THE USE OF INDUSTRIAL DESIGN PROJECTS AS A MEANS FOR INTEGRATING SENIOR ENGINEERING DESIGN AND ENGINEERING ECONOMICS

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ABSTRACT

Strategies for the development and maintenance of university/industrial relationships can take several forms. These include industrial boards of advisors, research contracts, internships, faculty sabbaticals, guest lectures from industry, etc. One strategy that is underutilized is the use of student design teams which complete projects suggested by industry. These types of projects provide opportunities for student/company as well as faculty/company interactions and additionally involve industrial professional staff with the educational process.

In recent years the author has developed student project activities with industry in senior design courses. These projects have been very successful in building positive relationships with numerous companies. For example, the capstone course, SYSTEMS DESIGN, requires that each student team start with a general design problem suggested by a company. The team then carries the project through the Problem Definition, Conceptual Design, Embodiment Design, and Detail Design phases. During the embodiment phase each team is required to evaluate their proposed design with respect to economic considerations. Depending on the proposed design solution and on the preferences of the particular company, the economic measures of benefit/cost ratios, return on investment, internal rate of return, or simple payback are used to evaluate and compare recommended design proposals.

The student experience of working with actual companies on real problems and being forced to justify their design proposal on an economic as well as a technical basis has been an excellent strategy for learning engineering economics. The methodology for selecting and administering these industrial projects will be presented.

INTRODUCTION

Industrial/Academic partnerships are essential for technological development, regardless of the discipline. The purpose of this paper is to show how student design projects furnished by industry cultivate this partnership and benefit both groups. The basic concept is to use actual "real world" problems suggested by companies for student team design projects which are a required component of senior mechanical engineering design courses. An essential consideration for a successful solution to any real world problem is, of course engineering economics. In addition to technological feasibility, the solution is not complete until the economic feasibility also has been established. In the Mechanical Engineering Department at Rose-Hulman Institute of Technology, all senior students are required to work as members of a team on a design problem furnished by industry and these projects are selected in order to maximize the student teams opportunities to explore, not only the technical feasibilities of their recommended deigns, but also, the engineering economic implications.

Different companies use different economic measures to compare alternative strategies for problem solving. Benefit/Cost ratios, return on investment, internal rate of return, and simple payback are typical approaches used for economic evaluations and comparisons. Arguably, some of these approaches are overly simplistic and lack accuracy but if a company has a history of use with, and is comfortable with, a particular approach, then they will insist that the student teams also use that measure. Usually in a student team's final report to "their" company, they will recommend one or more strategies for solving the design problem. Each recommendation is then presented along with it's appropriate economic projection. The "Do Nothing" option along with its costs is also usually presented and the students realize that sometimes this is the preferred strategy.

The experiences in the Mechanical Engineering Department at Rose-Hulman have been considered to be successful in providing all seniors experience with

- real world industrial projects,
- team building and people skills,
- the methodology of design,
- project management, and
- applications of engineering economics.

It is hoped that the following discussion of the procedures for the planning and the administration of these project design courses at Rose-Hulman will assist other institutions in realizing the same benefits.

PROJECT PLANNING

The two most important aspects of a senior design course are to learn the methodology of design, including engineering economics, and to gain design experience. The methodology can be learned in the classroom but the experience is best gained by completing actual projects, preferably as a member of a design team. These projects can be chosen by the students, i.e. something they're interested in, or they can be created by the instructor. But, there is a better way.

At any given time all companies with an engineering staff are faced with design problems of various degrees of difficulty and with a large range of priorities. Many of these problems, which the engineering departments fully intend to address eventually, but may not have the highest priority, are excellent design projects for student teams. It is just a matter of making the industrial contact and then matching their problems with student projects. Plant visitations, letters of invitation, calls to alumna, etc., are all appropriate strategies for initiating industrial contacts.

