

Field experiences in engineering courses

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ABSTRACT: Field methods are an important part of engineering often neglected in the undergraduate curriculum. Through a US National Science Foundation (NSF) grant, the College of Engineering at Rowan University, Glassboro, USA, has created opportunities for undergraduate students to carry out engineering field activities as part of traditional courses and Engineering Clinics. Faculty from the Departments of Civil and Environmental Engineering (CEE), Electrical and Computer Engineering (ECE), and Chemical Engineering (ChE) have participated in this project. The purpose of this paper is to introduce the initiative and describe two projects involving a portable data acquisition system and YSI 600XL environmental monitoring probes.

INTRODUCTION

Field methods are an important part of engineering often ignored in the undergraduate curriculum. Using funds from the US National Science Foundation (NSF), plus matching funds, the College of Engineering at Rowan University, Glassboro, USA, has incorporated field methods, both sampling and measurement, across its engineering curriculum, using the following elements:

- *Pre-planned* field exercises in laboratory components of select courses, including the Freshman Clinic;
- *Open-ended* field exercises as part of Junior and Senior Engineering Clinics.

Faculty from the Departments of Civil, Chemical and Electrical Engineering have been involved. Field equipment purchased for the project is used to obtain water, air and soil/sediment samples, measure fundamental soil/sediment, water and atmospheric parameters in the field, and survey/map field sites. Activities supported by the requested equipment are both pre-planned and open-ended. In pre-planned activities, students complete specific tasks similar to traditional laboratory exercises, except that the activities are conducted outside using field equipment. In open-ended activities, undergraduate students determine what media they need to collect and/or what field measurements they need to make to solve open-ended problems. Innovative features of the project are as follows:

- The incorporation of field methods into the undergraduate curriculum;
- The integration of activities across disciplines;
- Open-ended multidisciplinary small-team field activities.

The purpose of this paper is to introduce the initiative and to describe two projects, namely: a data acquisition system (DAS) designed and built by a team of ECE and CEE majors, and the measurement of water quality parameters. The DAS is solar powered, supports many different environmental measuring devices, and can provide data storage and/or radio frequency transmission. Students in multiple courses have measured water quality parameters in the field.

BACKGROUND

The field experience initiative is an effort by the College of Engineering at Rowan University to integrate motivational team-oriented fieldwork in freshmen through senior year classes. Much of the fieldwork activities involve multidisciplinary and, in some cases, multilevel teams. A survey of the National Society of Professional Engineers indicated that 80% of employers felt that the ability to work in teams is an important attribute in new graduates. The importance of cross-disciplinary interactions between scientists and engineers has been addressed extensively [1].

Multidisciplinary approaches, total quality management (TQM) and team dynamics have been cited among innovations in undergraduate civil engineering education, along with increasing emphasis on communication skills and hands-on laboratory experiences [2]. Finally, the National Science Foundation has supported projects that emphasise two areas believed to encourage academic reform, specifically: the integration of research and education, and interdisciplinary research [3]. The field experiences initiative improves the ability of undergraduate students to work in multidisciplinary teams and solve open-ended problems.

Rowan University and the Engineering Clinic

Founded in 1923, Rowan University has evolved into a comprehensive regional state university with six colleges, including a new College of Engineering initiated as a result of a major donation in 1992 from the Rowan Foundation [4]. The Engineering College is committed to innovative methods of learning to better prepare students for entry into a rapidly changing and highly competitive marketplace. Key objectives of Rowan University's engineering curriculum include the following:

- Creating multidisciplinary experiences through collaborative laboratories and coursework;
- Stressing total quality management for solving complex problems;
- Incorporating state-of-the-art technologies throughout the curricula;
- Creating continuous opportunities for technical writing and communication;
- Emphasising hands-on, open-ended problem solving, including undergraduate research.

