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Field Experiences in the Engineering Curriculum

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ABSTRACT

Field methods are an important part of engineering often neglected in the undergraduate curriculum. Through the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) program, the College of Engineering at Rowan University is creating opportunities for undergraduate students to carry out engineering field activities as part of traditional courses and Engineering Clinics. Faculty from Civil and Environmental (CEE), Electrical and Computer (ECE), and Chemical Engineering (ChE) are participating in the project. The purpose of this paper is to introduce the initiative and describe two projects:

- A weather station designed and built by a Clinic team of ECE, Mechanical Engineering, and CEE majors; and
- Soil sampling and measurement procedures developed by a team of CEE majors.

INTRODUCTION

Field methods are an important part of engineering often ignored in the undergraduate curriculum. Using funds from the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) program, plus matching funds, the College of Engineering at Rowan University is incorporating field methods, both sampling and measurement, across its engineering curriculum, using

- **Preplanned** field exercises in laboratory components of select courses and modules in Freshman and Sophomore Engineering Clinics, and
- **Open-ended** field exercises as part of Junior and Senior Engineering Clinics.

Faculty from Civil, Chemical, and Electrical Engineering are involved in this project. 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 preplanned and open-ended. In preplanned activities, students complete specific tasks similar to traditional laboratory exercises, except 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 (1) incorporation of field methods into the undergraduate curriculum, (2) integration of activities across disciplines, and (3) open-ended multidisciplinary small-team field activities.

The purpose of this paper is to introduce the initiative and to describe two projects:

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- A weather station designed and built by a Clinic team of ECE, Mechanical Engineering (ME), and CEE majors. The station consists of meteorological devices, solar panels and associated electronics, and a radio-frequency data transmitter. Weather data are automatically transmitted to a web site.
- Soil sampling and measurement procedures developed by a team of CEE majors. The Clinic team developed procedures for using a soil auger and a soil infiltrometer in the field as part of clinics and geotechnical engineering classes.

BACKGROUND

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. A survey of the National Society of Professional Engineers indicates that 80% of employers feel 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 in recent years (Zander et al. 1994). Multidisciplinary approaches, total quality management (TQM) and team dynamics have been cited among recent innovations in undergraduate civil engineering education (Pauschke and Ingraffea 1996) along with increasing emphasis on communication skills and hands-on laboratory experiences. Finally, the National Science Foundation's merit review criteria plan is designed to fund more projects emphasizing two areas believed to encourage academic reform: the integration of research and education, and interdisciplinary research (ASEE Prism 1997). The field experiences initiative will improve the ability of undergraduate students to work in multidisciplinary teams and solve open-ended problems.

Rowan University and its Innovative Engineering Clinics

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 (Rowan and Smith 1995). 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:

- 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, and
- Emphasizing hands-on, open-ended problem solving, including undergraduate research.

To best meet these curriculum objectives, the four engineering programs of Chemical, Civil and Environmental, Electrical and Computer, and Mechanical Engineering have common Engineering *Clinic* classes (Clinics) throughout their programs of study (Table 1).

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Table 1: Overview of Civil Engineering Clinic Content

Year	Engineering Clinic Theme (Fall)	Engineering Clinic Theme (Spring)
Freshman	Engineering Measurements	Competitive Assessment
Sophomore	Discipline Specific Design	Interdisciplinary Design
Junior	Open-ended problem solving in small teams	
Senior	Open-ended problem solving in small teams	

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

In the Freshman Engineering Clinic, students work in multidisciplinary teams of 4 - 5 students with one professor working with 4 or 5 groups at a time. The Fall semester of the Freshman Engineering Clinic has laboratory 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 will develop 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 (Perna and Hanesian 1996), while others engage students in discipline specific freshmen engineering design projects (McConica 1996). Rowan's engineering program seeks to unify these topics and provide an innovative multidisciplinary 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. 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 Sophomore Engineering Clinic quickly realize 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 will be used when field sampling or field measurement are needed in Sophomore Engineering Clinic.

In Junior and Senior Engineering Clinics, students work on an open-ended project in a multidisciplinary team of 3 - 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 presentation of results via written report and presentation. Projects have included product design, process modification, process development, and applied and fundamental research. Most projects are funded by industry or governmental

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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. To date, however, this has been accomplished primarily with “in-building” laboratory exercises (with notable exceptions, e.g., Surveying courses). The field experiences initiative will take more laboratory experiences out of the building and into the field.

Junior and Senior Engineering Clinics are 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 are examples of this. 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, one clinic team completed a funded project for the Air Force Center for Environmental Excellence. Students traveled to a contaminated site on an Air Reserve Base, surveyed the site, and collected soil/sediment and water samples. Another team funded by the Northeast Hazardous Substance Research Center is currently sampling local wastewater treatment plants and river sediments for the presence of nonylphenols. Both projects require 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.

Hand and Mechanized 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, and moisture conditions related to engineering and natural structures. An in-situ soil infiltometer helps student learn about barrier systems, infiltration, and groundwater flow.