Not all industrial problems of course are appropriate for student team design projects and it is here that the instructor must <u>screen</u> the proposed projects very carefully. The following questions need to be asked and discussed with the industrial contact before a project is approved.

* <u>Is the scope of the project of appropriate length?</u> The time required for the estimated completion of the project should match as nearly as possible the length of the quarter or semester. Projects that structured to run for longer than one quarter or semester can have advantages if they are carefully conceived. However, not all projects will run smoothly and maintain student interest and therefore it is usually of greater educational benefit to have two shorter projects rather than one longer one. It is frustrating for all concerned to commit to a long term project (2 or more quarters) and then determine that, for no one's particular fault, the project "dead ended" prematurely or became undesirably redirected. It must be kept in mind that the overall objective is to maximize student design experience and that is usually accomplished by the completion of more, rather than fewer projects.
* <u>Is there a reasonable expectation of the project's successful completion?</u> Clearly some design projects will require a degree of expertise that is beyond that of the typical engineering senior. It is the responsibility of the instructor to select topics that are matched to the students' professional level.
* <u>Is the proposed project really a "design" project?</u> Perhaps the company is just looking for some specific "analysis". It is tempting for a company to agree to suggest a design project when in fact what they want are specific answers to some analysis problem. In these cases the students just do what they're told and do not benefit from experiencing the open ended design process. * <u>Is there opportunity for student management of the project?</u> The student teams must be allowed to manage themselves and thus maintain "project ownership." The industrial contact and the instructor must restrain themselves from dictating the project direction even when they feel that would be more efficient. The degree of guidance requires considerable judgement on the part of the instructor but in order for the students to gain this valuable design management experience, they need to be allowed to develop their own design decisions. It should be obvious that this strategy is only possible when projects are on a "no-fee" basis. Company reimbursement for student travel to plant facilities is, of course, expected.
* <u>Is there opportunity for economic decision making?</u> The proposed industrial problem should be such that costs of the present situation can be reasonably evaluated. It is also necessary then for capital and annualized costs of proposed solutions to be able to be approximated.
* <u>Does the project have the potential for benefiting the company?</u> Usually a company is looking for some fresh ideas or new approaches to their design problem. Not all student projects will result in design breakthroughs but each one should present some new ideas in a rational, well thought out, format that will be of benefit.
* <u>Will the students' design education be benefited by their interaction with a company's engineering staff and by their visiting the company facility?</u> A visitation to the company at the

beginning of the project is important to getting the project off and running and in providing student motivation. Continued interaction with the company "contact" during the project is essential and should be expected.

PROJECT ADMINISTRATION

At Rose-Hulman the two design courses that use company suggested projects are Machine Design and Systems Design, both senior courses and both four quarter hours credit. The company design project represents 50% of the course grade in both courses. The enrollment in each course is approximately 100. The remainder of the discussion in this paper will be directed toward the SYSTEMS DESIGN (SD) course since that is where engineering economics is emphasized.

Once a company with an appropriate project has been identified, the company is asked to provide a "contact" person for the students to communicate with during the duration. The company is also asked to invite the student design team to meet with them at their facility.

In the SD course, the projects are somewhat broad in scope and the teams usually have five members. The selection of the teams is made by the instructor and this has been found to be an effective procedure. The students are reminded that in industry engineers are assigned to groups and are assigned projects and that an essential skill that they must learn is teamwork on projects and with others not necessarily of their choosing.

Each project team in the course, (typically 18-20 teams in SD) meets with the instructor once a week at a pre-arranged time and submits a written status report. The company contact may also request weekly status reports. Formalized design methodologies are required. (See for example Paul and Beitz [1] or Dekker and Gibson [2].) Basically this process is 1) <u>Define the Problem</u> in its broadest form, 2) <u>Conceptual Design</u> or identifying alternatives, 3) <u>Embodiment Design</u> or configuring the most likely candidate solution, and 4) <u>Detail Design</u> or completing the recommendation.

