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Integrating Research into Undergraduate Coursework to Provide Professional Experiences

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This paper explains how a funded research project was incorporated into a materials technology class to expose the students to real world problems early in their course work. Both construction and manufacturing majors were combined into teams to work on this project and apply their knowledge. The research project was conducted for a local company that refurbished plastic display racks. Damaged display racks were being landfilled and the company was interested in exploring other alternatives. The project was completed in two phases and involved the students from two different semesters. The first class of students identified alternative methods of reducing and recycling the plastics. They also prepared non-air-entrained concrete specimens that contained granulated plastics in various quantities by volume for commercial testing. The next semester's class investigated the effects of replacing specified quantities of aggregate with granulated plastics in air-entrained concrete. The students helped prepare concrete specimens for compression, flexure, and freeze-thaw tests that were conducted by commercial testing facilities. Each semester the students had to analyze the data from the tests and present their findings to management.

Key Words: Field Experiences, Material Testing, Concrete, Plastics, Recycling

Introduction

Field experience is an essential component in the formal education of engineering and technology students (Liedtke, 1994; Liu, 1994; Shapira, 1995; Ward, 1990). Students in these programs are more frequently being required to complete industry internships, professional practice arrangements, or cooperative work experiences to meet the requirements for graduation. These approaches help enhance the curriculum and improve the qualifications of the graduate through real world experience prior to graduation. They help reduce the anxiety and confusion sometimes experienced by graduates as they enter the real world. Often these field experiences can improve the career opportunities of the student or lead directly to employment with the host company.

Field experiences are a valuable part of the undergraduate curriculum and can help students more clearly understand the relevance of their course work through assigned activities in industry. However, prerequisites often prevent students from enrolling in any field experience until their senior year. In order to better prepare students for their professional career it is important to integrate industry-related work at an earlier point in their curriculum. One way to accomplish this goal is to integrate funded research projects into the classroom.

This paper discusses a funded research project that was integrated into an undergraduate course that the author taught. The project involved researching alternatives to landfilling plastics waste for a local company. The firm will be referred to as company "XYZ" for purposes of this paper. The specific name of the company has been withheld to enable honest discussion of the project.

Background of the Project

One of the services company XYZ provides is to refurbish plastic display racks for a larger firm. Used racks are shipped to a local warehouse where the XYZ employees inspect them for damage. During the 1994 spring semester the author was made aware of the fact that company XYZ was landfilling plastic display racks that were beyond repair. At the time of this study, approximately 30% of the display racks were damaged beyond repair and ended up in the local landfill. This typically amounted to about 12 open 30-yard capacity dumpsters of plastic waste per month.

The racks consist of three plastic materials bonded together with an adhesive: polystyrene (PS), acrylonitrile butadiene styrene (ABS), and acrylic. Plastics that are combined together like this are known as commingled plastic. Commingled plastic can consist of a mixture of multilayered bottles, coextruded films, copolymers, thermostats, high-melting polyesters, thermoplastics, etc. This mixed plastic waste component of the post-consumer solid waste stream is the hardest to recycle without innovative technological advances (Ehrig, 1992). Commingled plastics are also the biggest constituent in the post-consumer waste stream. Consequently, this segment of the municipal solid waste problem is ripe with opportunity to solve existing recycling problems. It is also a crucial part of the challenge facing the plastics industry if it is going to meet the EPA's goal of 25% recycling (Rowatt, 1993).

XYZ's management was determined to discover more environmentally conscious alternatives to their present disposal methods. Not only was XYZ concerned about the impact they were having on the local landfill, but they were also faced with collection and disposal costs that were slowly rising.

Preliminary analysis of the problem was done during the spring semester while the author was having students complete several other capstone projects for XYZ. This project appeared to have the potential to be a very practical and plausible way for students in the author's materials technology course to practice the theory and laboratory methods they encountered in this class as well as other course work. The enrollment in this course normally consists of both construction and manufacturing majors. Thus, their backgrounds were consistent with the needs of the project and provided them with an opportunity to experience how people with different areas of expertise need to work together as a team to solve real world problems. Additionally, the project would provide the students with field experience early in their curriculum since this was a sophomore and junior level course.