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Table 2: Field Experience Initiative Equipment

General	Equipment
Mapping	Total Station, Theodolites, Transits, Levels, Misc. surveying equipment, GPS unit.
Soil/ Sediment	Sampling: Lake sediment sampler, Hand-powered soil/sediment sampling kit (augers, push tubes, etc.), Mechanical auger. Measurement: Geotest double ring infiltrometer; ELE International Soil Moisture Temperature Meter
Water	Sampling: Horizontal Water Bottle; 2" Stainless Steel Vertical Well Sampler; (2) Watermark Stainless Steel Bailers; and Well Purge Pump. Measurement: Water Level indicator; Handheld Flowmeter; (2) YSI 600xl Multi Parameter Field Probes; Field conductivity, temperature, pH, DO, ORP probes and meters; and Field Spectrophotometer.
Air	Sampling: Sampling Pump Measurement: 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.

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

Pumps are used to collect airborne particulates. A weather station is used to measure meteorological parameters. This exposes students to measurements related to air pollution, pollutant transport, and techniques for analyzing time series of data and modeling.

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, computerized data collection as well as data reduction, manipulation, and analysis.

RESULTS TO DATE

In this section, the results from two projects are presented. For ongoing information about all of the projects, go to http://sun00.rowan.edu/~everett/projects/fldexp/FEHome.htm.

Weather Station

The Solar Powered Remote Weather Station is designed and built to be a WEB based data acquisition unit that will be used both by lower division students to study solar power, data acquisition and data analysis and by upper division environmental engineering students for weather related projects. The Station has been completely designed and constructed by student teams enrolled in the Junior/Senior Engineering Clinic. Students working on this project are

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majors in Civil and Environmental Engineering, Electrical and Computer Engineering, and Mechanical Engineering.

The weather data acquisition process begins with the remote weather station, which is housed in a field enclosure and powered by a solar-array charged battery system. The weather station collects data on air temperature, humidity, barometric pressure, wind speed, and wind direction. The students chose a Davis Weather Monitor II weather station. Weather data are wirelessly transmitted every fifteen minutes to a base station in Rowan Hall, the home of the College of Engineering. The base station stores this data locally and updates a log file on the engineering server. The server data files are used by a WEB page program that displays current conditions.

The students' first goal was to determine the power requirements for the full system, consisting of a Davis Weather Monitor II weather station and a Microhard System MX900 wireless transmitter/receiver pair. Initial design considerations had a more power-intensive computer based system but students were able to cut back on power consumption by using stand-alone wireless transmitters rather than a laptop computer with wireless LAN connection. The final calculations were used to estimate the number of solar panels required to assure constant power to the devices. 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. The students determined that 4 panels would be adequate to keep the battery charged for the weather station but added an extra panel for a total of 5 since the physical design of the enclosure enabled this to be done conveniently. Figure 1 shows a schematic of the finished physical structure.

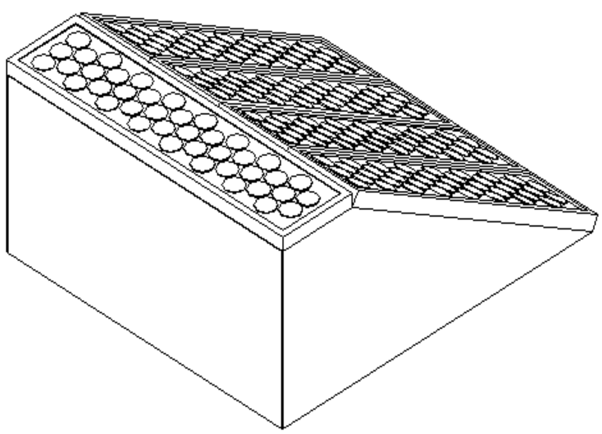

Figure 1: Permanent Station Design

Another goal was to create a design for the weather station that would be easily adaptable for other types of field-based data acquisition stations. 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. The overall design itself is easily transportable to other systems. 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 30km (~ 19miles). 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.

Site selection for the weather station, a major consideration, was based on three important criteria. First, the station had to be placed in an open area on campus that had no planned current

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or future construction. Second, National Weather Service regulations governing weather station placement require stations to be placed a minimum of 500 ft. from all buildings in order to obtain accurate wind and temperature readings. Finally, the location had to be remote and not receive a large amount of pedestrian traffic, to decrease the chance of random vandalism, but also had to be visible so that Public Safety personnel could easily spot any vandalism that might occur. More importantly, easy access from Rowan Hall for maintenance was desired. Based on these site requirements a number of proposed locations were evaluated, resulting in the selection of a site approximately 0.25 miles from the engineering building in an open field with minimal pedestrian traffic.

