Reverse Engineering of Water Filters

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Abstract

This paper focuses on the innovative use of portable water purification units to introduce concepts of reverse engineering to a freshman class. All engineering students from the four engineering disciplines namely Civil, Chemical, Electrical and Mechanical share a common engineering *clinic* class. This class is a major hallmark of the Rowan engineering program. The theme of the *Freshman Clinic* class in the spring semester is reverse engineering of commercial products. Students in teams of four or five spend an entire semester learning about engineering fundamentals such as fluid flow, heat and mass transfer, thermodynamics and engineering materials. They are also exposed to intellectual property rights, safety and ethics, ergonomics and environmental considerations in engineering design.

Introduction

The college of engineering at the Rowan University was created through a $100 million gift from Henry and Betty Rowan in 1992 to the then former Glassboro State College (1). This newly constructed state-of-the-art $28M Henry M. Rowan Hall has 92,000 sq.ft. space with multifunctional laboratories and classrooms suitable for interactive learning. Mr. Rowan is the founder and the CEO of Inductotherm, Inc. which is the world's leading induction melting equipment manufacturer.

The Rowan engineering program addresses use of new innovative methods of teaching and learning to prepare students for entry into a rapidly changing and highly competitive marketplace (2,3,4). The major hallmark of our Rowan engineering program is a unique common class known as the *engineering clinic*. The engineering clinic class is integrated throughout the entire curriculum for eight semesters. All four engineering departments of Chemical, Civil, Electrical and Mechanical Engineering have this common clinic class throughout their program of study. This class is designed to meet the challenges of the changing job market which demands our future engineers to develop

- a thorough understanding of engineering design
- a basic understanding of manufacturing and fabrication procedures
- problem solving expertise
- collaborative learning and leadership skills
- technical communication skills
- advanced computer skills
- professionalism and ethical judgment, and
- environmental awareness.

Freshman Clinic

Freshman engineering students at the Rowan University are introduced to the concepts of engineering design through a series of hands-on engineering experiments focussing on the principles of engineering measurements and reverse engineering. During the fall semester each engineering discipline introduces students to basic concepts of measurements through three-week modules (5,6). These modules are focussed on the following topics:

- Manufacturing and Fabrication
- Structural Measurements

- Process and Flow Measurements
- Electrical Measurements

The fall semester class in freshman engineering exposes students to the intricacies in engineering design even though they lack the technical and analytical tools to solve realistic design problems. The class emphasizes on building problem solving, technical writing and communication skills through collaborative laboratory experiments and teamwork. Professionalism and engineering ethics are also integrated throughout the laboratory modules. Efforts are made to place female students in leadership roles or in well-balanced teams.

The first semester is followed by a semester long project focussing on reverse engineering. This course subtitled *Competitive Assessment Laboratory*, consists of a semester long project that introduces freshman engineering students to reverse engineering of a consumer appliance. *Reverse engineering helps in developing sufficient information about a (product) form and function to allow replication with or without enhancement in original or current technologies, materials, and manufacturing processes.* The course is a 15-week, 3 credit course consisting of a 1.5-hour lecture and 3.0-hour laboratory. Relevant lectures and hands-on laboratories are also taught to provide students the fundamentals of engineering design and engineering business. The lecture and laboratory format for this class is presented in Table 1.

Table 1: Course Outline for Freshman Clinic II

Week	*Lecture (s)*	*Laboratory*
1	Introduction to Reverse Engineering	Assign teams and products Perform literature and patent search
2	Manufacturing, Ergonomics	Product Disassembly AutoCad Drawings
3	Material Properties: Hardness, elasticity, ductility, etc.	Experiments to determine modulus of elasticity and thermal expansion
4	Material Properties: Activated carbon, resins, membranes (ceramic, hollow fiber)	Non-intrusive testing with product; Product operation; identifying engineering principles involved in product operation
5	Conservation of mass and energy	Carafe cooling,
6	Fluid Mechanics: Flowrate, Pressure, Radial Flow	Design experiments to evaluate filter performance
7	Introduction to Water Quality	Water Quality Laboratory
8	Microcontrollers	Microcontroller Programming
9	Data Acquisition	Setting up experiment
10	Introduction to Microbiology	Sampling Protocol
11	Design for the Environment	Experiments with Water Filter
12	Cost Analyses	Experiments with Water Filter
13	Intellectual Property	Data Analyses
14	Data Analyses	Final Report Preparation
15	Final Presentations	

The reverse engineering process involves product dissection and disassembly, engineering drawings, study of material properties, cost analysis and preparation of technical reports. Freshmen engineering students learn about product design and engineering principles through disassembly, inspection, materials testing and technical assessment of consumer products.