To best meet these curriculum objectives, the four engineering programmes of Chemical, Civil and Environmental, Electrical and Computer, and Mechanical Engineering have common Engineering Clinic classes (clinics) throughout their programmes of study [5]. Course descriptions are given in Table 1.

It is important to note that clinic classes mix students of different engineering disciplines. Furthermore, upper level clinics often mix juniors and seniors.

Table 1: Overview of the contents of the Civil Engineering Clinic.

Year	Engineering Clinic Theme	
	Fall	Spring
Freshman	Engineering measurements	Competitive assessment
Sophomore	Design and writing	Design and oral communication
Junior	Open-ended problem solving	Open-ended problem solving
Senior		

In the Freshman Engineering Clinic, students work in multidisciplinary teams of 4 to 5 students with one professor working with 4 or 5 groups at a time. The fall semester of the Freshman Engineering Clinic gathers components from all major engineering disciplines and focuses on basic engineering measurements. In the spring semester, students work on a semester-long reverse product or process-engineering project. For example, students have reverse engineered coffee makers, hair dryers, remote-control cars, electric toothbrushes, beverage processes and portable water filters. The field experience initiative develops activities that require field sampling or field measurement in the Freshman Engineering Clinic.

Some institutions have used traditional discipline specific laboratory experiments at the freshman level, while others engage students in discipline specific freshmen engineering design projects [6][7]. Rowan's engineering programme seeks to unify these topics and provide an innovative multi-disciplinary laboratory experience for teams of engineering freshman. In addition, a major focus of this clinic is on problem solving skills, written and oral communication skills, safety and professional ethics.

The Sophomore Engineering Clinic is focused on engineering design [8]. Students are exposed to discipline-specific and multi-discipline design projects. For perhaps the first time, students are exposed to realistic design problems best solved by multidisciplinary engineering teams. Thus, this class truly addresses the needs of current and future employers who require engineers to be constructive, functioning parts of a multidisciplinary team. Students in the Sophomore Engineering Clinic quickly realise that they must *self-acquire* knowledge to solve the given problem within the time constraints. This course has significant communication components, both writing and speaking and is taught with engineering and communication faculty. Past projects include the design of landfills and baseball parks, and the design and construction of guitar effect pedals and small bridges. The field experience initiative will develop capabilities that are used when field sampling or when field measurement are needed in the Sophomore Engineering Clinic.

In the Junior and Senior Engineering Clinics, students work on an open-ended project in a multidisciplinary team of 3 to 5 students under the supervision of one or more professor. Each team works on a unique project, which can be multiple semesters in length. A typical sequence includes information search and review, development of a clear and concise problem statement, research and/or design and testing activities, and the presentation of results via a written report and presentation. Projects have included product design, process modification, process development, as well as applied and fundamental research. Most projects are funded by industry or governmental agencies. Some projects require students to collect field samples and/or take field measurements, especially projects with structural, geotechnical and environmental foci.

It is important to note that the field experience initiative also includes traditional (non-clinic) classes. Many engineering courses incorporate laboratory experiences. However, to date, this has been accomplished primarily with *in-building* laboratory exercises (with notable exceptions, eg surveying courses). The field experiences initiative takes more laboratory experiences out of the building and into the field.

The Junior and Senior Engineering Clinics have been incorporated into the field experience initiative in two ways. First, some are used to create field activities for Freshman and Sophomore Engineering Clinics and traditional courses. The two projects described in this paper were developed with the help of Junior/Senior Clinic teams. Second, in other Junior and Senior Engineering Clinics, students are given an open-ended problem that can only be solved with some fieldwork. For example, over 10 clinic teams have worked on site remediation projects. Teams have travelled to sites and conducted monitoring activities. Another team funded by the Northeast Hazardous Substance Research Center sampled local wastewater treatment plants and river sediments for the presence of nonylphenols. Both projects required undergraduate students to learn standard sample collection, preservation, storage, preparation and handling techniques.