This project provided the student teams with an opportunity to experience interaction among four different disciplines (Environmental, Civil, Electrical, Mechanical Engineering and Computer Science) in the completion of a single product. Currently, the weather station is installed and the web site on line. However, students are still working on the data transmission system, with an anticipated completion date in Spring 2000. The weather station web site can be accessed at http://engineering.rowan.edu/~weatstat/.

Students in Freshman Clinic will use the weather station to learn about measuring devices, solar power and wireless data transmission. Students in environmental engineering courses will use the weather station to learn about meteorological concepts, measuring devices, and data manipulation.

Soil Sampling and Measurement

The soil sampling project focuses on the development and use of geotechnical field equipment. Civil and Environmental Engineering students in Junior/Senior Engineering Clinic completed the project. The tasks undertaken by the teams include:

- Development of a user's manual to describe the procedure for using geotechnical field equipment, namely soil augers, soil sampling equipment, and infiltrometer.
- Development of preplanned field activities for laboratory components of traditional courses.
- Development of integrated preplanned field activities for Freshmen and Sophomore Clinics.

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The test site is in the vicinity of Rowan hall. The first task undertaken by the students to assemble and use the power soil drill and augers. The power soil drill was obtained from Geotest. The drill is designed for one-person operation, but is rather cumbersome to use. The gas-powered engine is mounted on 8” semi-pneumatic tires connected to the power unit by a 7 feet long torque tube (Figure 2). Augers for use with the soil drill can be easily snapped-on. The depth capacity on an average soil type using a 4 inch diameter auger and full flighted extensions is about 12 feet. Beyond these depths, a tripod frame and hand winches are used. The auger can be used to obtain disturbed soil samples. To obtain relatively undisturbed samples, Shelby tube and split spoon samplers are available. These can be used with a hand hammer assembly, comprised of connector, jar collar anvil, 35 lb hammer, and 2 feet long drill rod for the hammer to slide on. There are sufficient drill rods to reach depths of 16 feet. This equipment can be used for obtaining soil samples from almost any sub-surface condition likely to be encountered in preliminary site investigations.

Figure 2: Soil drill

The other field equipment used was the double ring infiltrometer (Figure 3). The infiltrometer is a commonly used field method to determine the rate of infiltration of water into soils. The apparatus purchased by Rowan University includes two individually calibrated plastic cylinders, one of 5 L capacity and the other of 13 L capacity. The two cylinders are fitted with beveled shoes to enable driving them into the ground. The cylinders are then filled with water and maintained at a constant level by float valves. The volume of water added from the graduated cylinder to the infiltration ring to keep the water levels constant is equal to the volume of water that infiltrates into the soil. The volume of water infiltrating into the soil during specified time intervals can be converted into an infiltration velocity and plotted versus time. The average infiltration velocity, once the readings have stabilized, is the infiltration rate. The infiltrometer also gives a measure of the coefficient of hydraulic conductivity.

Figure 3: Double ring infiltrometer assembly

Students in freshmen and sophomore clinic will use the field equipment for soil property determination or site investigation, as projects require. As described earlier in the paper, sophomore clinic projects are open-ended design problems. In the past, the projects undertaken

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by the students have included assessment of the suitability of a landfill site, design of a baseball stadium and design of a footbridge. Such projects include a module on site assessment for which the above-mentioned soil sampling equipment can be used. The equipment will also be incorporated into the geotechnical engineering and foundation engineering class.

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. Much of the fieldwork activities involve multidisciplinary, and in some cases multilevel, teams. Field experiences are

- **Preplanned** exercises in laboratory components of select courses and modules in Freshman and Sophomore Engineering Clinics, and
- **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 are examples of this. In other cases, students in upper level engineering clinics must complete field exercise in order to complete the goals of a clinic project. For example, one clinic team completed a funded project for the Air Force Center for Environmental Excellence. Students traveled to a contaminated site on an Air Reserve Base, surveyed the site, and collected soil/sediment and water samples. Another team funded by the Northeast Hazardous Substance Research Center is currently sampling local wastewater treatment plants and river sediments for the presence of nonylphenols. Both projects require undergraduate students to learn standard sample collection, preservation, storage, preparation, and handling techniques.

The two projects described in detail in this document occurred in upper level engineering clinics and were used to develop the college of engineering's field exercise capabilities. A team of ECE, ME, and CEE students designed and built a solar powered weather station with wireless data capabilities. In addition to obtaining valuable experience working in multidiscipline and multilevel teams, the students learned about design, construction, solar power, meteorological measurement, data acquisition, data transmission, and web data delivery. They also created equipment that will be used to provide field experiences to students in Freshman Engineering Clinic and Upper level environmental engineering courses.

Evaluation of the field experience initiative will concentrate primarily on field experiences used in Lower level clinics and traditional courses. To date, most of the project activity has occurred in Upper level clinics, thus evaluation results are not available. Two kinds of evaluation are intended, student surveys and hypothetical exercises. In the first, a survey will be used to evaluate students' perceptions of the field exercises. In the second, students will be given a hypothetical project requiring field exercises. The students will be asked to plan fieldwork.

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