

A synergistic interaction between industry and academia with a focus on chemical engineering undergraduate education

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Abstract

Rowan University is a public institution with a primary focus in undergraduate education. The College of Engineering has been in operation since 1996 and has four ABET-accredited engineering specialties. Rowan Engineering has created an exceptional program that fosters synergistic interaction between industry and academia. Through this program, engineering students of all four disciplines have the unique opportunity to participate in industrially sponsored research or design projects. Students work in multidisciplinary teams on semester-long or year-long projects that are supported by external industrial sponsors. The clinic program starts in the junior year and runs for four consecutive semesters. All engineering majors enroll in their junior or senior clinic, which are, approved 2-credit core courses. 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. This program offers the industrial sponsor a cost-effective approach to problem solving with potential for a high return on investment, through technical assistance from advanced undergraduate engineering students supervised by faculty. This paper presents a case study which examine successful synergistic interaction between industry and academia through the Rowan Engineering Clinic Program. The challenges and obstacles that have been encountered are also described.

Index Terms $\frac{3}{4}$ Industry-Academia interaction, project-based learning undergraduate research

INTRODUCTION

Rowan University is a comprehensive regional state university with six colleges: Business Administration, Communications, Education, Fine and Performing Arts, Liberal Arts and Sciences and Engineering. The College of Engineering was founded using a major gift in 1992 from Henry Rowan. Rowan University is pioneering a progressive engineering program that uses innovative methods of teaching and learning to prepare students for a rapidly changing and highly competitive marketplace, as recommended by ASEE^[1]. To best meet these needs, the four engineering programs of chemical, civil/environmental, electrical/computer, and mechanical engineering include an interdisciplinary engineering clinic every semester. Sharing many features in common

with the model for medical training, the clinic provides an atmosphere of faculty mentoring hands-on, laboratory setting. At the freshman level, students conduct engineering measurements and reverse engineer a process or product. The sophomore engineering clinic is communications-intensive and also introduces students to the design process of each discipline. The junior and senior clinics provide an opportunity for the most ambitious part of our project-intensive curriculum in which students work on a real engineering problem usually sponsored and mentored by local industry. Undergraduate engineering and technology students benefit from “real-world” experiences which are usually obtained through internship and co-op experiences. Through these work experiences, students have the opportunity to apply their technical skills to industrially-relevant problems, gain exposure to company culture, and build a foundation which helps provide motivation for future learning in an academic environment. While these “real-world” experiences are highly valuable to students, they are still separate from the engineering curriculum and academic experience. It would be desirable to integrate more “real-world” experiences into the undergraduate curriculum at universities; however, industry-academic relations have not, in general, been developed to their full potential. Rowan University has developed an Engineering Clinic Program which fosters collaboration between academia and industry and provides “real-world” project experiences to undergraduate students.

Typical Project Life

The typical engineering clinic project starts well before the first day of the semester, and the preliminary work in defining a project and securing funding requires a substantial time investment by the faculty members. The initial contact between a professor and a scientist or engineer from a regional company often results from a connection made through a professional society meeting, recruiting event, student internship, or newspaper article about the university or company.

Representatives of the interested company are invited to the university for an informational visit. They are introduced to the unique nature of the Engineering Clinics and the particular advantages that the flexible nature of the clinic sequence offers their company. The representatives also receive a brief overview of the expertise and interests of the college faculty members, while the faculty learn about the engineering priorities of the company. After this visit, interested faculty members often visit the plant site.

The next stage is to match faculty interest with the operations of the company. Then further meetings are set up to brainstorm and sketch out project ideas. Professors research these ideas to develop and scope the difficulty level of the project to upper level engineering students. The professor must also engineer the project to have outcomes that can be achieved within one and two semesters that will satisfy the students and the sponsor. Finally a budget is prepared for the project and negotiations are undertaken with the company to finalize the agreement. The average funding level for one Clinic project is about \$30,000. A confidentiality agreement is established between the company and the university. Normally, the time between first contact and obtaining a defined and funded clinic project averages about one year.

