

A Manufacturing Engineering Experiential Learning Program

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Abstract

The current paper describes the development and implementation of an industry/university collaboration in experiential learning. Each individual project in this program consists of the participating student, an industrial mentor, and a faculty mentor. The year long program is designed to offer the participating student the opportunity to participate in a design project at a level which is not possible with the more traditional summer employment. At the same time, the program allows a greater degree of flexibility for the industrial mentor, and provides for more industry/university interaction than often occurs with summer or co-op employment.

1. Introduction

Engineering design is an important component of the undergraduate engineering education. Additionally, workplace experience can provide engineering students with a perspective that is difficult to achieve in either the classroom or teaching laboratory. This paper describes an ongoing program which provides engineering students with both design and workplace experience in the area of manufacturing engineering.

While engineering design is recognized as a key component of engineering education, methods of providing undergraduate students with a significant design experience vary widely among disciplines and faculty. Dunn-Rankin, et. al.[1] state the "design training, though somewhat ill-defined, is crucial to enable graduating engineers to contribute in today's competitive manufacturing environment." A key aspect of this dilemma is that design practices vary by discipline and project criteria. In surveying 47 companies on their priorities in manufacturing engineering education, Mason [2] notes that "the importance of hands-on experience emphasized by the survey is a break from a traditional engineering curriculum."

At the same time, it is recognized that workplace experience is a key factor in enabling graduates in making a successful transition from academic life to engineering careers.

A variety of programs exist for providing this experience, including summer internships, co-op programs, and industry/university educational programs. Cooperative education has come a long way since 1906, the year this unique pedagogy was conceived. Sam Sovilla [3] reviews its history, current status, and the outlook for the future in a paper published in ASEE in 1998. Jeff Meade [4] lists co-op program advantages as increased retention and enhancement of the educational experience. On the other hand, disadvantages are the extra time required by co-op programs, typically one year, and extra cost to the offering institution. Research into the success of co-op placements shows that completed coursework and length of assignment both strongly correlate to the success of the experience [5] .

In the spring semester, 1996, a program was instituted at Clarkson University which provides hands-on experience and engineering design in the area of manufacturing engineering. The program involves Clarkson University and the Aluminum Company of America (Alcoa) at their Massena Operations. The program is designed to provide the benefits of a co-op or summer internship plus design experience specific to students interested in manufacturing.

2. Program Description

The Alcoa/Clarkson Experiential Learning Program is a year long program which starts in the spring semester, spans the summer, and concludes at the end of the fall semester. It is designed for students to begin the program in their junior year. This year (1999) we are also testing a sophomore student in hopes of increasing the work experience for the student and the benefit to the industry. Each student involved in the program has two mentors- an industrial mentor and a university mentor. The student spends eight hours (preferably one full day) at the industrial site per week during each of the two semesters. The program budgets for 20 days during the summer, although this time commitment can be adjusted upward if desired by both parties. During the last 3 years, nearly all students have had the option of working full time for the summer.

The student participating in the program enrolls in a three credit course in each of the two semesters of the program. The first course satisfies an undesignated elective in the student's program, and the second course satisfies a professional elective.

The student/mentor teams meet at the beginning of the program to set objectives. At two points during the course of the program, formal meetings are held to ensure that the program is on schedule and will be successfully completed. At the end of the program, the student presents a seminar on the project as well as a written final report.

The student's primary contact during the program is the industrial mentor. Throughout the program, the student maintains a journal that documents the work performed. It is the student's responsibility to keep the faculty mentor up to date between reviews. In some cases, however, the faculty mentor has needed reinforce this process.

The faculty mentor is responsible for monitoring the project schedule and ensuring that the course objectives are met. Just as importantly, however, the faculty mentor serves as a resource to the student and industrial mentor through the course of the project. This process provides a two way sharing of information between the two mentors, which benefits both parties involved.

Table 1 outlines the participation in the program over the 4 years of it's existence. The program has grown from 1 participant to as many as 6, with 5 engineering students participating in 1999. The disciplines of the students has also expanded, with electrical engineering (EE), mechanical engineering (ME) and computer engineering (CprE) majors having participated to date. In 1999, the program has included an Engineering and Management student in addition to the engineering students listed in Table 1. Also, there is a desire to include chemical engineering students as well in the near future. The growth of the program is a measure of the success of the program from all perspectives.