Contract Proposal

It was agreed that a proposal for funding would first be sent to the Central Illinois Manufacturing Innovation Consortium (CIMIC) and if additional resources were required then company XYZ would provide monetary support for the project. A proposal for $3000 in funding was submitted to CIMIC during the summer. CIMIC agreed to provide $1000 for purchasing materials and to cover the cost of testing a limited number of concrete specimens. CIMIC also agreed to provide additional funding at a later date if the results of the first phase were positive.

Another contract proposal was written during the following semester for the second phase of this project. This proposal called for joint funding by CIMIC and the company producing the display racks. Total funding for the second proposal was $4130.

The contract proposals consisted of several components designed to briefly describe the tasks to be performed, the timeline for the activity, the participants, and the projected budget. The contract for the first phase of the study proposed conducting preliminary research to identify recycling and source reduction methods. It also called for conducting compression tests on non-air-entrained concrete specimens containing granulated commingled plastic. This proposal was submitted through the Technology Transfer Program at the University.

The contract for the second phase of the study proposed using commercial testing facilities and conducting compression, flexure, and freeze-thaw tests on air-entrained concrete specimens containing granulated commingled plastic. Funding was included in the contract to construct flexure and freeze-thaw forms to make the specimens for the tests and for transportation to the testing facilities since one was located approximately sixty miles from the campus. The second contract was submitted through the Office of Research and Sponsored Programs at the University. For this process to occur approval was obtained for the project at the Departmental, College, and University levels.

The Course and Project

The materials technology course is a four credit hour class that meets six hours each week. Two hours each week are used for lecture and the other 4 hours are devoted to hands-on laboratory activities. The major categories of engineering materials (metals, polymers, ceramics, and composites) are covered from a materials science perspective in the lecture. The laboratory component consists of strength of materials activities such as tensile, compression, shear, hardness, flexure, and impact. The students complete the laboratory activities in teams by conducting the tests according to the American Society for Testing and Materials (ASTM) Standards, collecting data, and submitting a report.

In order to allow for the cure time that was needed for testing the concrete in the two phases of this project, the preparation of the specimens had to occur no later than midsemester. Consequently, the recycling project had to be interwoven into the rest of the course. Students were introduced to the major engineering materials and testing methods as before, but with an emphasis on using this information to complete the recycling project. Laboratory time was scheduled to cast the concrete specimens in the first half of the each semester. While the concrete specimens were curing and being tested in the commercial testing facilities the students continued on with the rest of their course work. This forced the students to work on multiple activities at one time similar to what they may encounter in the real world.

Plant Visits

Each semester the author had different students enrolled in class who were new to the project and had to be given an orientation to XYZ company, its operations, and the goals of the project. During the initial visit the Director of Operations for XYZ would describe the plant functions, services, and modes of operations. He would give the students a tour of the facilities, provide handouts and information concerning the company's operations, and discuss the scope of the problem.

Students took notes on the information presented with regard to the scope of the problem. They asked questions of the director with regard to refurbishing methods used to reuse the racks and disposal procedures utilized by the company. The questions ran the full gamut and gave them more insight into the scope of the problem. Students were invited to return to the plant and schedule future meetings with XYZ's management as needed.

The plant tour helped orientate the students to the assigned project and motivate them. It also gave them a better understanding of the expectations of XYZ's management and the author. They began to realize that the classroom extended beyond the University's laboratory and into a company's facilities similar to what they may encounter in their career. It was an attempt to help the students make the transition from the classroom to the real world early in the academic program.

Teamwork

Liu (1994) states that the team approach with three to five students per group is best when working on industry projects. Consequently, the class was divided into groups consisting of approximately four members. The author tried to maintain an even balance of construction and manufacturing majors in each group. The teams were formed by the author in this manner to help guarantee that each group had students with expertise in plastics and construction to provide the synergy required for this project.

