AC 2007-782: INDUSTRIAL CAPSTONE AND DESIGN PROJECTS FOR MANUFACTURING AND MECHANICAL ET STUDENTS ALREADY EMPLOYED IN INDUSTRY

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After experience in the army and the aircraft, petroleum, and chemical industries, he began his academic career in 1964 as the founding head of the MET program at the St. Louis Community College at Florissant Valley. As a research fellow he completed his doctorate in engineering at Washington University and then became an associate professor at the University of Petroleum and Minerals in Saudi Arabia from 1972 to 1974. He was appointed as a dean at Wentworth Institute of Technology in Boston, directing a joint project with MIT in Iran, after which he returned to St. Louis in 1975 as the associate dean of instruction. He headed the Department of Manufacturing Engineering Technologies and Supervision at Purdue University, Calumet, from 1978 to 1980. He then served for ten years as the dean of the College of Technology of the University of Houston. After a sabbatical year working on the Relativistic Heavy Ion Collider at Brookhaven National Laboratory, Wolf became the president of Oregon Institute of Technology. He retired from administration in 1998, designated as a president emeritus. He served a sabbatical year with the Boeing Company extending the MfgET program to the Seattle sites and working with PLM software in design and manufacturing. He teaches now in Portland and continues to be active internationally and of service to other universities, industry, and government.

Wolf received his B.S. and M.S. in mechanical engineering and his DSc in structural engineering from Washington University in St. Louis. He is a member of the ASME and of the SME. He is a fellow of ASEE, ABET and the ASME. He has been named a life member of the ASEE and has received the McGraw Award, a Centennial Award, and the Distinguished Service Award. He is a member of Sigma Xi, Pi Tau Sigma, Tau Alpha Pi, Epsilon Pi Tau, and the AAUP.

INDUSTRIAL CAPSTONE COURSES FOR MANUFACTURING AND MECHANICAL ENGINEERING TECHNOLOGY BACHELOR OF SCIENCE DEGREE STUDENTS ALREADY EMPLOYED IN INDUSTRY

Abstract

At the extension sites in Portland, Oregon Institute of Technology bachelor-degree students in Manufacturing and Mechanical Engineering Technology employed full-time in technical positions in industry have since 1999 been doing their senior projects on the job at their places of employment. Up to this time, seventy-three projects have been completed and more than forty employers have been involved in these projects. This approach has proven to be of great value to all concerned. Much experience that has been gained is shared in this paper.

The topics addressed are: The characteristics of the students and the employers who have participated; types and examples of projects performed; faculty visitations and supervision; the development of the relationship between the student, the industrial supervisor, and the faculty advisor; the project proposal-acceptance process; funding of the projects; the final visit; issues and assurances relating to proprietary information and student confidentiality; lessons learned regarding proprietary issues; reportage; and the seminar process.

The paper concludes with a list of the strengths, weaknesses, threats, and opportunities encountered by students doing their capstone experiences on the job at the sites where they are employed.

Introduction

The reasons for industry participation in student projects were legitimized by the National Academy of Science with the statement, "Capstone design faculty increasingly seek corporate sponsorship and involvement in senior projects, recognizing the value for students in responding to "real-world" needs, expectations, and constraints."[1] Recently several fine engineering technology papers have appeared in the ASEE literature on the involvement of industry in senior project or capstone course activities.[2,3,4,5] Those papers address full-time students working with industry on a temporary basis; however, this paper is about part-time students who have full-time permanent positions in industry. The conclusions are mostly the same, except for the added importance of attention to proprietary information and student confidentiality when the projects or on an industrial site.

The Oregon Institute of Technology (OIT) bachelor-degree students in Manufacturing Engineering Technology and Mechanical Engineering Technology (M&MET) at the OIT extension sites in Portland are what have been classified as "degree-completion students." To OIT this means that they transfer into the programs having completed associate degrees or the equivalent from a community college or another four-year institution. And they are normally employed full-time in technical positions in industry while enrolled in the BS-degree portion of their education. Since 1999, most of those students have been doing their senior projects, consisting of three academic quarters, "on the job" at their places of employment.

