Facilitating Interdisciplinary Hands-on Learning using LabStations

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Abstract

Culminating five years of planning by faculty and students, the Integrated Teaching and Learning (ITL) Laboratory opened its doors in January 1997. One of the goals of the new facility is to link theory and experimentation in a hands-on way. Custom designed LabStations facilitate this goal with the capability to easily take quantitative measurements from an experiment and store them electronically for analysis. This paper presents the details of LabStation design and describes some of the portable experimental modules that will utilize the LabStations.

Integrated Teaching and Learning Overview

The College of Engineering and Applied Science at the University of Colorado at Boulder is making a significant shift in the way undergraduate engineering students are educated. Integrated Teaching and Learning (ITL) is an interdisciplinary program that integrates team-oriented, hands-on learning experiences throughout the engineering curriculum and engages students in the design process beginning with their first year. ITL is horizontally integrated across all six engineering departments and vertically integrated through all four years. The program combines leading-edge computer and instrumentation technology with the knowledge and confidence that comes with hands-on, project-based learning.

The cornerstone of this new program is the 34,400 sq. ft. ITL Laboratory, which opened its doors in January 1997. The laboratory's curriculum-driven design accommodates a variety of learning styles and features two first-year design studios, an active-learning arena for 70 students, a computer simulation laboratory, a computer network integrating all the experimental equipment throughout two large, open laboratory plazas, capstone design studios, group work areas and student shops. The building *itself* is even an interactive teaching tool that gives students the capability to demonstrate, monitor and manipulate the facility's many complex engineering systems (Carlson and Brandemuehl, 1997).

Interdisciplinary Curriculum

Reflecting the interdisciplinary nature of ITL, planning for the new curriculum has crossed traditional departmental boundaries. The initial impact on students is First Year Engineering Projects, a College-wide course that introduces beginning students to the excitement of engineering and to the practical considerations of the design process (Carlson et. al., 1995, Piket-May et. al., 1995). Students design, build and test real products with real customers, such as an assistive glove that a quadriplegic student uses to grasp a soda can. At the other end of the curriculum, senior-level capstone design projects are being piloted with interdepartmental cooperation. For example, students from mechanical and electrical engineering recently teamed up to design a powered manipulator mounted to an electric wheelchair, and a sip and puff actuated gear shift for a paraplegic's hand-powered bicycle. Dedicated studio spaces in the ITL Laboratory support and showcase these hands-on design project courses.

The heart of engineering education lies in the middle two years, when the fundamental concepts that define disciplinary specialization are introduced. Many of these concepts are taught in multiple departments. For example, fluid mechanics is taught separately in four departments.

Our approach was to form teams of faculty with expertise in the following *focus areas* which cross departmental boundaries:

- Electronics and microprocessors
- Measurement and instrumentation
- Controls
- Fluid mechanics and thermal science
- Materials and structures
- Manufacturing
- Environmental engineering

Teams articulated concepts common to each department, then designed an appropriate curriculum, utilizing ITL curricular elements designed to facilitate hands-on learning, including *experimental modules*, *lecture demonstrations* and *hands-on homework*. Modules are small experiments, most of which are mounted on mobile carts that can be wheeled up to a standardized LabStation, or easily moved to the Engineering Center to provide vivid lecture demonstrations. To date, 35 experimental modules are in various stages of development; they are designed to be:

- Of multidisciplinary interest, crossing traditional departmental boundaries;
- Suitable for open-ended exploration;
- Stand-alone experiments requiring minimal supervision; and
- Sequence-independent

Examples of modules already piloted in courses include:

- Dynamic strain of a mountain bike - a bicycle instrumented with strain gauges allows students to measure stresses in real time. Currently confined to a test stand, the bike will eventually utilize telemetry and a portable data acquisition system to allow real-time off-road testing.
- Musical signal analysis - a virtual spectrum analyzer programmed in LabVIEW performs Fast Fourier Transforms on dynamic signals from an electric guitar.
- The Control System Demonstrator uses a computer-controlled motor to vary the effective spring rate, mass and damping coefficient of a second-order dynamic

system that is excited by another motor over a wide range of forcing frequencies. LabVIEW panels feature sliders that allow students to set all the appropriate parameters, measure and display dynamic response, etc.