When having students work in teams it is important for the instructor to provide support to the team. In the beginning of the semester the author discusses past experiences with the team approach and provides suggestions that can help groups be successful. This can include such things as the importance of good communication among team members and how to function in a group meeting. One of the first things the students are required to do is assemble in their teams and exchange names, phone numbers, and e-mail addresses so they can communicate outside of class time. The group members also share their schedules and identify a time that is convenient for everyone to meet outside of class. Do not assume that just because the instructor forms the students in teams that they are going to learn how to function as an effective group.

Once the teams began work on the project the author became more of a facilitator. Some of the facilitation provided by the author included referring students to appropriate references such as the ASTM standards, scheduling laboratory time for each group, providing tools and materials, scheduling plant visits, etc.

Another support mechanism that can be used is a peer evaluation as a means to keep students involved throughout the project they are assigned. Figure 1 shows the peer evaluation form used by the author in laboratory assignments. It contains six items that the student can use to evaluate their other team members performance. The evaluation form also has a place where the student can rank their peers' performance and write any additional comments they want to make. The ranking of one's peers and listing comments are considered optional components of the evaluation form. However, the students are asked to list each of the other group member's names and rate them according to the six performance items listed. The student adds up the totals for each member rated and writes it at the bottom of the column. The student is instructed to fill out the form in private and submit it directly to the instructor. This helps insure anonymity of each student and a more honest evaluation of their peers. The instructor then makes a subjective evaluation of each student's performance based on the feedback from the peer evaluations.

Peer evaluations can be a motivational tool. They can be a means for students to commend their peers for exceptional contributions or to vent their frustrations about poor performance or a personality conflict that has occurred. Ultimately, the peer evaluation is a means to practice evaluating the performance of others that is something that students will have to do eventually as managers. This is a tool that helps prepare them for that responsibility.

Preparation And Testing Of The Specimens

Company XYZ supplied the class with damaged display racks for the research project. The material was cut into small pieces approximately the size of kitty litter (granules 3-7mm in size) with a granulating machine in the department's plastics laboratory.

In both phases of the project the specifications for making one cubic foot of concrete (non-air-entrained concrete for the first phase and air-entrained concrete for the second phase) with three-quarter inch maximum size coarse aggregate was used as a basis for the batch mix (Kosmatka and Panarese, 1992). The absolute volume formula was used to determine the volume of the concrete and plastic material in the mix.

Calculating the batch mixes with the absolute volume formula gave the students a chance to work with the formula and become familiar with the Portland Cement Association reference. It also gave them a better understanding of the difficulties encountered in specifying concrete batch mixes. Additionally, it challenged them to use analytical and problem-solving skills.

In phase one of the project each team cast 5 standard 6 by 12 inch compression specimens containing non-air-entrained concrete using the quantities of plastic in Table 1. In phase 2 of the project each team cast 5 compression specimens containing air-entrained concrete using the quantities of plastic specified in Table 2. The company that conducted the tests for the students supplied the compression specimen forms. The quantities of plastic used in this study were based on a related study that the department's plastics professor had conducted for a different company using other plastics (Weede, 1993).

The students were instructed to read the ASTM Standards for preparing a laboratory concrete compression specimen (ASTM C192) and for testing the compressive strength of cylindrical concrete specimens (ASTM C39). Each team was required to understand and follow these standards in this project. The importance of preparing the specimens to the ASTM standard was emphasized to the students.

The compression test was chosen because it is the most common quality control tool in the industry (Hover, 1993). It was also a simple and low-cost test ($9.00 each) that fit into the course very well.

In the second phase of the project steel forms for flexure specimens were constructed in the department's laboratory. Two freeze-thaw forms were also constructed in the laboratory and another twelve were borrowed from a commercial testing facility. All the freeze-thaw forms required steel plates on both ends which held and centered a special machined bolt that was inserted into the specimen for testing purposes. Twenty-eight plates were precisely machined on a computer numerically controlled (CNC) milling machine. The department's maintenance supervisor and a graduate assistant, to maintain the precision and quality of work required by the ASTM standards, constructed the forms. Each team cast 3 flexure specimens and 2 freeze-thaw specimens.

The flexure test was chosen because it is a means to determine how concrete will perform in common applications like pavements and floor slabs. Likewise, the freeze-thaw test was chosen for its ability to determine how well the concrete would work in the natural environment.