Prior to the start of the semester, background work should be done so that undergraduate students will be able to “hit the ground running”. One graduate (Masters)

student is usually assigned to the project, and this student would initiate a literature search and become familiar with the technical aspects of the project before the semester begins. The learning curve is steep for both the graduate student and the faculty member, and the effort required for this aspect of the project should not be underestimated.

When the semester begins, undergraduate students are matched to projects based on their ranked project choices and on the needs of the project. The professor provides a brief introduction to the project, and the students are required to read introductory material for familiarization. Early in the semester, typically in the second week, the team meets with industry representatives who provide an overview of their industry as well as a description of the technical problem that is to be addressed. At this meeting, students begin to develop a rapport with the industry representatives. They begin to see what aspects of a project are important to industry, that industry has very short deadlines, and that they expect to see experimental results. They also see that these projects have a goal that will directly impact the operations of the plant and the engineers and scientists in the meeting room. Close interaction with industrial representatives is critical to success of the project, and regular meetings continue throughout the semester, typically on a bi-weekly basis.

Students begin immediately to review the technical literature, and then to develop a project plan. Students then establish a budget and begin to purchase equipment and supplies necessary for their experiments. Students learn that it is necessary to work diligently and aggressively through this phase of the project due to the inevitable lag time between choosing the equipment and receiving it.

The student team has weekly meetings with the faculty members involved in the project, as well as regular (biweekly or monthly) informal meetings with the industry representatives. The frequency of the meetings with the industry representatives depends on their availability and their desired level of involvement in the project. Our experience has been that frequent meetings are highly beneficial because accountability, progress and results are required. Formal presentations to the industry are given mid-semester and at the end of the semester.

These projects also help the program address many of the "softer" skills required by ABET [2]. Students function in multidisciplinary teams, design and conduct experiments, learn about safety and environmental issues, analyze and interpret data, communicate through oral and written reports, and use modern engineering tools.

CASE STUDIES

Durable Fluid Technology

DFT Inc is a check valve and control valve manufacturing company, located in Exton, Pennsylvania. DFT partnered with the Engineering department at Rowan University to solve the problem of predicting the noise generated by their control valves. Although extensive literature information can be found on how to predict and model such noise; the methods are limited to those valves configurations that are more commonly used for control purposes that is, globe valves, butterfly valves, and needle valves. DFT's unique design called for a new approach for predicting and modeling hydrodynamic and aerodynamic noise.

Due to the multidisciplinary nature and complexity of this problem a clinic team was formed. This clinic team included of six students, three faculty members and personnel from Rowan Cogeneration plant. The one main objective of this project was to correctly predict the noise that a DFT control valve produces.

Given the main goal for this team, three distinctive objectives were identified, these are:

1. Aerodynamic and hydrodynamic data generation in anechoic chamber.
2. Hydrodynamic data validation in flow loop at Rowan Cogeneration plant.
3. Development of a computer program that predicts the level of noise based on fluid conditions and geometry of the valve.

In this projects the students activities included: developing a detailed literature review, designing of the flow loops for the co-generation plant and for the anechoic chamber, specifying, quoting and purchasing all parts required for both flow loops, designing an experimental plan for the co-generation data gathering and one for the anechoic chamber, collecting, processing and analyzing data, working with Rowan's Public Safety to ensure the removal of all asbestos insulation before any other work started.

The students from the three disciplines involved in the project had the opportunity to acquire technical knowledge not typically covered in their programs. For instance, the chemical engineering students learned about acoustics, noise measuring, noise generation in hydrodynamic and aerodynamic flow regimes, and cogeneration. They also had a hands-on learning experience in how to operate a boiler in a utility plant. The electrical and computer engineering students learned fluid mechanics topics such as fluid flow in pipes, compressible and incompressible flow, cavitation, flashing and choked flow, design and operations of control valves and power generation in a steam plant.

All students gained experience in producing specific deliverables for an external industrial sponsor. They were also given the opportunity to present their work internally and externally ^[3].

