

## THE MULTIDISCIPLINARY ENGINEERING CLINIC AT ROWAN UNIVERSITY: BENEFITS TO STUDENTS AND FACULTY

Stephanie Farrell<sup>1</sup>, James Newell<sup>2</sup>, Robert Hesketh<sup>3</sup>, C. Stewart Slater<sup>4</sup> and Anthony J. Marchese<sup>5</sup>

**Abstract** Rowan University is pioneering a progressive and innovative Engineering program that uses innovative methods of teaching and learning to prepare students better for a rapidly changing and highly competitive marketplace. Key features of the program include: (i) multidisciplinary education through collaborative laboratory and course work; (ii) teamwork as the necessary framework for solving complex problems; (iii) incorporation of state-of-the-art technologies throughout the curricula; and (iv) creation of continuous opportunities for technical communication. The Rowan program emphasizes these essential features in an eight-semester, multidisciplinary Engineering Clinic sequence that is common to the four Engineering programs (Civil, Chemical, Electrical and Mechanical). The Engineering Clinic Sequence builds from a Freshman hands-on introductory course to a Senior level research and design project. Multidisciplinary collaboration and teamwork are common to all levels of the Clinic. This paper gives an overview of the Engineering Clinic sequence at Rowan University, and presents the objectives for each level with examples of the activities and projects that provide the framework for meeting these objectives. We also discuss how the Engineering Clinics successfully foster multidisciplinary faculty collaboration, enhance faculty development, and promote industrial interactions.

**Index Terms** Hands-on learning, teamwork, undergraduate research, multidisciplinary experience.

### INTRODUCTION

Rowan University is pioneering a progressive and innovative Engineering program that uses innovative methods of teaching and learning to prepare students better for a rapidly changing and highly competitive marketplace, as recommended by ASEE [1]. One of the key features of the program is the Engineering Clinic, an eight-semester, multidisciplinary sequence that is common to the four Engineering programs (Civil, Chemical, Electrical and Mechanical). The Engineering Clinic Sequence builds from a Freshman hands-on introductory course to a Senior level research or design project. The Engineering Clinic sequences emphasized important features of the Engineering program such as: (i) multidisciplinary education through

collaborative laboratory and course work; (ii) teamwork as the necessary framework for solving complex problems; (iii) incorporation of state-of-the-art technologies throughout the curricula; and (iv) creation of continuous opportunities for technical communication[2]. Multidisciplinary collaboration and teamwork are common to all levels of the Clinic.

This paper gives an overview of the Engineering Clinic sequence at Rowan University, and presents the objectives for each level with examples of the activities and projects that provide the framework for meeting these objectives. We also discuss how the Engineering Clinics successfully foster multidisciplinary faculty collaboration, enhance faculty development, and promote industrial interactions.

### FRESHMAN CLINIC

A two-semester Freshman Clinic sequence introduces all freshmen engineering students to engineering at Rowan University. In the Freshman Clinic we immediately establish a hands-on, active learning environment for the reason explained by scientist and statesman Benjamin Franklin: "Tell me and I forget. Show me and I may remember. Involve me and I understand."

The typical entering Freshman Engineering class has approximately 120 students, distributed among four engineering disciplines. Six sections of the course are offered by faculty from the four engineering disciplines, and the students are not divided by discipline. Objectives for the first semester course are:

- introduction to the practice and profession of engineering through engineering measurements
- survey of fundamental concepts from the four engineering disciplines
- introduction to team work and cooperative learning;
- overview of problem solving
- development of technical communication skills
- introduction to the design process, and
- introduction to safety, professionalism and ethics.

Each section of the two-credit course comprises a one-hour lecture period and a three-hour laboratory period. The lecture topics include unit conversions, problem solving, safety, professionalism and ethics.

