech Park) where they mount the same sensors on a ten meter tower and send the data by radio to a base station maintained by the USGS. Data is then fed to a WWW home page and made available to a network of meteorological stations in the Hudson River Valley.

Section	Week #	Topic for class	Lab Activity
I	1	Introduction. / Data Types / Precision and Accuracy	
	2	Instruments / Labview Introduction and Programming	Labview Lab
	3	DC and AC Circuits	Labview Lab
	4	Data logging / programming	Datalogging Lab
II	5	Field trip / Installation of Meteorological Station at RPI Tech park	Meteorological Station
	6	Strain Gauges/Wheatstone Bridges/Transducers	Soda Can lab
	7	Statistics & Field Trip / Well Installation	Borehole lab
	8	Statistics	NYSDOT Data
III	9	Discipline Specific Lab 1 (2 weeks each -- students choose topic and work in small groups)	Euler Buckling; Pump and Slug Tests; Induction loop traffic counting
	11	Discipline Specific Lab 2	Instrumented Bridges; Video traffic monitoring; Landfill monitoring
	13	Discipline Specific Lab 3	Concrete Failure; Stream and stormwater monitoring; Tube counts
	15	Presentations	

TABLE 1. COURSE OUTLINE

Statistical concepts are introduced and discussed in the context of the next three common laboratories. In the first, students affix pressure transducers (monitored by a LABVIEW program) to soda cans. When the cans are opened and the pressure is released, the students then use all the collected data to estimate hoop stress. In a second lab the students first witness a well boring in the field and then are asked to reduce a large data set of borehole information to produce soil profiles. In the third lab exercise, students access electronically traffic information from Long Island, NY courtesy of a data link with the NYD DOT and are asked to analyze the traffic patterns to obtain information (e.g. peak loading).

In the third part of the course students choose areas of interest and break into smaller groups (6 or 7). Discipline specific labs are then conducted over two week periods with the first week in the lab and the second in the field. These labs use modern instrumentation obtained through a grant from the NSF Instrumentation Laboratory Initiative Program. As shown in Table 1, these labs are diverse and cover many aspects of Civil and Environmental Engineering. The common theme running through these exercises is the analysis of the student's own local environment. For example an instrumented pedestrian bridge spanning the main thoroughfare through the campus allows the students to witness the response of the infrastructure to live loads. In concert with rainfall measurements, students are able to monitor and collect stormwater for chemical analysis (*first flush*) and to see the response of their home watershed (via stream discharge through a flume installed by the students) to runoff from different surfaces. At a local concrete plant (Clemente-Latham, Troy NY), students obtain their own samples of concrete that they then instrument and "fail" in a Universal Testing machine.

Preliminary Outcome Assessment

This new course was first given in the fall of 1997 with an enrollment of 11. It is currently being offered this semester (Spring 1988) with an enrollment of 40. In following years typical enrollments will hover around 60 with a 70/30 mix of Civil and Environmental BS students.

Tau Beta Pi surveys conducted after the Fall 1997 semester were informative. The students universally liked the course and gave it high ratings but reasons for the enthusiasm varied and several shortcomings in the course organization were identified, most reflecting impatience with a new course not yet running smoothly.

Unanimous praise was given to the overall course concept. The student's zest for actual field work and the ability to learn things in a hands-on fashion was stressed. The students liked the idea of "ownership" and felt pride in actually constructing things that were "real" and could be used to collect "actual" data from "their" campus. They especially appreciated getting to use typical instrumentation, to seeing things happening "on-line" and they viewed the experience as important in acquiring real-world skills that would help them in the work place.

The students had initially voiced doubts about the inclusion of what they viewed as "electrical engineering stuff" (the LABVIEW software and hardware). This was not their view of Civil/Environmental practice. The utility of the programming environment ("very cool software") and the recognition of the powerful capabilities eventually outweighed this doubt at hand. In their Tβπ responses they noted that the skills acquired would prove useful and that they could envision using this knowledge in the workplace. Several noted that their concept of what a measuring device was had fundamentally changed. To our amazement several students were enthusiastic about the stress placed on statistical techniques, volunteering that the statistical concepts finally made sense. We could not discern whether this was a paean to the coupling of statistics with actual data or an indictment of their earlier course work.

Future Efforts

Our intent is to begin to incorporate pedagogy developed in this course into several other courses in the curriculum at both introductory and advanced levels and to extend the number and types of exercises in this class to even more of the campus environment. Inclusion of lab exercises into courses like Applied Hydrology and Hydraulics, Infrastructure Engineering, Traffic Engineering, Seepage and Drainage, and introductory courses in Environmental, Geotechnical, Transportation and Structural Engineering classes will begin in the next year.

Several important ideas will be stressed. We are especially eager to develop not just discipline specific labs but multidisciplinary ones where several types of measurement will be used in concert. As an example, we hope to add air pollution monitoring equipment to our suite of transportation measurements and additional building sensors to our measurements of wind speed and direction.

The response of the infrastructure to changing conditions and the use of that information in modern engineering management is one common theme. From "smart" buildings and highways to innovative stormwater management techniques to identification and remediation of impacted environments, the use of real-time information is becoming an important concept for Civil and Environmental engineering practice. By giving our students a firm underpinning in the use of this kind of information technology, we hope to be in the forefront of training a new kind of Civil and Environmental Engineer educated to recognize and utilize information in a timely and constructive way to solve (or prevent) society's problems.

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