The Design and Manufacturing Clinic: Bringing Industrial Projects into the Classroom

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Abstract

For over a decade capstone design courses and other project related courses have implemented projects that have roots in industry. This was done on an informal basis between professors and contacts in industry. This process lacked consistency in that some projects would be repeated from previous terms or projects would be completely defined by faculty with no input from industry. With recent findings (1,3,8) from various technical societies, agencies and boards it was recommended those industrial projects be addressed by teams within the curriculum.

In 1996 a Design and Manufacturing Clinic was established at the University of Dayton for developing formal contacts in industry for the purpose of implementing team based projects in the curriculum. This paper will address the evolution of the clinic and the procedure for bringing industrial projects into the classroom. Major issues to be addressed will be:

1. The need for experiential learning and the importance of solving practical problems that are grounded in industry.

2. The organization of the clinic which includes the role of the advisory committees. The Council on Design and Manufacturing represents faculty input. The Design and Manufacturing Advisory Committee provides a vehicle for input from industry.

3. The roles of the industrial and faculty mentors during the project.

4. The "Design Project Agreement" a (legal) document that specifies the major phases of the project as well as a non-disclosure agreement. This also outlines the commitment of the clinic to provide specific deliverables to the sponsors, including oral presentations and written documentation.

5. The development of the budget and project fees.

To supplement the above, examples will be presented to show the diversity and interdisciplinary nature of the large number of projects that have been implemented.

I. Introduction

In order for companies to be competitive in the global marketplace, efficient design and manufacturing processes must be implemented. A shift from "traditional design" and manufacturing methods has been made where these functions have gone from a sequential process of design followed by manufacturing to concurrent engineering practices characterized by interdisciplinary product development teams. A number of scenarios have been recommended (1-5) which has culminated in the Product Realization Process (PRP). This process emphasizes the team approach to the engineering design and manufacturing function. This process, covered in detail later in this report, involves establishing "customers needs, developing specifications, designing the product as well as its production and support processes, and operating those processes". (1)

Embracing the principles of the product realization process provides the basis for the development and implementation of industry sponsored projects within the curriculum (6). It is important that engineering students supplement courses that concentrate on theory and analysis with experiences that demonstrate the application of the theory and analysis to real problems. An anonymous proverb states that "Tell me and I will forget, Show me and I will remember, Involve me and I will understand, Step back and I will act."

Experiencing engineering involves "solving a problem that has a practical 'consequence'". (7) These problems cannot be effectively delivered by a faculty member but require a problem from industry that has a mentor. "Industry must be committed to the problem; it must matter to them and they must want and expect it to be solved." It is also emphasized that these problems combine "substantial and continuous industry interaction (including weekly on-site activities by the students), formalized instruction in design methodology, and intensive faculty oversight".

Terry Shoup states in the publication "Innovations in Engineering Design Education" (1) that "Improving design methodology has been recognized as the single most essential step in industrial excellence and national competitiveness of U.S. products". With this background it is "evident that engineers in both industry and academia share the responsibility for improving engineering design and manufacturing processes. We in academia have the responsibility to provide instruction to and experience for our students so that graduates that choose engineering design as a career path are prepared to function in an environment that will provide the most competitive products.

What do employers want from engineering graduates? A survey led by the American Society of Mechanical Engineers (8) lists the characteristics engineers in industry believe graduates should possess. In addition, companies employing engineering graduates have presented their thoughts regarding these characteristics (9). In summary the characteristics are:

1. Technical competence is a given.
2. Teams/Teamwork
3. Oral and Written Communication
4. Collaboration

5. Leadership
6. Customer Focus
7. Professional Ethics

It is clear that companies are looking for more than someone that has just a good GPA. They want individuals that are broadly educated and can function effectively with others, especially in a team environment. This has also been emphasized in the revisions to the Accreditation Board for Engineering and Technology (ABET) guidelines. Comparison of these characteristics and the opportunities available from industry sponsored projects indicate that significant achievements can be obtained through industry collaboration.

This paper will address how a central project organization within a school of engineering is organized and how it seeks and assigns industry projects throughout the curriculum. The project is conducted using the sequence shown in Figure 1.

