Sponsored Industrial Research Experiences for Undergraduate Students: Perspectives on Collaborative Projects with Petrochemical Industry

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1. Introduction

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.

At Rowan University, all engineering students participate in an eight-semester course sequence known as the Engineering Clinics. In the Junior and Senior years, these clinic courses involve multidisciplinary student teams working on semester-long or year-long research and design projects sponsored by a company in our region. Every engineering student participates in these projects and benefits from project-based learning, exposure to emerging technologies, industrial contact, teamwork experience and technical communications.

New Jersey is home to several major petroleum refining facilities. Undergraduate Rowan Engineering students have worked on a variety of research projects sponsored by companies such as Johnson Matthey, Sunoco, and Valero. This paper presents case studies which examine successful synergistic interaction between industry and academia through the Rowan Engineering Clinic Program. A case study is presented presented from the student perspective, focusing on the educational and professional benefits to students who have worked on these projects.

1.1 Engineering Clinics

The Engineering Clinics are taken each semester by every engineering student at Rowan University. In the Engineering Clinic, students and faculty from all four engineering departments work side-by-side on laboratory experiments, real world design projects and research. The solutions of these problems require not only proficiency in the technical principles, but, as importantly, require a mastery of written and oral communication skills and

the ability to work as part of a multidisciplinary team which are essential skills for professional success [1, 2, 3]. Rowan's Clinic Program integrates these diverse challenges of "real-world" projects with pedagogically valuable hands-on learning experiences [4, 5] and technical communications[6, 7, 8].

1.2 The Junior/Senior Engineering Clinic Project

The development of industrial Junior-Senior Clinic projects has been described previously [9] and is included here for clarity.

The typical engineering clinic project starts well before the first day of the semester, when the preliminary work of defining a project must be complete. This work usually begins when an industrial engineer is invited to Rowan for an informational meeting which includes a tour of the facilities. At this meeting, the Engineering Clinic Program is introduced and a brief overview of expertise and interests of college faculty members is provided.

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. Outcomes must be achievable within one semester or, more typically, one academic year. Finally a budget is prepared for the project and negotiations are undertaken with the company to finalize the agreement. 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 is done so that undergraduate students will be able to "hit the ground running". A graduate or advanced undergraduate student is assigned to the project during the summer, and this student initiates a literature search and becomes familiar with the technical aspects of the project before the semester begins.

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 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 (2000). 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.

2. Project Descriptions and Outcomes

The project description has been submitted to the sponsor and its content is currently being reviewed by company attorneys for confidentiality protection.

This project involves a group of five engineering students and has been in progress for two semesters. Working on a collaborative project between industry and academia has allowed students to see objectives of projects from multiple angles. The educational aspect of the project allows the professor to nurture and evaluate students' ability to use technical skills learned in common engineering courses to solve industrial problems.

The project has provided the opportunity for students to develop and enhance their problem solving skills. Students have learned that the first step in problem solving is to identify the problem, and then proceed toward developing the best method of solution. This project involved an open-ended problem, and its solution required an experimental approach and application of data analysis skills. The experimental aspect of the project required a substantial amount of troubleshooting, an experience which was invaluable in the development of problem solving skills. Students realized the importance of scouring literature for knowledge as needed to solve problems.

One senior student working on this project has accepted a job offer with a large petrochemical company in the NJ region. The three junior chemical engineering students have interviewed for internships for company that sponsored this project. Not only does the Clinic Project provide a "foot in the door" for students seeking employment, but it provides unique material for discussion at a job interview. Students are able to offer descriptions of their teamwork experience, contributions to a project, application of classroom knowledge to open-ended industrial problems, ability to meet deadlines, and understanding of how to achieve (sometimes ever-changing) objectives of a project.

3. Assessment

The impact of the industrial Engineering Clinic projects on industrial constituencies and the benefits to faculty have already been addressed. In this section we will examine the benefit of the industrial Engineering Clinic projects to the engineering students. In their 2005 senior exit interviews, 100% of the graduating students indicated that Junior Senior Clinic was very a very valuable component of their chemical engineering education. Industrial internships often require the same skills (beyond basic technical knowledge) that are critical to the success of an industrial Clinic project, and interns are often hired for their industrial Clinic experience. The

development of these skills is a Clinic educational objective, and therefore employers' evaluations of summer interns are useful instruments in determining whether Clinic objectives are met. Employers' evaluation of summer interns is consistently very positive, as shown in Table 1. Summer intern ratings were outstanding in areas that are essential to the success of an industrial Clinic project: the ability to design and conduct experiments, the ability to analyze and interpret data, mastery of written and oral communication skills, ability to function with minimal guidance, the understanding of professional responsibilities and the ability to work as part of a multidisciplinary team. It is difficult to isolate the contribution of the Junior/Senior Clinics to the development of these skills; however, these skills are essential in Clinic projects and are used more extensively than they are in traditional classes. Therefore, we believe that the Junior/Senior Clinic contributes significantly to the development of these skills.

Table 1: Mean ratings of chemical engineering students working as summer interns in 2004. 1=poor to 5=excellent.

	Summer 2004
Ability to design/conduct experiments and analyze/interpret data:	4.33
Understanding of professional responsibilities:	4.23
Ability to function independently with minimum guidance:	4
Ability to work in teams	4.60
Multidisciplinary teams:	4.57
Ability to communicate effectively - Verbal:	4.15
Ability to communicate effectively - Written:	4.08

4. 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 several new process modifications and process units that have resulted in greener processes, 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. 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. 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.

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