Rowan Hall Field Site and Equipment

The Rowan Hall field site includes the state-of-the-art Rowan Hall Engineering building, a small pond, a small stream flowing through a wooded area, parking lots, roads and grass areas. Depth to groundwater is relatively shallow. The area around Rowan Hall thus provides an ideal location for mapping, sampling and measurement.

Equipment used for the field experience initiative, already in-hand or purchased specifically for the initiative, is listed in Table 2. A total station automatically reads angles and distances, and stores the data in internal memory. Data are directly downloaded to a PC for fast and easy processing. Students at Rowan University survey field sites using the total station and create maps using *AutoCAD*. Other survey equipment is available. GPS units are also utilised for mapping purposes.

Table 2: Field experience initiative equipment.

General	Equipment
Mapping	(2) Total stations, theodolites, transits, levels, surveying equipment, (2) GPS units
Soil/ Sediment	Lake sediment sampler, hand-powered soil/sediment sampling kit (augers, push tubes, etc.), mechanical auger, geotest double ring infiltrometer, ELE international soil moisture temperature meter
Water	Horizontal water bottle, 2” stainless steel vertical well sampler, (2) watermark stainless steel bailers, well purge pump, water level indicator, handheld flowmeter, (2) YSI 600xl multi parameter field probes, field conductivity, temperature, pH, DO, ORP probes and meters, field spectrophotometer
Air	Sampling pump, indoor/outdoor weather monitoring station
Data Acquisition and Power	Notebook and desktop computers, data acquisition cards, data acquisition software, data loggers, radio frequency transmitters and receivers, solar panels, batteries

Hand and mechanised augers and push tubes are used to obtain samples of soil/sediment from the vadose zone, below the water table, and at the bottom of streams, etc, for environmental and geotechnical analyses. A soil moisture and temperature system exposes students to field measurements related to soil freeze and thaw cycles, as well as moisture conditions related to engineering and natural structures. An in-situ soil infiltrometer helps student learn about barrier systems, infiltration and groundwater flow.

Bailers, pumps, horizontal and vertical depth samplers are utilised to collect surface and groundwater samples for environmental analyses. Probes are used to measure water quality parameters in the field. This helps students learn about natural processes and the effects of pollution.

Pumps are used to collect airborne particulates or gasses. A weather station has been used to measure meteorological parameters. This exposes students to measurements related to air pollution, pollutant transport, and techniques for analysing time series of data and modelling.

Field measurements of some parameters are accomplished with equipment capable of automatic data retrieval, storage and transmission. Students design and construct solar and/or battery powered modules capable of data storage and/or remote transmission. This allows students to gain experience with modern, computerised data collection, as well as data reduction, manipulation and analysis.

RESULTS

In this section, the results from two projects are presented. Information about all of the projects can be found at users.rowan.edu/~Everett/projects/fldexp

Data Acquisition System

A Data Acquisition System (DAS) was designed and built for use by both lower division students to study solar power, data acquisition and data analysis, as well as upper division environmental engineering students, for data acquisition projects. The DAS has been completely designed and constructed by student teams enrolled in the Junior/Senior Engineering Clinic. Students working on this project are majors in Civil and Environmental Engineering, Electrical and Computer Engineering, and Mechanical Engineering.

The data acquisition process begins with a probe that is connected to either a data logger or data transmitter and powered by a solar-array charged battery system. Students have used YSI 600XL multi-parameter probes with the DAS. The 600XL is capable of measuring a number of water parameters; the current units are used to measure depth, conductivity, temperature, dissolved oxygen and pH. The DAS is designed to be able to work with a variety of probes; it has also been used to operate a weather station.

The students’ first goal was to determine the power requirements for the full system, consisting of probes (YSI 600XLs or other), a Campbell CR10X-2M data logger, and/or a Microhard System MX900 wireless transmitter/receiver pair. Lakehurst Naval Air Station donated solar panels for this project. The 1' x 4' panels have a maximum open circuit voltage of 18 V and maximum short circuit current of 2 A. Students determined that two panels would be adequate to keep the battery charged for the envisioned activities.