Johnson Matthey Metals Purification Processes

Johnson Matthey, Inc. is a global specialty chemicals company with a focus on precious metals, catalysts and fine chemicals. A precious metals "refinery" is operated at West Deptford, NJ, which is less than 10 minutes from our campus. This close proximity facilitates numerous interactions and projects that we have with Johnson Matthey. Johnson Matthey has provided significant support to our chemical engineering department and was a "charter member" of the PRIDE program, Partners with Rowan in Developing Engineers. They have continuously employed Rowan chemical engineering students as interns, weekend shift workers, and permanent employees. Johnson Matthey was a pioneer of the Engineering Clinic Program, sponsoring two projects in the first year of the program and 1-2 projects for the five years that have since passed. These projects have focused on precious metals separation and recovery. The objective of all these projects has been to investigate novel techniques that have the potential to replace current "traditional" refinery process units.

At the refinery, precious metals such as Pt, Pd, Rh, are purified from feed streams containing many unwanted metal species and other impurities. The feed streams are

made up of spent catalysts from which precious metals are recovered and recycled to feed stream from mines. In the refinery, there are many dissolution, selective-precipitation, and filtration steps. Using innovative processes, like membranes, the plant capacity, product purity, and 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.

One of the Johnson Matthey projects the development of a membrane process to use electro dialysis for separation of a precious metal chloride ion solution, in an intermediate process step, that is contaminated with unwanted acids and salts. Technical aspects of the project focused on process design, performance evaluation, economic evaluation, and scale-up. Other technologies investigated through different projects include liquid-liquid extraction, ceramic membrane microfiltration, ion exchange, and adsorption.

These projects have been beneficial to Johnson Matthey, students, and faculty. Based on the results of these projects, JMI has added several new process units to their refinery processes that result in increased capacity, higher product purity, and shorter “hold-up” time for precious metals. Students have learned new technology through industrial projects, have gained exposure to industrial culture, and in many cases have secured summer or full-time employment with Johnson Matthey. Faculty have developed valuable relationships with industrial partners, secured funding for research projects, and learned about new technologies.

General Mills

General Mills is an international company with a wide range of food products. The company’s major business includes Big G cereals, the leader in the \$7.5 billion U.S. ready-to-eat cereal category, with consumer favorites like *Cheerios*, *Wheaties* and *Lucky Charms*. Other business divisions focus on meals, baked goods, snacks, and yogurt. Our interaction with General Mills involves the Pillsbury division which produces dough-based products.

Our relationship with General Mills began with Pillsbury before it was bought by General Mills. Pillsbury has a manufacturing facility in nearby Swedesboro, NJ, and Pillsbury engineers were involved with the Rowan Chemical Engineering Capstone Design Course. As the relationship between Rowan and Pillsbury evolved, and Pillsbury saw other successful Clinic projects, we began to discuss possible Clinic projects with Pillsbury (now part of General Mills). In September 2002, General Mills boldly sponsored *three* Clinic Projects for improvement and optimization of their dough line processes. One project focused on the analysis of raw materials, the second project aimed to optimize a process line, and the third project investigated wastewater minimization.

The structure and lifetime of the Clinic Project was very similar to that described above for the Johnson Matthey Projects. The nature of the work, however, required a significant amount of time on-site at the manufacturing facility. Students were required to complete the General Mills safety training program and to learn good manufacturing practice (GMP) requirements for food production before they were granted permission to work in the production area. They were given access swipe cards so that they could enter

the plant at any time without having to sign in and have an official host from the company.

The on-site work included careful observation of the current process, quantitative analysis of the individual process steps, and modification of the process to test proposed solutions. The wastewater minimization team investigated several novel technologies both in the laboratory at Rowan and on-site at General Mills. They have designed a water recovery system that will be implemented at the plant this year, and will likely be implemented at several other facilities around the world. The dough line optimization team performed a thorough analysis of all process steps and proposed a process modification that has already been implemented and will result in more than \$1 million annual savings.

The students working on this project benefited tremendously from working directly with operators and technicians at the plant. Engineers from General Mills also reported to us that their operators had an increased sense of pride and ownership in their own work, because University involvement meant that their project was particularly important to the company. They were highly cooperative with the students who were working on the plant floor. The students were invited to give a short presentation to the entire company at their quarterly meeting last spring; this high visibility showed the students how significant their work was to the company.