II. The PRP, Industry and the Curriculum

In presenting the concept of experiential learning to industry mentors, faculty mentors and students it is important for everyone to understand the framework within which the project will be conducted. Because of the length of the term (semesters or quarters), various institutions will handle projects differently. Since our institution is on a semester system and since many of our students pursue co-op it was decided to break the projects into one-semester modules. Many one-semester projects will involve establishing specifications, conceptual design, detailed designs and final designs. (Figure 2) This concludes with a final written report. (10)

In some cases an initial project will conclude with the final design phase. This includes a final report, a final oral presentation and a complete set of drawings for a design project. If the customer so desires, such a project could be extended by a new team that may or may not include some of the original team members. They address design modifications and fabrication of hardware.

III. Clinic Organization

The Design and Manufacturing Clinic resides in the School of Engineering and is headed by a coordinator who reports to the Dean of the School. The coordinator is a full-time member of the faculty who teaches a full course load. Input is received from a number of sources: The Council on Design and Manufacturing, The Design and Manufacturing Advisory Committee, faculty who have agreed to incorporate projects into their courses, and faculty mentors.

Coordinator

The clinic is led by a full-time member of the faculty who has a dual role, teaching and administration of the clinic. It is an asset that the teaching function involves venues where clinic projects can be implemented. Roughly, eight months of the year are devoted to teaching with administration of the clinic being an administrative type function. During the summer, the coordinator devotes nearly full-time to the administration of the clinic. A part of the fee charged to companies providing clinic projects goes toward the part-time summer stipend. The dual appointment represents an equal proportion of teaching and administration. However, funding of the activities is not equally balanced.