Another goal was to create a design for the DAQ that would be portable and secure. The solar panels are fixed to an aluminium box, with internal access through a back panel. The battery, connections and data logger are kept in the box. The power components chosen (solar panels, charge controller and re-chargeable battery) are connected to a universal screw-panel connector with space for adding more data acquisition components to this station.

For communications, a system was selected that could function with a single receiving point and multiple transmitters, so expansion to a full complement of field stations would be feasible. The system is based on the Microhard, Inc. MX900, a 900MHz wireless transmitter/ receiver that can be used to either transmit or receive data and has a range of 30 km (~19 miles). Single units can be purchased to add one or more additional transmitters to the system using the single receiving point to transfer data to the base station from the field sites.

This project provided student teams with an opportunity to experience interaction among three different disciplines (Civil and Environmental, Electrical and Computer, and Mechanical Engineering) in the completion of a single product. The DAS currently powers and stores data from two YSI 600XLs placed in a nearby stream.

Students in the Freshman Clinic can use the DAS to learn about measuring devices, solar power and wireless data transmission. Students in environmental engineering courses can use the DAS to learn about measuring devices, data manipulation and environmental phenomena, and to collect data.

Water Quality Measurements

YSI 600XLs have also been used in the Freshman Clinics. A portion of the Freshman Engineering Clinic laboratory has traditionally dealt with measurement of environmental parameters or environmental engineering processes. Examples of past laboratories include determining the amount of coagulant required for water treatment of a sample of pond water, and measurement of oxygen transfer rates in bench-scale reactors. In the latter experiment, students use polarographic probes to measure the change of oxygen concentration over time in an aeration tank.

Another laboratory module was developed that incorporates field measurements of water quality in lakes. Before the laboratory, students are introduced to various indicators and measures of surface water quality, including temperature, pH, oxygen concentration, clarity, suspended solids concentration and nutrients. During the laboratory exercise, students measure water clarity and vertical profiles of temperature and DO concentration in the pond adjacent to the engineering building.

Water clarity and depth are measured using a Secchi disk, and the temperature and depth profiles are measured using different instruments, namely: two YSI 600XL field probes connected to laptop computers, and YSI models 58 and 5100 dissolved oxygen meters and probes. From the data collected during the field experiment, students are able to make assessments of water quality in the pond. Similar activities, measuring more parameters and including streams and groundwater, are conducted in Junior-level environmental engineering courses.

CONCLUSIONS

The field experience initiative is an effort by the College of Engineering at Rowan University to integrate motivational team-oriented fieldwork in freshman through senior year classes. Much of the fieldwork activities involve multidisciplinary, and in some cases multilevel, teams. Field experiences are

- Pre-planned exercises in laboratory components of select courses and modules in Freshman and Sophomore Engineering Clinics;
- Open-ended exercises as part of Junior and Senior Engineering Clinics.

Experiences in Junior and Senior Engineering Clinics are of two types. In some cases, students in upper level engineering clinics develop field exercises for traditional courses or lower level engineering clinics. The two projects described in detail in this paper started this way. In other cases, students in upper level engineering clinics must complete field exercise in order to complete the goals of a clinic project.

The projects described in detail in this document occurred in an upper level engineering clinic and Freshman clinic, respectively. In the first project, a team of ECE, ME, and CEE students designed and built a solar powered data acquisition system with data storage and wireless data capabilities. In addition to obtaining valuable experience working in multidiscipline and multilevel teams, students learned about design, construction, solar power, meteorological measurement, data storage, data acquisition and data transmission. They also created equipment that can be used to provide field experiences to students in the Freshman Engineering Clinic and upper-level environmental engineering courses. In the second project, freshman engineering students measure water quality in a nearby pond.

Many engineers are involved in field activities, either directly or indirectly. Providing students with field experience in college will help them deal with similar experiences once they enter the workplace.

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