Last year for the first time the students that entered the degree-completion program were surveyed in order to confirm or set aside our assumptions about their characteristics. Exactly two-thirds of the thirty students responding had associate degrees. Of these students, 15 % of them already possessed bachelor's degrees in some field. While no demographic data was gathered, their ranks included many ethnicities; and two of the participants were women.

Exactly two-thirds of the students surveyed already had full-time jobs; and they were also coming in with substantial amounts of training for the jobs they then held. A little over a third (37%) had obtained corporate training. A small percentage (15 %) had benefited from "specialized" training in the military. And the cohort even included some (7%) who had served significant apprenticeships of over one thousand hours. A good number (41 %) reported having attended some other kind of relevant "specialized school."

As would be expected, the students are people having many responsibilities other than school and who are not in a position at this point in their lives to relocate to a residential campus. The majority (56%) reported having spouses, with 30% raising children. Many (52 %) reported having mortgages, and 41% reported having "other commitments." They are clearly what some would call "place-bound students." Although not of the same thirty-student cohort that was surveyed upon entry, twenty-one degree-completion students graduated at the end of the year from the M&MET programs being discussed herein. This demonstrates that the programs do have good retention characteristics, though that is not the point of the paper.

As word gets out, the two programs have been growing as shown in Figure 1. Ninety-one senior projects over eight years have now been completed. Seventy-three projects were done while the students were employees on the job. In some cases it was as part of the job. In others they were required to do their work on off-time hours. Those students who did not elect industrial projects consisted overwhelmingly of those who could not exercise the option because they were not employed in technical positions at the time. However, there were indeed a few who chose to do their projects at the university site for other reasons entirely. Forty employing corporations and government organizations have now hosted these projects. Those forty employers have included small, medium-sized, and large organizations in just about equal proportions. They have included local and national governmental agencies in addition to industrial employers.

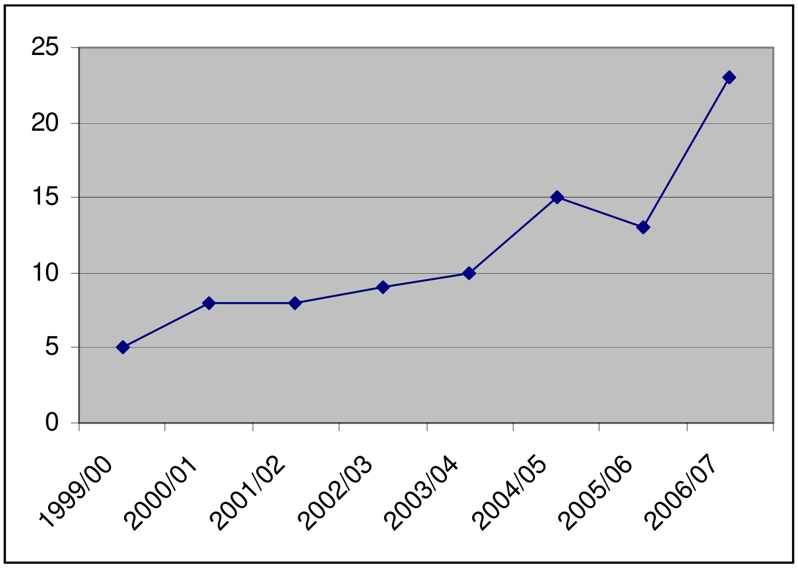

Figure 1. Numbers of Senior Projects by Year.

The Characteristics of the Projects

Virtually any topic is accepted that integrates the use of two or more of the technical courses in the BS-degree program of the student. The students have tackled a broad range of projects. The best way to describe them is simply to give the names of the projects over the last two years without associating them with the students' employers for proprietary reasons. It is obvious from the project titles that designs, analyses, production plans, and studies of a professional level were being entrusted to the students.