Oral presentations and final written reports are required of each design team in each course. Additionally, many of the companies invite the teams to their facility for an in-house briefing. Both oral and written reports are required which contain a final economic analysis of the solution(s) recommended. Again, these economic summaries will be in the form requested by the individual company. The students soon learn that there is no universal method for presenting costs or making economic comparisons. By this time they are familiar however with the concepts of present worth, future worth, capital, and annualized costs, etc., and certainly have become aware of the importance of engineering economics in formulating solutions to design problems.

EDUCATIONAL BENEFITS

In addition to experience in project definition, development, and management, there are other important benefits to the student in completing industrially sponsored projects.

* "<u>People skills</u>" is an attribute that companies place emphasis on in hiring entry level

engineers. These types of projects are excellent in providing opportunities for students to build these skills. In addition to working under pressure with classnotes toward a common goal, the students must also interact with their industrial contacts.

* An exposure to "real world problems" is an opportunity provided by these types of projects. After the initial plant visitation and the discussions with company engineering staff, students invariably return to campus with feeling that they have an opportunity to contribute to an actual problem. From experience it can safely be stated that their motivation is higher than it would be on project topics they have chosen and definitely higher than it would be on topics created by the instructor.

* Applicatons of the concepts of engineering economics to real world design problems from industry.

* The development of new job opportunities is made possible by student/company contact. It is not unusual for a graduate to obtain employment as a result of his or her experience with a company-sponsored project.

* Faculty have the opportunity to learn more about contemporary industrial problems. Educators need to take advantage of every opportunity to stay in touch with the types of design problems faced by industry.

INDUSTRIAL BENEFITS

In addition to the many implicit benefits that industry realizes in working with academia on student projects, there are also some very direct payoffs.

* Many of the student design projects recommendations receive quick implementation. The projects that they suggested were actual problems that they had and that they needed solutions for. They actually "contracted" out a task and received a deliverable in the form of a report even though there was no fee involved. Student recommendations that are not immediately implemented are usually still beneficial for the fresh and unbiased response from "outsiders" to an internal problem.

* Companies have an opportunity to work with young and energetic engineers and develop long term contacts, and even to take advantage of the hiring possibilities of these entry level engineers after seeing their performance.

* Relationships that these project activities foster allow industry to have an impact on curricula. As practicing engineers learn more about recent educational trends and requirements they can suggest and influence activities the undergraduate programs.

CONCLUSIONS

Industrial/academic partnerships are essential in our growing technological society. In this paper the author has described how this partnership has been enhanced at Rose-Hulman Institute of Technology through required student design projects which are furnished by specific companies. The benefits, both to Rose-Hulman and to the individual companies, have been well established and have been discussed here. In particular one educational benefit these projects have provided has been the opportunity for students to apply the concepts of engineering economics to actual industrial problems and to present their results in formats required by the companies. Although the advance planning and organizational efforts required for organizing these activities are substantial, they are considered to be justified. It is hoped that the positive experiences with student projects described here can be effectively implemented at other institutions.

REFERENCES

[1] Paul, G. and Beitz, W., Engineering Design: A systematic Approach, Edited by Ken Wallace, Springer-Verlag, The Design Council, 1988.

[2] Dekker, D., and Gibson, J.D., "Learning Design in a College Setting", International Conference on Engineering Design, Tampere, Finland, August, 1997.

BIOGRAPHICAL INFORMATION

J. DARRELL GIBSON is a Prof. of M.E. at Rose-Hulman Inst. of Tech., where he teaches design. He also teaches Noise Control and Structural Analysis. His BS and MS are from Purdue in Aero Engineering and his PhD is from the Univ of New Mexico in M.E. He has also been an Associate Professor at the Univ of Wyoming and a Visiting Professor at Colorado State. His industrial experience includes General Dynamics Corp., The J.I. Case Co., SandiaLabs, NASA/Langley Research Center, and NASA/Jet Propulsion La.