<sup>1</sup> Stephanie Farrell, Rowan University, Department of Chemical Engineering, 201 Mullica Hill Road, Glassboro, NJ 08028 farrell@rowan.edu

<sup>2</sup> James A. Newell, Rowan University, Department of Chemical Engineering, 201 Mullica Hill Road, Glassboro, NJ 08028 newell@rowan.edu

<sup>3</sup> Robert P. Hesketh, Rowan University, Department of Chemical Engineering, 201 Mullica Hill Road, Glassboro, NJ 08028 hesketh@rowan.edu

<sup>4</sup> C. Stewart Slater, Rowan University, Department of Chemical Engineering, 201 Mullica Hill Road, Glassboro, NJ 08028 slater@rowan.edu

<sup>5</sup> Anthony J. Marchese, Rowan University, Department of Mechanical Engineering, 201 Mullica Hill Road, Glassboro, NJ 08028 marchese@rowan.edu

Students are introduced to each engineering discipline as they rotate through four, three-week laboratory modules in Chemical, Civil, Electrical and Mechanical Engineering. The laboratory modules are tied together using engineering measurements as a common thread. Examples of the topics explored in each discipline's laboratory module are:

- Chemical Engineering: Experiments in drug delivery [3] introduced students to concentration measurement; and a fluidized bed powder coating experiment involved temperature and coating thickness measurements [4].
- Civil Engineering: Water Resources experiments investigated open channel flow and hydraulic turbines, and focused on measurement of hydraulic phenomena. 5
- Electrical Engineering: Voltage and amplification investigated through construction of a strain gauge.
- Mechanical Engineering: Manufacturing experiments focusing on fabrication of an aluminum flashlight introduced students to metrology.

The theme of the second semester is the reverse engineering of a commercial product or process. Previous reverse engineering projects have involved products such as automatic coffee makers [6, 7, 8], hair dryers and electric toothbrushes [9] as well as the brewing process [10].

The organization and structure of the second semester is similar to that of the first semester, with the exception that the laboratory periods are devoted to a single, semester-long reverse engineering project. Through reverse engineering, students are exposed to

- The science and art of design by instrumentation and evaluating of a product of process
- Unifying engineering principles such as mass, momentum and energy balances; materials; thermodynamics, and electricity/magnetism
- Impact of material properties, manufacturing techniques, cost, safety requirements, environmental considerations and intellectual property rights on the design of a product

Through the innovative Freshman Clinic program, Rowan faculty have gained exposure in the engineering community in the areas of laboratory and curriculum development. Several of the freshman experiments have been adopted at other universities, and some have been the focus of award-winning publications [3, 11].

### SOPHOMORE CLINIC

As the Engineering Clinic sequence continues with Sophomore Clinic, two major objectives of the second year are to integrate design and communication and to introduce students to the Product Realization Process as employed by those engineers who develop products.

The Sophomore Engineering Clinic is team-taught by faculty from the College of Communication and the College of Engineering. This diverse, interdisciplinary faculty group

has fostered a culture of collaboration and scholarship into areas that are typically outside the domain of engineering research. Within the past 2 years, faculty from engineering and communication have collaboratively written and/or presented papers on:

- TQM in engineering design and technical communication[12],
- Campus and personal impediments and enablers in interdisciplinary team teaching [13],
- The effect of team teaching on the engineering students' attitudes toward writing [14, 15, 16],
- The power of rhetoric in technical documentation [17] and
- Integrating design courses with standard engineering curriculum[18].

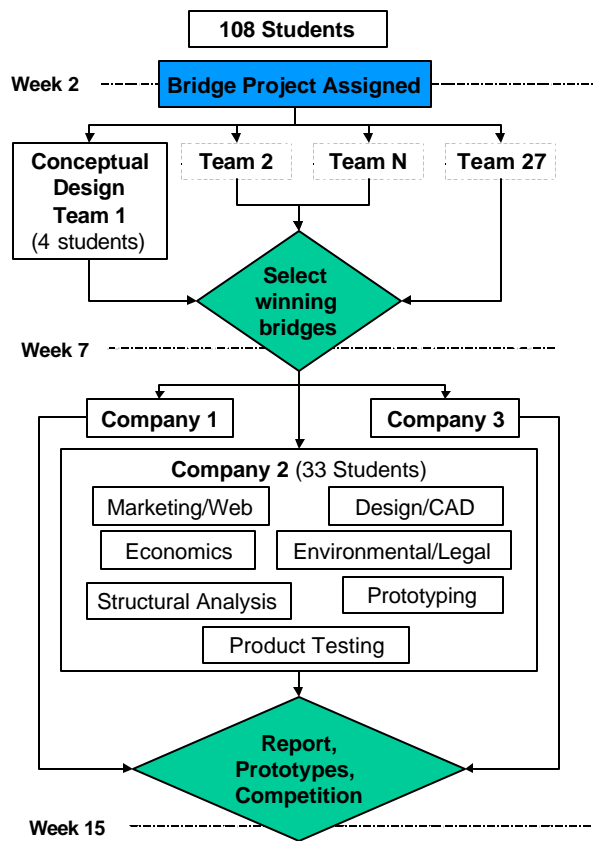
These results have been widely disseminated at engineering education (ASEE), writing (WAC) and educational (AAHE) venues.