Table 1. Program participants and engineering majors.

Year	Numbers of participants	Majors of participants
1996	1	EE
1997	2	EE, ME
1998	6	EE, ME, CprE
1999	5	EE, ME, CprE

In a typical program, the students go through an initial period of training and plant familiarization. An initial assignment is made, and the student will work closely with the mentor in completing this assignment, and gaining exposure to the procedures involved in problem definition, planning, design, review, procurement, and implementation. The students then move into a true mentoring situation, taking a lead role in the project under the mentorship of their advisors.

3. Experiential Learning in Manufacturing Engineering

The experiential learning program must be attractive to all participants to continue to exist.

Student perspective At the completion of their year in the program, the student participants have been uniformly positive about their experience. In addition to the design experience, they have noted the benefits in

- Communication skills: The program requires written and oral final reporting, similar to campus based design courses. In addition to this, the students have reported benefiting from developing communication ability with production and maintenance

personnel, vendors, contractors, and management. In fact, these latter communications have been essential to the more successful student projects.

•Standards The students have found the exposure to both company and industry standards to be an important benefit of this program. These include the Occupational Safety and Health Administration's Code of Federal Regulations, National Fire Protection Association standards from IEC, IEEE, ANSI, NEMA, and other such organizations. These codes and standards often represent many years of engineering and research and are the accepted authoritative references for practical applications in the industrial environment. Their basis stems from the same engineering principles being learned by the student in his/her academic training, although specific standards per se are many times not directly addressed in the engineering curriculum.

•Safety training The students receive initial safety training and are involved in ongoing safety reviews throughout the program. Perhaps more important is the emphasis that is placed on incorporating safety considerations in their designs.

•Design Implementation Project implementation has taken a variety of forms due to the differing nature of the projects. In several instances, bid specifications have been required for contractors to perform the installations or fabricate the equipment. In other cases, fabrication was done on-site with materials procured in the design process. The students have been directly involved in justifying their designs and obtaining budgetary approval for implementing them.

•Multidisciplinary teamwork In every case, the students have been involved in multi-disciplinary projects involving a range of engineers, management, technician, operations, and production personnel. These multi-disciplinary experiences have been broader than what is available on campus.

Note that the basic program involves 50 days of on-site work. This is similar in time to the time involved in a summer internship: the difference being that it is spread over a full year. The work schedule on the program accommodates the natural delays in a project which result from meeting scheduling, fulfillment of information requests from vendors, preparation of bid/purchase documents, etc. As a rule, the students have been able to participate in procurement, installation and testing of their designs for the majority of their work.

Industry Mentor Perspective The industrial mentors benefit from this program in several ways. Plant personnel benefit from the program by developing legitimate engineering resources with minimal interruption of normal schedules. New interns require a large amount of training for safety purposes when entering large production facilities. They also require a significant amount of training on the business systems utilized, interfacing with the various personnel and the engineering methods employed at the location. This learning usually requires one on one attention from an experienced engineer on their initial tasks, time not usually afforded to today's plant engineer. By

spreading out the time commitment over a full year it is much easier to schedule this time into a regular year round pattern that repeats every year.

Students can be assigned to assist in large projects or given projects where they hold primary responsibility. Some projects with a lower sense of urgency but of significant importance that may not normally be given attention are ideal for the project. The student performs the necessary engineering development, design and implementation, under the mentoring relationship. Ideally, the project improves production and benefits the plant engineer with the knowledge gains.

In summary, those participating clearly prefer this to a summer internship for two primary reasons:

- The students being on site once a week at the beginning of the program results in their being brought up to speed without placing an undue burden on the mentor's time.
- The productivity of the students is much greater when their time is spread over a full year rather than concentrated in a summer.

In summer internships, the experience has often been that the student is just beginning to work independently when the program ends. Mentors from the Massena Operations site have confirmed these advantages over previous co-op students.

Faculty Mentor Perspective There are several benefits to the faculty who have become involved in the program.