Table 1

Percentages of Plastics in the Non-air-entrained Concrete Batch Mixes

Specimen Number	**Percentages of Plastics**
1	0% (Standard concrete mix)
2	5% (by volume) of the coarse aggregate
3	15% (by volume) of the coarse aggregate
4	5% (by volume) of the fine and coarse aggregates
5	15% (by volume) of the fine and coarse aggregates
6	5% (by volume) of the fine aggregate
7	15% (by volume) of the fine aggregate

Table 2

Percentages of Plastics in the Air-entrained Concrete Batch Mixes

Batch Number	**Percentages of Plastics**
1	5% (by volume) of the coarse aggregate
2	15% (by volume) of the coarse aggregate
3	5% (by volume) of the fine and coarse aggregate
4	15% (by volume) of the fine and coarse aggregates
5	5% (by volume) of the fine aggregates
6	15% (by volume) of the fine aggregate
7	0% plastic (Standard concrete mix

The department supplied the students with a cement mixer, slump cone, rodding device, and trowels for preparing the concrete. The students to determine the quantity of each material in the batch mix when casting the compression, flexure and freeze-thaw specimens used precise instruments such as a scale and 500 milliliter beaker. Each team was scheduled for approximately 45 minutes to mix the concrete and cast their specimen for a specific type of test on a given day. The students and the author each kept a written copy of the batch mix ingredients used by each team. Care was taken to clean the mixer, tools, and containers to avoid build up and contamination between the batch mixes.

A slump test was completed on each batch of concrete that was mixed according to ASTM C143 (Standard Test Method for Slump of Portland Cement Concrete). The students were instructed to stay within the range of 2 to 5 inches of slump. They also determined the water-to-cement ratio to help determine if the quantity of water used influenced the results. This gave the students practical experience with slump testing and water-to-cement ratios. It also allowed them to see first hand how the water can greatly affect the concrete.

During the second phase of the project an air meter was borrowed from a local contractor to determine the air content in the batch mixes. Six percent was the desired air content based on American Concrete Institute specifications. The ASTM standards were used as a guide for taking the readings with the air meter.

As each specimen was cast, they were marked and tagged for testing. The specimens were stored in a controlled environment in the laboratory for 24 hours and then transported to commercial testing facilities. The compression and flexure specimens were taken to a local commercial testing facility while the freeze-thaw specimens were taken to another facility that had the capabilities to conduct this test. The specimens were placed in a mist room upon arrival for continuous moist curing according to the ASTM standards.

The compression specimens were tested on the 7th, 14th, 28th (two specimens were broken at this time period), and 56th day. The flexure specimens were tested on the 14th and 28th (two specimens were broken at this time period) day. The freeze-thaw specimens were subjected to approximately 350 cycles of freezing and thawing.

The test results were sent to the students on an official report form in the same manner, as they would have been for any other commercial project. Each group had to keep an on-going file of the reports as they arrived. The students were expected to extract information from the reports, analyze it, and compare it with the results of other groups. At the end of each semester they used this information to make a presentation to XYZ's management and write a project report.

Visits To The Commercial Testing Facilities

The students toured the commercial testing facilities each semester during the testing phase of the project. They were given a tour of the facilities and a demonstration of the tests that were being conducted. The management at these facilities also explained the services they provide and how they are involved with the construction industry.

The students were given questions to answer that pertained to the project. They also asked questions of their own with regard to the curing and testing of their specimens. These tours gave them another opportunity to see facilities that they may encounter in the real world and to be better prepared to make their presentation to XYZ's management.

Report And Presentation

At the end of each of the two phases the teams had to prepare a report based on their findings which contained major sections such as the: introduction, objectives/goals, purpose and rationale for the study, procedures, test results, applications and recycling alternatives (including a cost justification and supporting documentation), recommendations for further study, long range plan, and appendices. The presentations were given at company XYZ's facility.