Low cost consumer products like hairdryers, coffee-makers, electrical toothbrushes and water filters were selected by four faculty as their vehicle for introducing reverse engineering to a class of approximately twenty students. This paper focuses on the use of portable water purification filters to introduce engineering design principles. Focus was on topics related but not limited to the following:

- *Engineering Materials*
- *Manufacturing Processes*
- *Cost Analysis*
- *Microbiology*
- *Physico-Chemical Water Treatment Methods*
- *Environmental Considerations in Design*
- *Environmental Regulations*
- *Life Cycle Management*
- *Safety*

Project Details:

Two PuR and two MSR water filters are used by four teams of twenty students. Each team has a different model of the water filters, so that performance, features, costs and experimental results can be compared. The students conduct non-intrusive and intrusive testing on the filters to determine the operating principles, material properties, ergonomics, safety, ethical and environmental considerations in the design of the filters.

During the first four weeks the students are asked to write a report which contains the following information:

- external dimensions
- list of parts with material identification
- function of each filter component
- common and special (safety, ergonomics and aesthetic) features of their product
- detailed AUTOCAD drawings of their product with proper dimensions and labels
- comments on intellectual property rights
- environmental considerations in design of the product (recylability, reuse etc.)
- literature survey of current water filters in the market
- deficiencies in product design
- improvements in overall design of the filter

This exercise helps students strengthen not only their technical communication skills but also fosters an interest in learning about the engineering concepts that went behind the design of their product. A parts list of a MSR filter is presented in Figure 1.

Figure 1: Components of a MSR filter

The rest of the semester is spent on designing experiments to evaluate filter performance. Students learn to identify parameters that they can monitor to evaluate filter performance. Parameters that were monitored in the Spring of 1998 included:

- Flowrate
- Pressure
- Turbidity
- Conductivity
- Organics
- Presence and Absence of Bacteria

Flowrate and pressure is measured by using Gilmont flowmeters and conventional pressure gauges. Turbidity measurements are made with a Hach 2100N Turbidimeter (HACH, Loveland, Colorado). A Orion Model 824 Conductivitimeter is used for conductivity measurements. Organics are measured at a wavelength of 254 nm with a Hach DR-4000 (HACH, Loveland, Colorado) spectrophotometer. Students receive lectures and demonstrations on measurement techniques for these parameters.

Students are also given an introduction to microbiology and the muti-disciplinary nature of water treatment. The *Presence/Absence (P/A) Media* (HACH, Loveland, Colorado) method is used to test for presence and absence of bacteria in the water treated by the filters. This method provides a quick and accurate way to detect microorganisms in water. P/A testing is simple and results can be available in as little as 24 hours after incubation at 20^{o}C. The media which is originally pink turns yellow in the presence of bacteria.

A process flow diagram of the experimental setup to assess filter performance is presented in Figure 2. Students use a sump pump, pressure gauges and flowmeters to assess flow and pressure changes during the duration of their experiment. They also acquire hands-on experience in selecting tubing, fittings, pumps etc. for their experiment.

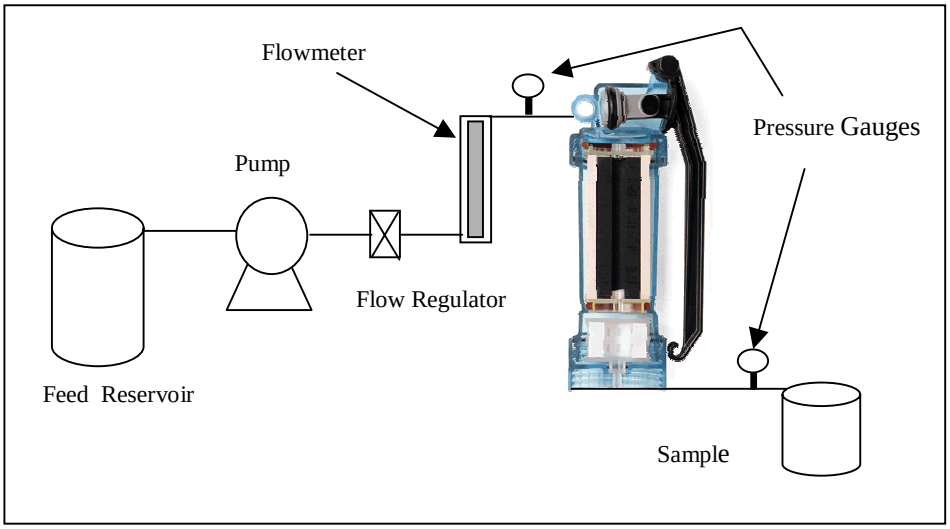


Figure 2: Experimental Setup

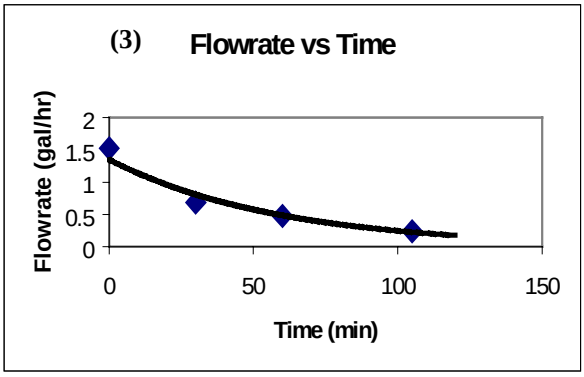
The water that is used for the evaluation of filter performance is obtained from a lake (Rowan Pond) adjacent to our College of Engineering. The students initially characterize the water quality of the pond before the start of experiments. They also identify a sampling protocol as to time and amount of sample that they need to assess the filter performance. The influent water quality for the Rowan pond is presented in Table 1.