The product realization process is accomplished through design projects that reinforce the engineering science principles that are being taught concurrently in the more traditional engineering courses. After a common freshman year, the curricula of the four engineering departments begins to diverge in the first semester of the sophomore year. The diverging curriculum presents a challenge for the instructor, who must provide a valuable design experience to all engineering students. More importantly, though, it represents an opportunity for the student to learn the valuable lesson that he or she will often be called upon to be a team member (or leader) on a project in which he or she is not a technical expert.

During the Fall 2000 semester, the semester project was to design and develop a portable bridge for domestic use that would enable a homeowner to cross a typical backyard brook or stream with their riding lawn mower. The portable bridge, which was intended to be marketed directly to the homeowner via a retail outlet (e.g. The Home Depot), needed to be easily assembled by the consumer and adaptable to various sized spans.

Completing this ambitious project required coordination among 8 faculty and 108 students. The logistics of the project are shown in Figure I. During the first half of the semester, students were divided into 27 separate conceptual design teams of four students each. Each conceptual design team was given 5 weeks to develop and document their conceptual and configuration designs. At the midpoint of the semester, three proposals were chosen for full-scale prototype development. During the second half of the semester, students were reassigned to a product development team, which had a specific task to complete in support of the full-scale development of one of the three chosen bridge products.

In the portable bridge design project, the mechanical and civil engineering students were concurrently enrolled in



**Figure 1** Logistics required for completing the bridge design project

Statics and Solid Mechanics. The electrical engineering students were enrolled only in Statics. The chemical engineering students had taken neither Statics nor Solid Mechanics. Although it may seem odd for ChE / EE students to be involved in the design of a portable residential bridge, the clinic experience has proven that these students played a significant role in formulating engineering specifications, generating several concept designs, computer simulation, cost analysis, prototyping and writing the design report.

Our experience has shown that projects which are quite complex in scope can be effectively accomplished as early as the sophomore level. In fact, the “just-in-time” philosophy for teaching engineering design is largely responsible for the overall success of this project. This approach allows for immediate application of theoretical concepts while material is still fresh in students’ minds. The majority of the supporting coursework required to complete this project was provided either just prior to or concurrent with the project. However, like all real-life design projects, many of the technical issues could not be solved using typical textbook solutions. The latter lesson is best learned early. And, by engaging in a series of engineering clinic projects, each unique in their own way,

each student will gain an appreciation for the life long learning required for any engineering professional.

### JUNIOR - SENIOR CLINIC

The Clinic sequence culminates with research or design-based project experience(s) in the Junior-Senior Clinic. Students work in multidisciplinary teams on semester-long or year-long projects that are supported by external sponsors when possible. In addition to providing a mechanism to introduce emerging technologies relevant to regional industries, the clinics provide the students with exposure to industrial projects with real deadlines and deliverables, and an opportunity to develop their project management, teamwork and oral and written communication skills.

The standard teaching load at Rowan university is two courses per semester plus Junior-Senior Clinic project management (typically two projects per semester per faculty member, with participation by all faculty). Management of a Junior-Senior Clinic project requires a substantial time investment, and represents a large portion of faculty research activity in Rowan’s primarily undergraduate program. It is essential, therefore, that the projects present adequate opportunity for faculty development to be worthwhile from a faculty resources point of view.

The following examples elucidate how the Junior Clinic projects have introduced Rowan students to emerging technologies in a multidisciplinary, team environment while providing opportunities for faculty development.

#### Advanced Vegetable Processing Technology Project

In a project sponsored by Campbell’s Soup Company, a team of students researched cutting edge technologies applied to the processing of vegetables for soups and juices. The multidisciplinary team comprised two undergraduate chemical engineering students, one civil engineering student, and one biology student. In addition, one chemical engineering master’s student served as the project manager.

Through this project, students investigated advanced membrane separation techniques as well as enzymatic, thermal, and physical/mechanical treatment techniques applied to vegetable processing. Their responsibilities included HAZOP analysis, project planning, budget formulation and management, literature and patent reviews, experimental design, data analysis, and developing a proposal for a second phase of the project. In addition to the engineering expertise the students acquired through this work, they gained familiarity with FDA regulations on food processing.