- Liquid level control - a first-order system in which the height of water in a standpipe is dependent on inlet flow and outlet resistance. Students in their Applied Math class in differential equations perform experiments to compare the predicted response with actual results.

The assignment of laboratory experiments as homework problems provides students with an alternative mode of learning that permits practical reinforcement of theoretical concepts. Supported by NSF, *hands-on homework* (HOH) augment theoretical courses. They are characterized by the use of relatively simple apparatus and materials that are typically available at home. They generally involve solving a problem analytically, recreating the effect with a simple experiment, describing the results qualitatively, or in an approximate quantitative way, and contrasting observations and analysis. Examples of concepts and simple materials used as HOH experiments in fluid mechanics include:

- Instabilities of viscous flow down a sloped surface *using salad oil on a cookie sheet*
- Buckling flows *using liquid detergent poured onto a flat plate*
- Standing hydraulic jump *in the kitchen sink*

Thus far, 27 HOH experiments have been developed, 9 are in progress and 16 are in planning stages. Because of their “low threshold, high ceiling” nature, these experiments are highly transportable to other institutions.

LabStation Concept

Two of the fundamental concepts that guided the architectural design of the ITL Laboratory are *flexibility* and *visibility.* This is particularly seen in the two large laboratory plazas where most of the sophomore and junior level experimentation will occur. Each plaza measures approximately 4,000 sq. ft. and houses 15 experimental LabStations designed for students working in teams of 4-6.

Each LabStation (Fig. 1) is a powerful data acquisition center measuring approximately four by six feet, capable of taking data from any mobile experiment which can be wheeled up to it. It includes two Hewlett-Packard Pentium-based PCs running Windows NT, National Instruments MIO-16 multipurpose I/O interface cards and LabVIEW software to control data acquisition, several SCXI signal conditioning modules, and a comprehensive array of Hewlett-Packard instrumentation including oscilloscopes, signal generators, multimeters, counters and spectrum analyzers, all connected through an HPIB interface. Each computer can take data simultaneously from up to 16 channels. And, of course, students will have access to the wide variety of virtual instruments that LabVIEW provides. While the capability of virtual instrumentation is clearly a powerful engineering tool, we believe that students will benefit from the appropriate interaction between real and virtual instruments.

The mobile experimental modules are pre-wired to standard military connectors so that they can easily be connected, either to a LabStation in a Lab Plaza, or as a lecture demonstration. In addition, extensive breakout panels on each LabStation allow patch cord access (BNC and binding post connectors) to virtually all internally wired signals of interest between the data acquisition cards and computers, as well as direct communication out to the experiments to control them (Fig. 2).

Use of LabVIEW

One of our faculty estimates that, by the time our students complete four years plus of engineering, they will be exposed to over 30 different software applications. The more standardized we can make our students' software options, the more productive they can be. This is one of the reasons we have chosen LabVIEW as the standard data acquisition and control package for the ITL Laboratory.

Students will learn LabVIEW in parallel with course assignments requiring its use. As students advance through their four years, their lab assignments will become progressively more open-ended and their need for higher sophistication in LabVIEW programming will grow. ITL will provide on-line training and documentation for much of this process. In addition, students will be exposed to the proper design of standard LabVIEW programs for industrial applications.

Conclusion

The new ITL Laboratory was designed as a learning environment to enable undergraduate engineering students to experientially validate engineering science fundamentals in an interdisciplinary way. We anticipate that it will take several years to fully capitalize on the potential of this exciting new facility, but preliminary results are encouraging.