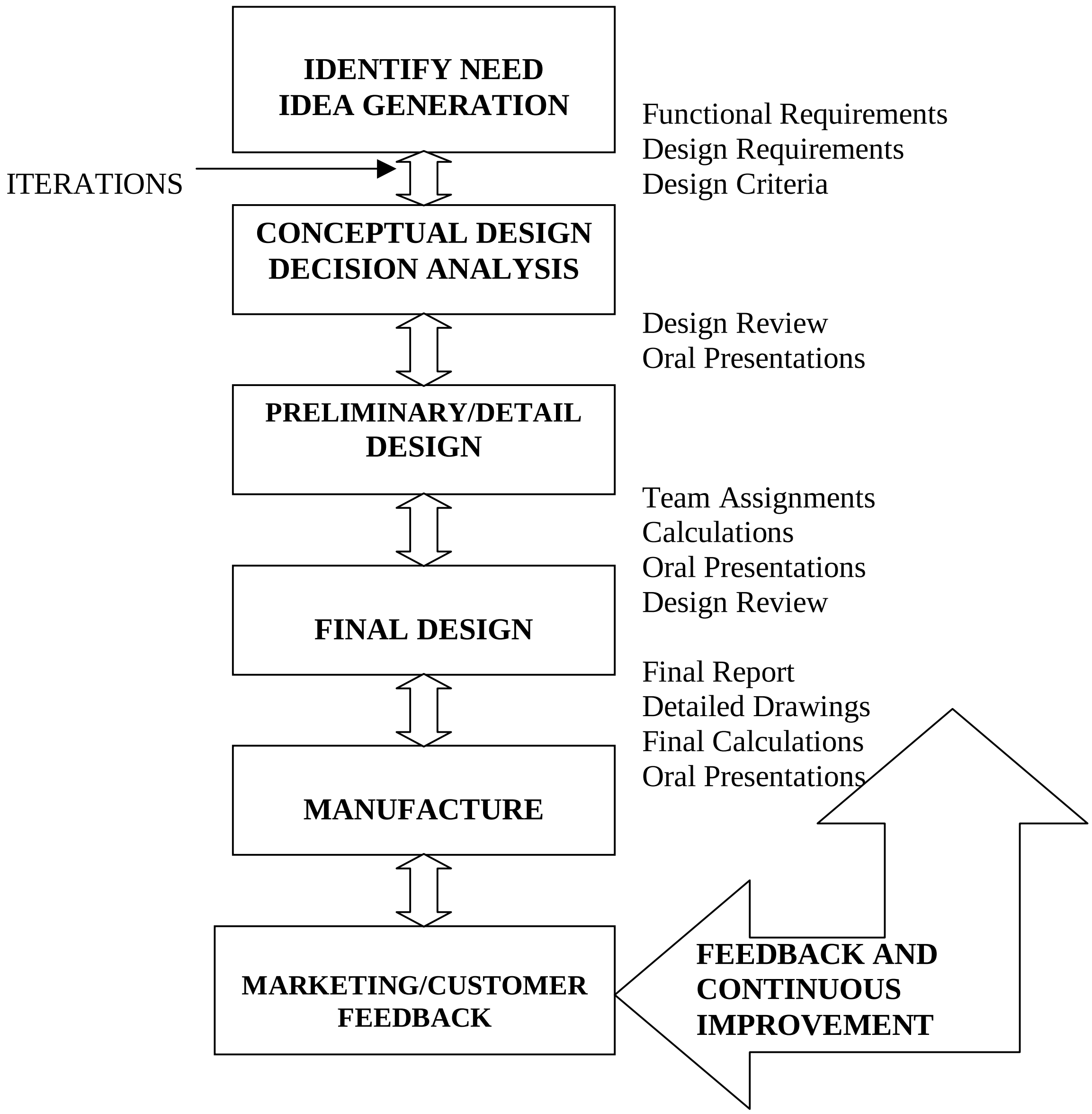

Figure 1. The Product Realization Process in a Design Course

Figure 2. Gantt Chart and PRP Schedule

	SCHEDULE			
Activity	**Month 1**	**Month 2**	**Month 3**	**Month 4**
Establish Need Select Project Functional Req. (1) Design Req. (1) Design Criteria (1) Identify Deliv. (1)				
Conceptual Design Dev. Ind. Concept (1) Team Req. & Crit. (2) Ind. Decision Anl. (1) Team Decision Anl (2) Oral Presentation (2) Dev. Gantt Chart (2) Submit Designs (2)				
Detail/Prelim. Design Evaluate Sponsor Feedback Revise Team Dec. Anl. Determine Feasibility Initial Calculations (1) Develop 3 View Draw. Develop Parts List (2) Identify Req. Calcs (2) Submit Detailed Des(2) Oral Presentation (2)				
Final Design Select Components Design Components(1) Perform Analysis(1) Cost Estimate (2) Engineering Dwgs (2) Write Narrative (2) Assemble and Submit Final Report (2) Final Oral Pres. (2)				

Activities of the coordinator include:

1. Liaison with established companies
2. Cultivation of new opportunities with new companies
3. Participation in presentations and visits for all clinic sponsored projects
4. Development of project agreements for all projects
5. Work with faculty mentors and lead professors of courses having projects to assure that goals, objectives, responsibilities and deliverables are clear
6. Invoicing project sponsors
7. Liaison with Development Office to visit new clients
8. Provide regular status reports for Dean and Development Office
9. Formal presentations to potential clients and visitors to campus
10. Chair of the Council on Design and Manufacturing
11. Call and write minutes of the Council meetings (6-8 per year)
12. Inform members of the council and other faculty of project opportunities
13. Member of the Design and Manufacturing Advisory Committee
14. Call and organize meetings of the committee (1-2 per year)
15. Approve funding allocation for purchases for student projects
16. Organize files for final reports written by students and send completed reports to sponsors
17. Establishment of the budget, including income, and expenditures
18. Focal point for companies and individuals seeking to sponsor projects
19. Develop publicity brochures and work with PR office for development of articles
20. Conduct surveys and assessment of projects with industry and faculty mentors
21. Seeking faculty mentors and instruction mentors on procedures

The Council on Design and Manufacturing

The Council on Design and Manufacturing is made up of nine members of the faculty from departments that regularly implement sponsored projects. This includes mechanical, electrical, civil and chemical engineering, engineering technology, psychology (ergonomics and human factors), business administration (MIS) and fine arts (industrial design). Members of the council act as a liaison to provide a conduit to the departments. They solicit projects and seek venues (courses) for conducting the projects.

Periodic meetings with the council are held to discuss the following:

1. Areas (design, manufacturing, marketing, industrial design, and community service) on which to focus to seek projects
2. Ways to improve communication to effectively allocate projects
3. Procedures to be used in the administration of the clinic
4. Review of financial data including budget, income and expenditures
5. Recommend establishment of policy, especially project fees
6. Recommendations for contacts and companies for projects

Members of the council serve as the “go to” people for the clinic coordinator. Questions regarding both policy and projects are brought to the attention of the council members.

The Design and Manufacturing Advisory Committee

The advisory committee is made up of individuals from industry that provide input from an external perspective. The committee is made up of upper level executives through middle managers from large and medium sized companies. The size and composition of this committee requires a delicate balance to assure that not only is there a proper mix but also a size that is workable. In general the composition of the committee should be as follows:

1. Size of 5-8 members provides the best dialogue in meetings.
2. A mix of individuals that represent various phases of the design and manufacturing enterprise.
3. Members should be people that can “make things happen” within their own companies and through their contacts in the region.
4. Members should be able to provide at least one project for each member per year. (In one case we receive about 5 projects from one member’s company)
5. Small, medium and large companies should be represented
6. All members of the committee should be at least managers that have a good knowledge of technical issues, have some budget control and are in a hiring position.