Engineers from Campbell’s demonstrated a high level of commitment to the project and to student learning by attending monthly progress meetings. At these meetings, students gave oral presentations on their progress. Then, the industrial representatives, faculty and students had brainstorming and discussion sessions in which the project was refocused and fine-tuned. This industrial interaction

helped maintain a high level of motivation among the students, and helped maintain focus and a fast pace of productivity. In addition to the progress meetings, the student team also conducted two lunch-and-learn seminars at Campbell's to share their research with engineers, scientists, and marketing representatives from the company. The enthusiastic response of the audience at Campbell's reaffirmed the industrial relevance and impact of the team's research.

The project promoted multidisciplinary teamwork among faculty from Chemical Engineering, Chemistry and Biology. Faculty were exposed to technology outside their areas of expertise. A confidentiality agreement prevents faculty from publishing research results; however, four educational publications have already resulted from the project. The grant provided funds for acquisition of state-of-the-art equipment for membrane separations and supercritical fluid extraction. Three of the technologies developed in the project served as the basis of three proposals for major educational grants, and have also been the focus of new experiments in traditional courses.

#### Metals Purification Project

The metals purification projects have been sponsored by Johnson Matthey Inc. A precious metals refinery is operated at West Deptford which is less than 10 miles from the university. This close proximity facilitates the numerous interactions and projects that we have with Johnson Matthey. Johnson Matthey has sponsored three years of engineering clinic projects. The objective of all of these projects is to investigate novel and innovative techniques that have a potential to replace current refinery process units.

At the refinery, precious metals such as Pt, Pd, and Rh are purified from feed streams containing many unwanted metal species. These feed streams range from spent catalysts in which precious metals are recovered and recycled to feed streams from mines. In the refinery are many dissolution, selective precipitation, and filtration steps. Using new and innovative processes the plant capacity, product purity, and the processing cost have the potential to be improved. In essence, students have an opportunity in the engineering clinic to conduct engineering projects that are equivalent in scope to those done by engineers in the plant. Our most successful project resulted in Johnson Matthey adding several new processing units to their refinery.

A grant from the National Science Foundation's Division for Undergraduate Education helped support the membrane-related equipment costs necessary to undertake this project [19]. These funds enabled the college to expose students to the latest membrane process technology, which helped secure industrial funding for subsequent projects in this area. The impact of these projects on students has resulted in the following outcomes:

- Understanding of the economics of high value added chemicals

- Design, fabrication and operation of new and innovative technologies
- Examination of scale-up from laboratory scale at Rowan to pilot plant scale in both West Deptford and Sonning England.
- Experience with direct interaction of students with plant operators, chemists, engineers and managers.

Faculty members involved in this project attended a workshop on electrochemical engineering as part of this project. They have gained expertise in electrochemical engineering that has been incorporated into a new course as well as an NSF-sponsored undergraduate research program (REU).

#### SUMMARY

The Rowan Engineering Clinic is an eight-semester sequence required of all students. In keeping with the program objectives, all clinics involve multidisciplinary teamwork, hands-on learning, and an emphasis on oral and written communication skills. In addition, the clinics are used to introduce students to state-of-the-art technologies.

The Engineering Clinic requires a substantial commitment of faculty time and effort, and it is therefore essential that it produce opportunities for faculty growth. The Clinic sequence has resulted in innovative laboratory and project development which has been the basis of numerous journal publications, conference presentations, and even national awards. The multidisciplinary nature of the Clinics has fostered multidisciplinary faculty collaboration that would be difficult to achieve in a more traditional environment. The focus on introducing students to emerging technology has the added benefit of introducing faculty to emerging technology as well, and this has provided opportunity for additional laboratory development, grant activity, publications, and conference presentations.