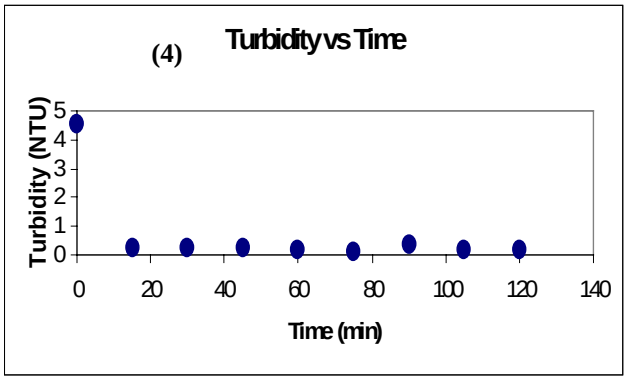
Table 1: Influent Water Quality for Filters

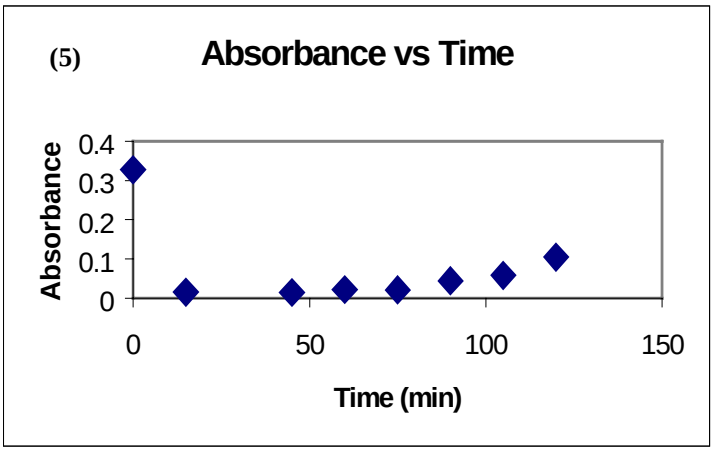
Water Quality Parameter	Value/Color
Conductivity µS/cm	220
Turbidity NTU	4.8 NTU
Organics (Absorbance at 254 nm)	0.327
Bacteria P/A Test	Yellow

Experimental Results:

Some of the results of the student-designed experiments are presented in Figures 3, 4 and 5.







Figurse 3,4 and 5: Typical Flowrate, Turbidity and Absorbance vs. Time plots for a Water Filter

Students analyze and plot the data from their experimental runs and provide technical interpretations of their data. They are asked to discuss why they note changes in flowrate, pressure and water quality with time of operation of the filters. The entire exercise also exposes them to basic water treatment processes such as filtration, ion-exchange, disinfection and adsorption. The student teams also compare the performance of their water filters by sharing their experimental data.

This project is also instrumental in exposing students to different materials and their unique properties that allows for their use in engineering design. Plastics, resins, activated carbon, ceramics, polycarbonates, rubber and silicone are some of the materials that the students are exposed to through this reverse engineering experience.

The entire semester long project culminates in a final report and formal presentation. The class of 1998 also participated in a poster competition sponsored by the New Jersey American Water Works Association for their annual conference. The class was well rewarded by winning the third prize at a poster competition sponsored by the New Jersey American Water Works Association's Annual Conference in March 1998.

The unique aspect of this entire project is the use of water filters to introduce the concepts of reverse engineering. Many schools have used various appliances such as toasters, hair dryers, coffee makers, electric drills etc. to introduce reverse engineering to students (7,8). The water filters spark the students' attention irrespective of their engineering choices because of the interest everyone has in drinking water quality. The fact that many students use these types of filtration units during camping and hiking expeditions also accounts for their enthusiasm to learn about the engineering principles involved in the design.

The course evaluations for this project were extremely positive. The class was comprised of a multidisciplinary group of students belonging to all four engineering disciplines. Students enjoyed working in teams and mentioned that it helped the learning process. Some commented on the fact that they also liked the idea of using a water filter for learning aspects of engineering design. Some even mentioned that they would like to see more or specific water quality parameters to be included in the future.

Conclusions

Portable water purification systems are an important tool for teaching engineering design, materials and scientific principles. The water filters are also instrumental in teaching students about water treatment processes like filtration, adsorption, ion exchange and disinfection. Students are also exposed to concepts of microbiology. The whole project exposes students to design their own experiments for evaluating product performance. It further helps them strengthen both their oral and written communication skills.

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