The Design and Analysis of Front Frame Reinforcements
The Design of New Mounts for Larger Sleeper Cabs
The Re-Sourcing and Retooling of the Right-Hand Instrument Panel
The Redesign and Construction of a Hospital Laundry Utility System
The Design and Improvement of Test Processes for Optical Projector Engines
Cab Modifications for the *Proprietary* Engine
A Maintenance Time-Study and a Wireless Recording Device for Same
A Pump Station Discharge Manifold Design
The Design, Modeling, and Calculations for a Thermal Sizing Mandrel
The New Hoist Product Line-up: Design, Manufacturing, and Testing Of
The Fatigue Test Development for Saw Chain Cutters
The Evaluation of Material Removal During Sand Blasting
The Development of a Pneumatic Shock Testing Machine
A Dam Maintenance Project
A Dam Cooling Water Piping Modification
Development of an End-Effecter for Automated Wafer Handling
A Quick Response System for Lead-Time Reduction
The Rebuilding of a File Frame Die
The Mechanized Grinding of Parts with Parallel Surfaces
The Design and Implementation of an Inventory Balancing System
The Design and Building of a Prototype Sight Bracket
Reducing Corrosion of *Proprietary* Couplings
The Development of Casting Processes Using a New Pattern Material

Faculty Visitations and Supervision

The first issue that had to be decided was the appropriate involvement of the faculty in the off-site projects. Since these projects are not being done under the direct supervision of the faculty advisor, as is the case with the projects of resident students, their quality and even existence must be demonstrable, at least to accrediting agencies (such as ABET[6] in this case). Much of the project advising necessarily becomes delegated (but not relegated) to one industry supervisor (or more). Therefore, the faculty role involves visitations and the review of reports, although the reportage turns out to be essentially no different from that of an on-campus senior project.

The insertion of a corporate "outsider," in the person of a faculty member, into an industrial project is a sensitive undertaking involving: First, the building of a three-way relationship among the faculty project advisor, the student, and the on-site industrial supervisor; Second, assurances of the preservation of any proprietary information and material belonging to the employing organization; and Third, the preservation of the confidentiality of the student, who is in this case also an employee.

The establishment of the relationship involving the student, the industrial supervisor, and the faculty project advisor begins with the student (who makes the decision whether or not he or she wants to complete the capstone requirement on the job site as opposed to doing a project on the campus). Of the three parties, only the student can invite the faculty member to the job site, and then usually only with the prior approval of corporate supervision. The first several weeks of the term are necessarily involved in the students' working out the necessary logistics and permissions.

To facilitate the process, the term begins with a two-hour group meeting of all the senior project students to make sure that at the outset they, the students, understand all the steps that will follow. This is an interactive group discussion. It provides an opportunity for students to hear comments and answers to questions, their own as well as those of others. The latter tend to be questions that they might not have thought to ask themselves. To facilitate the students' making the arrangements, it is helpful to them if they are provided with a one-page copy of the faculty resume. This enables them to have something to give their supervision about the person the student may be inviting into the company. They also need a list of time slots when the faculty advisor can be available, within which they can plan a range of possible visit appointments. Bosses like to be offered some options.

The purpose of the first meeting on the job site is for the faculty member and one or more members of the company supervision, with the participation of the student, to develop a mutual understanding of the purposes of the senior project sequence, what will be happening, and over what time frame.

Sometimes a specific project is proposed at this first meeting on site. But usually the discussion involves a range of possibilities. For the faculty supervisor to suggest a specific project has some drawbacks; although for the faculty supervisor to give some examples of past projects, like the list provided previously, can be very helpful. It is a good idea to have the requirement that the project actually be done during the dates the student is enrolled in the sequence of consecutive senior project courses. In the event a project, as is often the case, may have a history and/or a future beyond these dates, establish milestones that can occur or can be accomplished while the student is actually enrolled within the capstone course sequence.

It is desirable that a project be selected on the basis of what may be expected of an entry-level engineer or technologist, and that it have a relatively high corporate priority so that it has a low probability of being cancelled or transferred to others. (Such unfortunate happenings could have start-over consequences for the student.) Sometimes it is best also to choose a subject with a rather low level of proprietary information.

It is a faculty responsibility to ascertain at this point whether or not the job site offers the wherewithal and willingness to execute and support the project, although this rarely turns out to be an issue. The companies are generally better equipped and staffed with the expertise for the specific technical activities that are proposed than any educational institution would be. And, they are usually very enthusiastic about supporting both their employees and higher education in this way.