- [1] *Engineering Education for a Changing World*, Joint project report by the Engineering Deans Council and Corporate Roundtable of the American Society for Engineering Education, Washington, DC, 1994.
- [2] Rowan School of Engineering – A Blueprint for Progress, Rowan College, 1995.
- [3] Farrell, S. and R.P. Hesketh, Introducing Freshmen to Drug Delivery, *Proceedings of the 2001 Annual Conference of the American Society for Engineering Education*, Session 1526, 2000.
- [4] Hesketh, R., C. S. Slater, S. Farrell and M. Carney, Fluidized Bed Polymer Coating Experiment, Submitted to *CEE*, March 2001.
- [5] Orkins, J., Water Resources Experiment in Freshman Clinic Laboratory, *Proceedings of the 2001 Annual Conference of the American Society for Engineering Education*, Session 2793, 2001.
- [6] Hesketh, R. and C. Stewart Slater, Demonstration of Chemical Engineering Principles to a Multidisciplinary Engineering Audience, *Proceedings of the 1997 Annual Conference of the American Society for Engineering Education*, Session 2513, June 15-18, 1997.
- [7] Marchese, A.J., R.P. Hesketh, K. Jahan, T.R. Chandrupatla, R.A. Dusseau, C.S. Slater, J.L. Schmalzel, Design in the Rowan University

- 
- Freshman Engineering Clinic, *Proceedings of the 1997 Annual Conference of the American Society for Engineering Education*, Session 3225, June 15-18, 1997.
- [8] Hesketh, R.P., K. Jahan, Marchese, A.J., C.S. Slater, J.L. Schmalzel, T.R. Chandrupatla, R.A. Dusseau, Multidisciplinary Experimental Experiences in the Freshman Engineering Clinic at Rowan University, *Proceedings of the 1997 Annual Conference of the American Society for Engineering Education*, Session 2326, June 15-18, 1997.
- [9] Ramachandran, R., J. Schmalzel and S. Mandayam, *Proceedings of the 1999 Annual Conference of the American Society for Engineering Education*, Session 2253, June 20-23, 1999.
- [10] S. Farrell, R. P. Hesketh, J. A. Newell, and C. S. Slater, Introducing Freshmen to Reverse Process Engineering and Design through Investigation of the Brewing Process, *I.J.E.E.*, In press.
- [11] Hesketh, R. P. and C. S. Slater, "Demonstration of Chemical Engineering Principles to a Multi-disciplinary Engineering Audience," 1997 Annual Conference of the ASEE Milwaukee, WI, June 15-18, 1997, Session 2513.
- [12] Harvey, R., Johnson, F., Marchese, A. J., Newell, J. A., Ramachandran, R. P., and Sukumaran, B. (1999). Teaching Quality: An Integrated TQM Approach to Technical Communication and Engineering Design. ASEE Zone Meeting, Monmouth University, Spring 1999.
- [13] Marchese, A. J., Mosto, P. and Johnson, F. (2000). Crossing Interdisciplinary Boundaries: Impediments and Enablers to Faculty Collaboration and Integration. Eighth AAHE Conference on Faculty Roles and Rewards, New Orleans, LA, February 2000.
- [14] Harvey, R., Johnson, F., Marchese, A. J., Newell, J. A., Ramachandran, R. P., and Sukumaran, B. (1999). Improving the Engineering and Writing Interface: An Assessment of a Team-Taught Integrated Course. ASEE Annual Meeting, St. Louis, MO.
- [15] Johnson, F. S., Hutto, D., Dahm, K., Marchese, A. J., Sun, C., Constans, E., Hollar, K. and von Lock-ette, P. (2001). An Investigation into Interdisciplinary Team Teaching in Writing and Engineering: A Multi-Year Study. ASEE Annual Meeting, Albuquerque, NM.
- [16] Johnson, F. S., Hutto, D. and Marchese, A. J. (2001). Engineering Education in New Contexts: Creating and Improving A Multidisciplinary Learning Environment. Writing Across the Curriculum Conference, Indianapolis, IN, May 2001.
- [17] Hutto, D. and Hollar, K. (2001). Use of classical rhetorical framework for critical analysis of science and engineering issues. ASEE Mid-Atlantic Section Spring 2001 Regional Conference, April 2001.
- [18] Marchese, A. J., Constans, E., Dahm, K., Hollar, K., Hutto, D., Johnson, F., Sun, C. von Lockette, P., Kadlowec, J., Cleary, D., and Sukumaran, B. (2001). The Sophomore Engineering Clinic I: Integrating Statics, Solid Mechanics and Product Development in a Sophomore Level Design Course. ASEE Annual Meeting, Albuquerque, NM.
- [19] C. S. Slater, K. Jahan, S. Farrell, R. P. Hesketh, and K. D. Dahm, "Using Membrane Process Experiments in a Project-Oriented Environment," *Proceedings of the 2000 ASEE Annual Conference*, Session 1526, St. Louis, (2000).