Regular project meetings were limited to weekly meetings between students and faculty. General Mills engineers did not attend regular meetings at the University, as was done with Johnson Matthey. Frequent meetings with General Mills engineers were unnecessary because of the regular informal contact between students and sponsors on-site at the plant. Two formal presentations were given by the students to the sponsor each semester. These presentations were given on-site at General Mills, and they were attended by engineers, technicians and operators, as well as managers from Finance Operations, Manufacturing, Maintenance, Quality and Regulatory Control, and Human Resources.

General Mills worked diligently with the students to produce different types of documentation, some for internal use and "sanitized" versions for external use. This helped overcome what is often a limitation of industrially-sponsored projects: the inability to share/publish work externally. Some of the work was presented by an undergraduate student at the AIChE Spring Meeting in New Orleans, LA [4]. The students' fall semester report was nominated for consideration as the best paper in the AIChE student paper competition – and received the First Place AIChE Zeisberg Award for the best report.

Campbell Soup Company

Campbell Soup is the world's largest maker and marketer of soup and also a leading producer of juice beverages, sauces, biscuits and confectionery products. The Campbell Soup Company World Headquarters and Corporate Research and Development facilities are in nearby Camden, NJ. Campbell has sponsored Clinic projects for two consecutive years.

In a project sponsored on 2001-2002, a team of students researched cutting-edge technologies such as novel membrane processes and supercritical fluid technology for the processing of soups and juices. The multidisciplinary team consisted of two

undergraduate chemical engineering students, one civil engineering student, and one biology student. In addition, one master's student served as a 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 responsibility included HAZOP analysis, project planning, budget formulation and management, literature and patent reviews, experimental design, and development of a proposal for a second phase of the clinic project. In addition to the engineering expertise the students acquired through this project, they gained familiarity with Food and Drug Administration regulations, Good Manufacturing Practices, and labeling requirements.

Engineers from Campbell's demonstrated a high level of commitment to the project and to the student learning by attending monthly progress meetings. At these meetings, students gave oral presentations on their progress. This was followed by brainstorming and discussion sessions in which the industrial representatives, faculty, and refocused and fine-tuned the project. This industrial interaction helped maintain a high level of motivation among the students, and maintained the 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 clinic research project. Students were surprised by the high interest level exhibited by the marketing employees who believed that the project would significantly impact product marketing.

Campbell Soup Company is a strong supporter of our program, not only supporting the clinic project mentioned above, but also employing both full-time and internship students from our program. In the summer following the vegetable processing project, two Rowan undergraduate students accepted summer internships at Campbell's. The students had the rewarding experience of successfully implementing two of the technologies developed at Rowan into Campbell's processing facilities in California and New Jersey.

SUMMARY

Rowan University has developed a program that fosters synergistic interaction between industry and academia which provides a mechanism for performing industrially sponsored research or design projects in an academic environment. Undergraduate junior and senior engineering students work in multidisciplinary teams on semester-long or year-long projects that are supported by external industrial sponsors. 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.

This program offers the industrial sponsor a cost-effective approach to problem solving with potential for a high return on investment, through technical assistance from advanced undergraduate engineering students supervised by faculty. Successful projects have led to the implementation of several new process modifications and process units that have resulted in increased capacity, higher product purity, decreased labor cost, and

less process down time. In addition, the company has the opportunity to watch for potential interns and employees for future hire.

Students have learned new technology through industrial projects, have gained exposure to industrial culture, gain experience with deadlines, progress meetings, presentations and written deliverables, and in many cases have secured summer or full-time employment with the sponsoring company. Students have won external awards for their work and have presented their work at national conferences. Faculty members have developed valuable relationships with industrial partners, secured funding for research projects, learned about new technologies, and occasionally have published results externally.

The Clinic model provides a framework for academic-industrial interaction involving undergraduate students. To ensure success of the project, a significant effort is made to focus and define the goals so that they are achievable in a semester or year-long time frame. It is crucial to maintain the flexibility necessary to tailor the project to the company's needs and corporate structure, and the three case studies provide three different project structures that fit with the needs of the sponsor. It is necessary also for the University administration to work with the company on issues such as confidentiality agreements, intellectual property agreements, budgets and payment schedules. Rigid policies in any of these areas would be an impediment to the collaboration.

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