Industry Mentors

Industry mentors are assigned to the project at the outset and follow it through to completion. In nearly all cases the industry mentor is someone intimately familiar with the project or problem and may also be the person that proposed the project. It is estimated that the industry mentor may need to spend between 20 to 60 hours during the semester interacting with the project team. Some of the responsibilities of the mentor are:

1. Provide the initial description of the need for the project.
2. Provide answers to the group at the outset of the project.
3. Review the specifications of the project and determine if the student team has adequately defined the functional requirements, design requirements and design criteria.
4. Attend and/or arrange for a venue for the oral presentations (3).
5. Obtain information as requested by the student team. The student team will assign one person to be the liaison so that the industry mentor will not receive multiple inquiries from the same team.
6. Provide detailed drawings of components and products and possible vendor information
7. Escort the student team to the job site when needed (usually three times each project)
8. Handle administrative aspects such as signing project agreements and the project purchase order.

Faculty Mentors

The role of the faculty mentor will vary from class to class. In some cases the faculty mentor will be the person teaching the lab or course and will be consistently available for consultation for the students. In some cases members of the faculty are asked to participate in classes that they do not teach. In this case the mentors are expected to maintain regular contact with the students. This later case provides some challenges. Clear lines of communication need to be established and a regular meeting (weekly) between faculty and students is required. Some faculty have been assigned as mentors and nearly never take the initiative to meet with the students, instead relying on the student team or the faculty responsible for the course to facilitate communication. The student team may have difficulty following the right path when the faculty mentor takes a passive role. The bottom line is that the faculty mentor should do whatever is necessary to assure that the team stays on schedule and is successful in providing the agreed to deliverables. It will not take many projects that do not meet their objectives before companies will no longer supply projects.

The incentive for the faculty to mentor projects is that one-third of the approximately $3000 charged to industry for the project is assigned to them to use as they see fit (new equipment, travel funding, etc.). There is a stipulation that this is not to be used for salary or personal payment. As identified by others that have managed similar operations, this is perhaps one of the weakest links in the system. Even though a faculty mentor may subscribe to the need for these projects there is usually little personal benefit from these projects. (No increase in salary, no financial compensation, little opportunity to publish, etc.)

Some of the responsibilities for the faculty mentors are:

1. Provide technical guidance to students for obtaining needed theoretical or applications information.
2. Work with students to establish a plan, identify deliverables and develop a schedule.
3. Follow up with students to assure they are on schedule and will meet deliverables.
4. Assist in preparing students for oral presentations.
5. Understand the context within which the projects must be performed.
6. Ask questions.
7. Serve as a guide on the side for document preparation and scheduling.
8. Provide ideas after students have had a chance to develop concepts and brainstorm.
9. Provide feedback regarding presentations and general progress.

It is important to repeat that the faculty mentor is one of the keys to a successful project. Although the mentor is not expected to do the work he/she is expected to be the “guide on the side” to make sure that the goals and objectives are being met and that the project is brought to a successful completion.

IV. Project Venue

In general the project venue will be an established course in the curriculum. A "full" project that includes most of the components of the product realization process could best be implemented in a three credit hour course in the curriculum the primary focus of which is the project. Some planned learning could also be included in the course that addresses the PRP and or specific technical subjects that would enhance the performance on the projects.

The Course

Projects have been implemented in various types of courses. Besides projects incorporated into a standard three credit hour course, in some cases projects have been successfully implemented in 1 or 2 credit hour laboratory courses (attached to other courses like design of machine elements) in which the students meet several times each week. In these cases most of the laboratory is spent on team activities related to the project.

Other venues could include experimental laboratories where both fabrication and experiments are performed. Depending on the course it has been observed that the total amount of time spent per student on a project throughout the duration of the term will vary from 80 to 160 hours. When a laboratory course is involved it can be expected that the amount of time spent out of class will be greater than or equal to the amount of time spent in the class. Thus if a lab meets for 3 hours per week in a 15-week semester a total of 90 to 120 hours could be expected to be needed to successfully complete the project.

Grading

Because this is a team project there are various methods used for calculating the final grade on a project. The simplest approach is to grade the project and give the same grade to everyone on the team. This permits "slackers" to ride on the coat tails of the rest of the team without meeting team commitments. Another approach that combines the individual efforts along with the team result to provide varying individual grades is outlined in reference 9. Here there is a combination of grades for team and individual assignments along with a final project grade that is weighted according to individual efforts as measured by members of the team.