- Improves ties to the engineering community
- Provides exposure to industry problems and practices in the manufacturing area
- Improves the program by providing students with interest in manufacturing better design coursework than is possible on-campus.

4. Unique Aspects of the Program

The Alcoa/Clarkson program has several characteristics which make it unique. A primary aspect of this program is that it is a year in length. From the industrial mentor's point of view, it has an advantage over a traditional summer or co-op program in that it involves a smaller time commitment in the early stages of the program when bringing the student up to speed. While the time commitment on the student's part is similar to a full time summer job, there are advantages to spreading this time over a full year period, allowing the student to get a more meaningful experience. This is due to the time required by vendors and other parties on whom project work is often dependent. The student may initiate several aspects of a job where interfacing with production departments, purchasing, contractors, material suppliers and other engineering resources is required but some time must elapse prior to a response. These factors can limit the traditional summer and/or co-op student to short projects, or preclude the student from participating in the completion of a project.

The program does require that the university and industrial partners be in close proximity, and that the student can arrange his/her schedule to accommodate either a full day or two half days away from campus every week during the semesters. While the twenty day summer commitment is not attractive to all students, there have been sufficient numbers of students who will accommodate this time commitment. The students have spent the remaining part of the summer in a variety of ways, as described in Table 2. The program structure allows for flexibility beyond the 20 day summer commitment, which is particularly attractive to students interested in taking summer courses.

Table 2. Student summer activity beyond their minimum program commitment.

Program year	Total number of students	Worked full time in program	Worked in program plus took class(es)	Number of students who worked elsewhere
1996	1	1		
1997	2	1	1	
1998	6	4		2
1999	5	3	1	1

5. Project Descriptions

The program requires the students to perform significant design during the course of the project. In some cases, students have spent the majority of their effort on a single project, while other students have been involved with several different projects. Brief descriptions of several projects are included to provide perspective on the overall program.

Electrical Engineering Project: Rail Car Heating System. This project formed the primary effort for the student involved. In an existing process, incoming rail cars of pitch needed to be heated prior to unloading. The existing system had both safety and reliability issues. Project planning included reviews involving company operating and engineering staff plus the pitch vendor staff. The design involved adherence to NEC code as well as company safety and operating standards. Cost considerations also influenced the final design.

The second stage of the project involved developing a concept and preliminary cost estimate. In this particular case, initial cost estimates were deemed excessive, and the concept had to be revised. A significant level of effort was involved with showing that the revised concept would satisfy the demand under all weather conditions while meeting the cost objectives.

Following the approval of the revised concept, the design was undertaken. The student undertook a significant portion of the design responsibility during this phase. The design team included the student, the mentor, and a mechanical engineer. The primary issues in the design included:

- Satisfying the power requirements
- Getting the cabling to the car in a safe and convenient fashion
- Providing the control for temperature regulation
- Meeting the National Electric Code requirements

The student was intimately involved in each of these issues. It was noted during this process that the student's schedule of being on site once a week worked very well, by allowing inquiries on product specifications, etc., to be on his desk when he arrived the next week.

Following the completion of the design phase, the student became involved with getting final budget approval for the project. When this was granted, orders were generated for equipment procurement. A particular point where the student was involved at this stage was in the development of the specifications and diagrams for the temperature control cabinet. The final item that the student considered at the end of the program was to develop installation instructions for the personnel who would be involved in installing the new system.

From the faculty mentor's perspective, the project went very well. Regular meetings with the student were held to monitor progress. In this particular case, it was apparent in these meetings that the project included significant design and engineering experience. The reviews of the laboratory notebook and the meetings between the industrial mentor and the faculty mentor confirmed this.

Computer Engineering Project: Lab equipment software upgrade This project involved the upgrade of software for a tensile testing machine. The machine has a proprietary communications interface and operated under locally developed Visual Basic 2.0 program in Windows 3.11. The existing computer system logged and printed test results. Problems with this system included naming limitations requiring cross-referencing, and frequent computer crashes. In addition, the system was connected to an aging print server which was to be discarded in favor of a network connection.