The spring 1997 semester saw the first classes to utilize the new ITL Laboratory. In addition to five sections of First Year Engineering Projects and numerous classes experimenting with active learning formats, there were two interdisciplinary classes in the laboratory plazas. A Circuits for Non-Majors course, taught by the department of electrical and computer engineering for the rest of the College, utilized the extensive capabilities of the electronic instrumentation, all connected to the networked computers via an HPIB interface. The departments of mechanical and civil, environmental and architectural engineering coordinated a junior-level fluid mechanics course utilizing fifteen experimental modules. Most of the experiments were open-ended, encouraging students to discover and understand fundamental fluid mechanics concepts by applying them in a hands-on way.

Those of us fortunate to be part of the ITL planning process have been pleasantly surprised to learn that the fundamental tenet of the ITL program - learning by doing - applies to us, as well as to our students.

Fig. 1. ITLL LabStations provide powerful computer and data acquisition capabilities for two teams of students to conduct hands-on experiments in the open lab plazas.

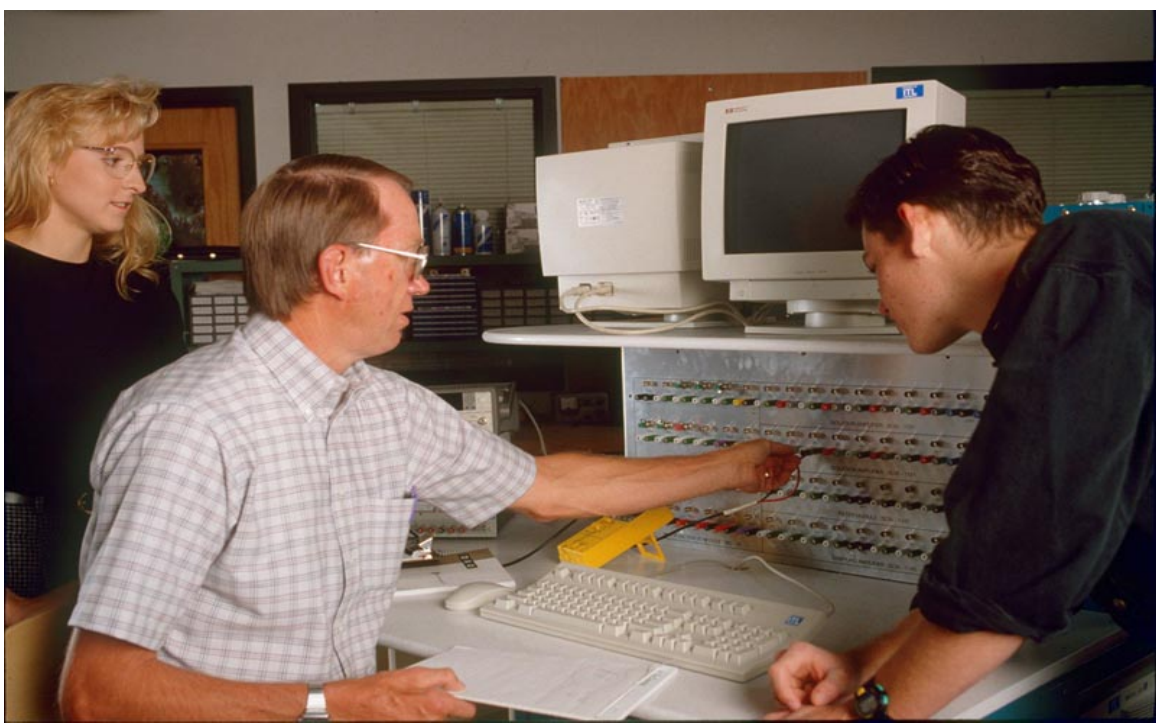

Fig. 2. Input/output panels on each side of the LabStation allow access to internally wired signals, as well as a means to get signals out to the experiments.

References

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