Project Agreement

One of the largest obstacles in implementing projects has to do with intellectual property rights and non-disclosure of information on projects. The first time this was addressed involved an industry sponsored project in which a non-disclosure agreement was signed. Since that time a project agreement was developed that includes many facets and has been widely accepted by sponsoring companies, faculty and students. The major parts include:

1. Definition of the parties involved
2. The specific course in which the project will be implemented

3. Establishment of formal presentations and communication requirements
4. The transmittal of drawings, data and samples by both the sponsor and the university
5. The procedure for arranging visits
6. Non-disclosure of information – permission to disclose
7. Submission of final reports
8. Publication of findings and results at meetings or outside the university
9. Disposition of discoveries and applications for patents
10. Project fees
11. Disclaimer and responsibility for results
12. Arbitration of any dispute
13. Signed agreement of sponsor, faculty, coordinator and students

In essence, all results are the property of the sponsor for a period of six months. After this time has expired the university, faculty and students are free to present papers, apply for patents with some limited permission from the sponsor. If any of the parties involved do not wish to abide by the agreement then alternatives are sought. If a student is not in agreement then they will be placed on a team that is working on a project that is not sponsored by a company.

The agreement described herein was developed over the period of a year with input from faculty, members of the council and advisory committee, the dean and the legal department of the university.

Benefits of the Program

These projects and in particular the clinic program were started to be a win-win situation for the company sponsors, faculty and the students. A big step has been taken and this is happening. In particular the following can be noted:

1. Industry sponsored student projects provide students with the experience required by companies as outlined in the introduction. This experience includes application of science and technical principles, participation in engineering teams, opportunities for oral and written communication, collaboration, leadership opportunities and a focus on customer needs and requirements.
2. Students appreciate that the projects are real and that there is a high probability that the results will be implemented or used.
3. Industry has an opportunity to have back-burner projects addressed including a fresh look at approaches to problems.
4. Students have an opportunity to look for unique solutions and “think outside of the box”.
5. Students gain an in-depth exposure to industry and industry to students.
6. Faculty and students expand their knowledge of design and experience the design methodology.
7. The connection of industry with faculty and students provides a networking opportunity for exposure and employment.

Assessment of the Program

Assessment is conducted both formally and informally throughout the university. Surveys of students both before and after graduation indicate that they felt that as the result of industry sponsored design projects that they were better prepared to obtain employment and function effectively in a business and industry environment. The results in the area of oral and written reporting improved significantly. It was also reported that there was an increase in the student's ability to find creative solutions to engineering problems.

Many projects have an assessment performed by the industry mentors. A vast majority reported the following:

1. The results of the project would be of significant benefit to their organization.
2. The results of the project met their initial expectations and that the students either attained or exceeded the goals outlined in the original proposal.
3. They felt that the students benefited from the interaction with the mentors.
4. In most cases the communication was adequate between the students and mentors.
5. The three oral and written presentations were professional and were at the same or higher level expected of engineers at the sponsoring organization.

Conclusions and Recommendations

Initially, there were some start-up problems in convincing industry representatives that this was a win-win situation. However, once we "got in the door" and performed, more projects were proposed by the same company. Several successes were turned into examples that encouraged other organizations to participate. In the two and one half years that the clinic has been in operation 70 projects have been implemented and completed in 10 courses that have been sponsored by 24 industries and businesses. In the latest semester there were 27 projects that were proposed with 14 finding homes in the curriculum.

Members of the Design and Manufacturing Advisory Committee are excited about the progress made thus far, indicating that the clinic has far exceeded the initial expectations when the clinic was established.

The maximum number of projects that can be implemented in one term is approximately 15. This limitation is based on the number of courses accepting projects and on the staff that is able to effectively monitor and administer the technical and financial activities.

The advisory committee has recommended that we keep this at a steady state for the near future rather than attempt extended growth. It is the preference of the committee and the administration that we concentrate on doing the job well rather than expanding beyond our human resources.

The clinic has met the initial mission as established by the original School of Engineering vision and plan. The infrastructure is in place and we are providing very good opportunities for experiential learning.

It is recommended that more opportunities and venues be established to make the projects more interdisciplinary.

In most cases companies that choose not to provide projects are not constrained by financial resources. The biggest restraint is providing people that can monitor projects in an ongoing fashion.

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