Recommendations were made to the management in the first phase of this project for source reduction of the plastics waste and for recycling. The managers and students engaged in constructive dialog regarding these recommendations. The direction of future research for phase 2 and a long-range plan for the project were also discussed. The management of company XYZ expressed their appreciation to the students for the excellent alternatives that they suggested. They also indicated that they would pursue some of the suggestions such as granulating the plastics, redesigning the display racks, and recycling some of the plastics through injection molding or extrusion. The continuation of the project into phase 2 can be credited to a certain extent to the impressive work that was done by the students in phase one.

The presentations in phase 2 focused on the results of the compression, flexure, and freeze-thaw tests as well as other alternatives that the company might explore since the material failed the freeze-thaw tests. They formally presented the methods of testing and data collection, their analysis of the data, and results of their work using media that included charts and graphs.

Benefits of the Research Activity

It is the author's opinion that the students benefited from this experience in that they were able to apply what they learned in the materials course to a real industrial problem. It was not just another simulation activity in the laboratory. The author encouraged the students to keep copies of their reports and other materials for the project as part of a portfolio for interviewing for a job. This project provided the means for students to bring real world experience into an interview that employers are often seeking in a potential employee.

The students also received the benefit of touring several companies in the process of completing the project. This gave them an opportunity to observe the operations and practices of companies similar to those in which they will be employed. Additionally, the students had the opportunity to network with the management in company XYZ and the companies that did the testing. The students were in a position to impress the management in these companies and perhaps even gain a reference for internships or job interviews.

Completing this research activity also helped prepare the students for their culminating experience that, in the author's department, is either an internship or a capstone course. This activity provided the student with experience that could be expanded upon in either of the two culminating requirements for the author's department. One of the companies even announced that they would be looking for interns during the summer while the class was working on the project.

Furthermore, this project gave the students a chance to receive recognition for their work across campus. The best reports were sent to the University's Honors Office for publication in their journal that publishes outstanding undergraduate scholarship and is circulated throughout the campus.

Company XYZ benefited from the synergy that resulted in this research activity. The students provided ideas and recommendations that XYZ's management had not been aware of prior to that time. As the company begins to implement these recommendations, they should save money and become more efficient in their business. The project also provided research with regard to recycling plastics in concrete that was something company XYZ did not have the time or facilities to begin.

The University benefited from this activity as well. It was a means of providing community service to a company that helps the community and local economy. The public image of the University is greatly improved through this type of service. Most importantly, it is a means for the University to provide high quality education to its students and further advance its programs.

Conclusions

Quite often the majority of the student's preparation for their career is through classroom learning. Liedtke (1994) states "students will best apply that learning when faced with real problems to solve in the work setting". Contracts with industry and funded research projects are both a means to involve students in real world problems while bringing classroom learning to the forefront. These industry experiences can enhance the student's preparation for culminating program requirements and job opportunities.

This research activity provided the students with a vehicle to apply their learning to a real problem in a company. It challenged the students to produce solutions for company XYZ and gave them the opportunity to grow professionally. The students accepted the challenge and company XYZ's management was impressed with their level of performance. This was another example of how students will rise to our expectations when faced with a meaningful challenge. In this case, a funded research project was used as the means to provide the students with opportunities to excel.

Faculty need to continually be creative with regard to involving students in real world activities, especially early in their course work. It is through this creativity that opportunities to excel originate for both students and faculty. These opportunities are an essential ingredient to reducing the culture shock graduates may experience when starting that first job and to improving the quality of the program and its graduates.

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Appendix

Peer Evaluation Form

**NOTE: Complete this form privately. This information will be used to help determine individual contribution Grade and will not be available to anyone but the instructor.

Student Name ____
Group Number ____
Date ____

I. Distribute 17 points to the members of your group (excluding yourself) for each of the following categories. Total points for each category should add up to 17. Higher number points implies more contribution and lower points implies less contribution.

(Alphabetical last name here) ___________

1. Amount of work contributed					
2. Attendance at group meetings					
3. Quality of individual meeting participation					
4. Completion of assigned work within schedule					
5. Quality of assigned work					
6. Individual' value and over all contribution to the group					

II. Rank the members of your group (excluding yourself) in the categories below. Do not place all members in the same category.

1. Best performer (s) ____
2. Good performer (s) ____
3. Average performers (s) ____
4. Minimal performer (s) ____

III. Add any comments you would like to make