Projects done by students on the job are not funded by Oregon Institute of Technology. They are supported by the employing organization, and it turns out that there is a limited need for the faculty advisor to know the details of those internal processes. Equipment installation or construction projects are examples of projects that might have clear budget lines, since sometimes an appropriation request is an actual part of the project. Other times the project is supported as part of the normal activities of the student's employment unit.

A final visit by the faculty advisor is needed near the end of the last term. The purpose of that visit is, of course, to see the results of the project. Again, this visit must be at the invitation of the student; and the student must make the arrangements. Whether or not the student's on-site supervisor or supervision needs to be there is at the option of the employing organization. At this visit the faculty advisor also reviews the development of the final report, and makes suggestions on the report and the upcoming seminar presentation. It is common for the final visit to be a very celebratory occasion.

Issues and Assurances Relating to Proprietary Information

In order to establish a productive relationship, the company management must be reassured at the outset that their proprietary information will be secure. A faculty member should expect to be offered a non-disclosure agreement for signature at the first meeting. If not offered one, it is a good idea to make sure that the company knows that the university person is not adverse to this formality. It is better to get that out of the way at the beginning so that a legal person doesn't stop things midway in the project. It is also a good practice to inform management in the presence of the student that the second level of control is the on-site supervisor's seeing all reports or other information and materials before the student gives them to the faculty advisor.

Beyond that there are other levels of control that can be brought into play if the need arises. Among those are pink pages in reports that are removed and returned after the advisor reads them in the presence of the student. Corporate managers are best advised that, while intermediate reports are returned to the student after they are graded, the intent is that the final report may be kept in a school file and may be seen by others (including other faculty, students, and accrediting representatives) in the future.

Also, if needed, the final student seminars can be conducted on company premises in the presence of only invited company employees and the faculty advisor. Our experience is that one of these private seminars is opted at the employer's request each year. Sometimes companies do not even want their competitors to know what they are working on. If that is the case, it might be best to remind the employer at the outset that the discrete choice of a project is entirely under their control and to suggest that maybe an alternative project should be considered.

Among lessons learned, there is a need for less and less information in order to make faculty assessments as the faculty advisor becomes more experienced in doing these projects off-campus. In most cases faculty will be offered a plant tour in which everything is opened to them. Industry is generally happy that the university takes an interest in their operations. But, while a complete tour is helpful and appreciated, it is best to graciously accept whatever is offered, even if it amounts to as little as a look through a door window of a facility. However, just being on site, and meeting and discussing the project with company staff is sufficient to determine that the project has indeed been executed. The students and their management usually provide enough photos, diagrams, hardware, test samples, and test data to satisfy the informational needs of an astute faculty advisor (even if he or she doesn't make it beyond an adjoining conference room rather than to the test site itself).

A further lesson learned is that it is better for the faculty member to have the tendency to be the party advising industry not to disclose unpublished business information such as pricing, sales figures, production quantities, materials, or supplier sources even if it is directly related to a project outcome like cost reduction. For example, one might not need to know actual cost figures, just that a reduction was achieved. That way nothing is disclosed; and, in the present market economy, what competitor would not be expecting the company to be seeking to reduce costs?

Issues Relating to Student Confidentiality

The fact that a faculty member is visiting at the invitation of the student for a specific purpose must be foremost at all times. This is not an appropriate occasion for fund raising, recruiting, or other university business development. Faculty might offer to give specific engineering help, but this is best kept strictly pro-bono. Another lesson learned is that such help will rarely be accepted. The companies have staff more up-to-speed on the specifics than most faculty people could become in the time frame of a project.

Faculty should not meet with the student's supervisors except at the invitation of and in the presence of the student. Students need to be reassured of this. Their evaluations should be made only through the normal university grading processes. In most cases the student shares grades with the employer as part of the corporate tuition reimbursement agreement, in which case the university is not a party.

Reportage

Most industrial projects will normally be initiated with a proposal, have periodic progress reports, and have some sort of final documentation. However, industrial enterprises are also human organizations and sometimes time pressures get in the way of their creating a picture-perfect set of reports. In the capstone course, however, it is important to strive to create a complete set of reports.