The project included upgrade of the proprietary communications software and operating system, which in turn required upgrading the hardware. Bugs were uncovered in the propriety software, and the student and mentor were involved in lengthy discussions with the vendor to resolve these. The Visual Basic 2.0 program was upgraded to Visual Basic 5.0, a significant upgrade.

The student also worked closely with the technicians operating the equipment, and was able to add several features requested to facilitate their tasks. Additionally, as product

could not be shipped without the completion of these tests, he was required to complete the upgrades with minimal downtime of the system. At the conclusion of the program, the hardware, operating system, and software upgrades had been completed and the system was being used daily. There were some remaining issues with the proprietary software still to be resolved, however. Both the mentor and the lab technicians were pleased with the project results.

Mechanical Engineering Projects: Students worked on several projects in the Massena Operations Plant. Engineers at ALCOA are continuously engaged in improving the smelting process and are responsible for keeping the plant running smoothly and efficiently. Safety is a high priority at ALCOA and students working under this program are given extensive training in OSHA and ALCOA standards to be sure that the project, or the process meets these standards. Noise levels, suspended particles, machine guards and weight limits are just a few examples that engineers and students working with them should watch out for. Following are descriptions of two of several projects undertaken by the mechanical engineering students.

Deformation of Superstructure Legs: Superstructure is located at the top of the pots and is visible when walking down the potline. The superstructure stands above the pot shell (the “pan” that contains the molten aluminum) on four steel legs and houses the alumina feeders. It also holds the electrical components for the anode and is used to keep it at a specified distance from the cathode which is the floor of the shell. The heat generated by the pots over time and the weight of the superstructure will deform the superstructure legs. When the legs deforms, the distance between the anode and the cathode is altered and there is a significant risk that the deformed legs may not be able to support the weight of the superstructure causing them to fail. The existing system that employed a two-ton come-a-long attached to the bottom of the deformed leg and the feeder was considered unsafe for the purpose and a new system was designed. The come-a-long was replaced with a ten-ton pull cylinder with a six inch stroke. The stroke was long enough to straighten the deformed legs and to eliminate the slack between the cylinder and the legs, a 22,000 lb capacity ratcheting cargo strap was used between the legs and the cylinder. The design was supported by calculations using the yield strength of the material with suitable factor of safety.

Shot Blaster Noise Reduction: The shot blaster is used to remove loose material from the used carbon anodes after they are removed from the smelting pots. The anodes are suspended from a conveyor and pass through a U-shaped passageway. The last step of the process before the anodes exit the passageway is the blowing off of any remaining loose material with high pressure air. The combination of airflow and large flat vibrating surfaces of the passage way results in noise which exceeds 80 dB, the allowable noise level. To reduce the noise level to be well within the allowable limit, it was decided to line sections of the interior with vibration absorbent foam. The tasks of determining the amount of material required, establishing the best method of attaching the material, obtaining quotes from vendors for foam that met or exceeded the specifications and ordering the material with the best combination of values were

carried out by the student in the program. As mentioned earlier, students work on several such projects over the co-op term of one year.

These are only samples of some of the projects carried out by mechanical engineering students over the last three years. The Clarkson/ALCOA experiential learning program provides students a very valuable opportunity to gain industrial experience over an extended period of time by working in an engineering department on industrial projects under the direct supervision of a project engineer.

6. Conclusions

This paper describes a novel approach to experiential learning in manufacturing engineering. This program involves a year long effort where an upper level engineering student majoring in electrical, computer or mechanical engineering spends one day a week in industry working on a team that includes a practicing engineer as an industrial mentor and a faculty mentor from the student's academic department. This particular program involves assignments in manufacturing engineering, although the basic program could be used in other areas of engineering practice.

The program offers several advantages over the more traditional summer internship. By extending a similar level of effort over a full year, the student is able to be more productive. At the same time, the industrial mentor is able to interface with the student more effectively without unduly burdening his/her own performance. The program includes several of the most desirable aspects of a co-op program while maintaining a four year program of study. As a result, the program has been judged to be successful, and has been renewed and expanded. It is the feeling of those involved in the program that this program could serve as a model for universities across the country and could be successfully implemented in other locations.

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