INDUSTRY AND ACADEMIA: A SYNERGISTIC INTERACTION THAT ENHANCES UNDERGRADUATE EDUCATION

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Abstract

Rowan University has developed a program that fosters synergistic interaction between industry and academia. This program provides a mechanism for performing industrially sponsored research or design projects in an academic environment. One of the unique features of this program is its integration into the undergraduate curriculum at our university. Participation in this Engineering Clinic program is required of all Engineering undergraduate students for all four semesters of their junior and senior years.

Students work in multidisciplinary teams on semester-long or year-long projects that are supported by external 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. In addition, the company has the opportunity to watch for potential interns and employees for future hire.

This paper presents case studies which examine successful synergistic interaction between industry and academia through the Rowan Engineering Clinic Program. The case studies focus on the integration of industrial problem solving into the curriculum, the development of three successful and different relationships with companies in the region, and benefits to students, faculty and industry.

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 [1]. 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.

The Clinic Sequence

The College of Engineering at Rowan is comprised of four departments: Chemical, Civil and Environmental, Electrical and Computer, and Mechanical. Each department has been designed to serve 25 to 30 students per year, resulting in 100 to 120 students per year in the College. The size of the College has been optimized such that it is large enough to provide specialization in separate and credible departments, yet small enough to permit a truly multidisciplinary curriculum in which project-based courses are offered simultaneously to all engineering students in all four disciplines. Indeed, the hallmark of the engineering program at Rowan University is the multidisciplinary, project-oriented Engineering Clinic sequence.

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 [2, 3, 4]. Rowan's Clinic Program integrates these diverse challenges of "real-world" projects with pedagogically valuable hands-on learning experiences [5, 6] and technical communications [7, 8, 9].

With a total of 32 faculty members across the four engineering disciplines participating in the clinic, the small student-to-faculty ratio facilitates a high level of faculty-student interaction. This proves valuable to both the student learning and the success of the project. Typical teaching loads for Rowan University Engineering faculty are two courses per semester plus project management for junior/senior clinic projects.

Typical Project Structure

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.

The industrial engineer or scientist is invited to the university for an informational visit that includes a meeting with faculty and a tour of the facilities. They are introduced to the unique nature of the Engineering Clinic Program and the potential advantages that the Program 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 funding level for one Clinic project is typically \$30,000-\$60,000. 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 is done so that undergraduate students will be able to "hit the ground running". One graduate 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 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 [10]. 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.

Three case studies are presented below for projects that have been conducted in collaboration with companies in our region – Johnson Matthey, General Mills, and Campbell Soup Company. The case studies are written to emphasize the unique features and individual nature of the projects. Beyond having clearly expressed project objectives, expectations, timeline, and budget, we believe that there is no "formula" for the framework of a successful project and that flexibility is the key to success.

Case Studies

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, and Rh, are purified from feed streams containing many unwanted metal species and other impurities. 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 involving membranes was a process development project examining electrodialysis for separation of a precious metal chloride ion solution, in an intermediate process step, that is contaminated with unwanted acids and salts. The objectives of the project were (1) to design and build an electrodialysis unit for the separation and purification of the desired process stream, (2) to investigate the performance of electrodialysis in the removal of the salt contaminant from the product on a laboratory scale, (3) to perform an economic analysis of the proposed process in comparison with the traditional technique, and (4) to scale up the process to pilot scale. Other technologies investigated through different projects include liquid-liquid extraction, ceramic membrane microfiltration, ion exchange, and adsorption.

In another project with Johnson Matthey, students developed a novel adsorption technique for the removal of a precious metal from an acidic solution. In the first semester of the project, students conducted laboratory-scale batch and column experiments to screen different resins for their effectiveness. In the second semester, the team focused on the optimization of operating conditions for the feed, washing, and elution steps. In the third semester, they tested a laboratory scale three-column setup for continuous cyclic operation, and performed calculations for scale-up to pilot scale. During the winter break that followed the third semester of the project, the students worked at the Johnson Matthey facility as paid employees to install and test the pilot equipment. During this time they worked together with their academic advisor and an industrial engineer.

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. Many familiar products are included in their repertoire: *Betty Crocker* potato mixes, *Old El Paso* Mexican foods, *Progresso* soups, *Green Giant* vegetables and meal starters, *Pillsbury* waffles and rolls, *Betty Crocker* dessert mixes, *Chex Mix* snack mix, *Nature Valley* granola bars, and *Yoplait* and *Colombo* Yogurt.

Our relationship with General Mills began with the Pillsbury division, located in nearby Swedesboro, NJ, before it was bought by General Mills. Pillsbury engineers served as industrial consultants 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. These technologies for wastewater minimization are mechanical treatments that can be used with process water in the food industry: centrifugation, microfiltration/ultrafiltration trains, and vibratory separation. They have designed a water recovery system that will be implemented at the plant this summer, 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 the weekly meetings between students and faculty. General Mills engineers did not attend regular biweekly 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 [11]. The students' fall semester report was nominated for consideration as the best paper in the AIChE student paper competition – and received the First Place 2003 AIChE Zeisberg Award for the best report [12].

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, GMPs, 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 with 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 such as the AIChE Spring Meeting. 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.

A set of surveys has been developed to gather assessment data from the Engineering Clinic constituencies. Industrial liaisons, faculty, students, and alumni will be surveyed in order to gather information about the value and benefits of the industrial Engineering Clinic projects.

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Biographical Information

Stephanie Farrell is Associate Professor of Chemical Engineering at Rowan University. She received her B.S. in 1986 from the University of Pennsylvania, her MS in 1992 from Stevens Institute of Technology, and her Ph.D. in 1996 from New Jersey Institute of Technology. Prior to joining Rowan in September, 1998, she was a faculty member in Chemical Engineering at Louisiana Tech University. Stephanie has research expertise in the field of drug delivery and controlled release, and she is currently focusing efforts on developing laboratory experiments related to membrane separations, biochemical engineering, and biomedical systems. Stephanie won the Dow Outstanding Young Faculty Award in 2000, the Joseph J. Martin Award in 2001, the Ray W. Fahien Award in 2002, and the ASEE Distinguished Teaching Award in 2003. .

Robert Hesketh is Associate Professor of Chemical Engineering at Rowan University. He received his B.S. in 1982 from the University of Illinois and his Ph.D. from the University of Delaware in 1987. After his Ph.D. he conducted research at the University of Cambridge, England, and joined the faculty at the University of Tulsa in 1996. Robert's teaching experience ranges from graduate level courses to 9th grade students in an Engineering Summer Camp funded by the NSF. Robert employs innovative methods such as cooperative learning and inductive teaching techniques in his classes His dedication to teaching has been rewarded by receiving several educational awards including the 2002 Quinn Award, 1999 Ray W. Fahien Award, 1998 Dow Outstanding New Faculty Award, the 1999 and 1998 Joseph J. Martin Award, and four teaching awards.

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