Originally, whatever report formats were customary were accepted. But, as the number of student participants began to grow, the need for some consistency became apparent. So now students are given a style guide. As of last year this evolved to an e-mailed "template" (including binder specifications, organization, outline, and typefaces) in electronic form. This has been appreciated.

The proposal and the progress reports are graded and returned to the student. All reports are then accumulated as appendices in the final report. The final report is kept as course documentation.

In the project proposal the student needs to give a title to the project, define the participants and necessary signoffs, write an abstract, provide a discussion, establish milestones, include a time line using the milestones, and develop a budget. The project proposal is the basis for the grade in the first course.

One progress report is required. More are encouraged, but rarely are generated. However, students are encouraged to build an internal enthusiasm for their project by sending out spot reports or "nuggets" to those who have a legitimate interest. The evidence suggests that some students learn to do these things; although, like most new technical people, they are a bit shy about it.

The progress reports often include a change in scope one way or the other. Things turn up as the students execute their project. There are unforeseen events. And, they can find that they have been a bit overambitious. So they alter their scope, objectives, and time lines. It's part of the learning process. Progress reports are graded and returned to the student.

The final report summarizes the project and is very important. It contains the other reports as appendices. It is good practice to review the final report as it is developing and, in the final faculty visit, to make some suggestions regarding content. This is also a good time to ascertain whether or not the student is ready for a seminar presentation. Since occasionally the seminar leads to some changes in the final report, the final report itself may not need to be due until after the seminar presentation.

The instructional objectives of the seminar are to have the students demonstrate readiness and ability to deliver a presentation on a technical subject and to field technical questions from the floor. The seminars are presented in the evening in programs of six or seven per night, and are limited to twenty minutes for each person. They are usually cut off at ten minutes to allow for questions. They are video-recorded, as has been requested by ABET visitors in past visits to the university.

All senior project students are required to attend all seminars unless they have a class conflict, which is now common since there are more students than can be accommodated in one night of seminars. The programs are published in advance giving the date and exact time of each student's presentation so that the student can invite family, friends, supervisors, and colleagues. Guests should not have to sit through the entire evening's program. Those who come seem to add a lot to the proceedings.

A Strengths-Weaknesses-Opportunities-Threats Analysis – Or, More Lessons Learned

It has recently become common in industrial settings (and in some academic ones because of this) to conduct a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis of a project. Such an analysis was made of the industrial capstone approach to senior projects for Manufacturing and Mechanical Engineering Technology students at Oregon Institute of Technology, Portland. In summary here are the results of that analysis, manipulated so as to end on a positive note with Opportunities.

Strengths

1. Industrial capstone and design projects are "real," and thus have more credibility than simulated projects.
2. The hosting companies usually have the latest and best equipment and organizational expertise to bring to bear.
3. Industrial capstone and design projects provide for students who have to work full-time what co-op programs provide for full-time resident students.
4. Students get to use the projects to both make a living and to advance their education.
5. Students report having received some visibility and recognition within their organizations.
6. The academic feedback to the institutions about industrial trends is valuable.
7. The bridges between the university and industry are strengthened.
8. There is some similarity to the basic ABET structure in that ABET accrediting teams are deliberately constituted so that half of their members come from industry and half from education.

Weaknesses

1. Academic institutions may be unaccustomed to such close industrial ties.
2. The student needs a technical job to participate, meaning that some may feel left out.
3. Proprietary information must always be secured, which does create some challenges.
4. Employed students have difficulty "teaming" with students having other employers – although employees of technical firms today are on lots of teams within their own employment situations.

Threats

1. The projects are subject to challenge by those in academia who may be unfamiliar with or uncomfortable in the industrial environment.

2. The university must set itself apart from legal liabilities.

Opportunities

1. The university's being closer to industry can lead to many benefits in the future.
2. Industrial capstone and design projects can demonstrate the viability of the academic program in meeting its stated objectives (including those necessary for accreditation).
3. The reportage and the participation of corporate personnel in an industrial project can be useful in university evaluation.

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