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# Integrating the Product Realization Process into the Design Curriculum*

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*Industry-sponsored team projects have been implemented in design-related project courses. Although many of these courses are capstone-type courses, some may be laboratory project courses linked with more traditional design courses. This paper outlines the implementation of the Product Realization Process (PRP) in team design projects. The major elements addressed are formation of teams, defining specifications, developing conceptual and final designs, written and oral communication, grading of projects and assessment.*

## INTRODUCTION

TRADITIONAL DESIGN PRACTICES have been replaced in World Class Companies by concurrent engineering practices. One approach has been referred to as the Product Realization Process (PRP) and includes determining the customer's needs, developing specifications, generating conceptual designs and designing the final product as well as its support processes [1]. The responsibility for implementing efficient processes has been identified by Dr. Terry Shoup [2] where he states that 'improving design methodology has been recognized as the single most essential step in industrial excellence and national competitiveness.' Thus, it is 'evident that engineers in both industry and academia share the responsibility for improving engineering design and manufacturing processes'. Industry-sponsored projects are integrated into the curriculum using the PRP. This is described in general terms in Fig. 1 and is based on the processes described by Pugh [3] and Phal-Beitz [4].

## DESIGN AND MANUFACTURING CLINIC

The newly formed Design and Manufacturing Clinic is a formal organization within the School of Engineering whose function is to obtain sponsored projects and find a venue for them within the curriculum. A design project agreement (form) has been developed which protects the confidentiality of information for the sponsor as well as address the intellectual property rights for the sponsor and the student teams. Project proposals are presented to the faculty who in turn introduce them to the students during the first week of class.

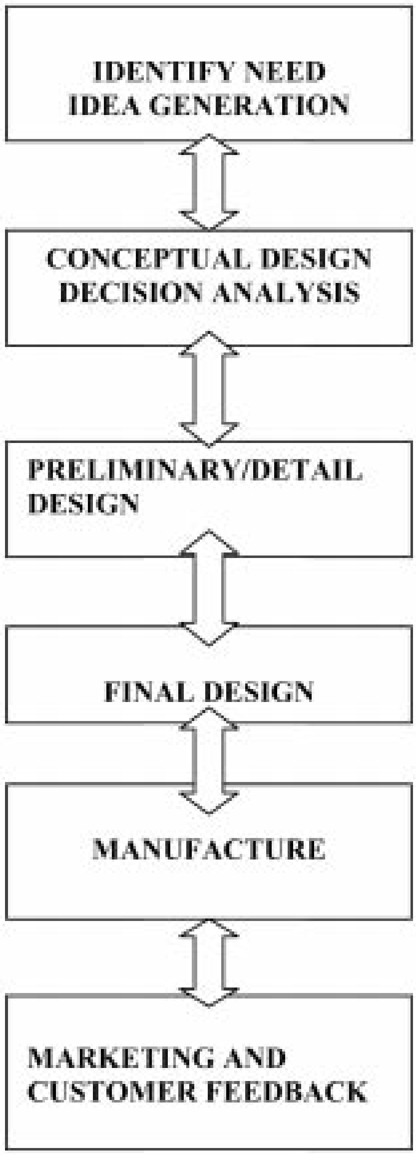


Fig. 1. Product realization process.

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| | SCHEDULE | | | |
|---|---|---|---|---|
| | MONTHS | | | |
| **Activity** | **1** | **2** | **3** | **4** |
| **Establish Need** | | | | |
| Functional Req. | | | | |
| Design Req. | | | | |
| Design Criteria | | | | |
| Identify Deliv. | | | | |
| **Conceptual Design** | | | | |
| Dev. Concepts | | | | |
| Team Specs | | | | |
| Decision Analysis | | | | |
| Oral Presentation | | | | |
| Dev. Gantt Chart | | | | |
| Submit Designs | | | | |
| **Detail Design** | | | | |
| Evaluate Feedback | | | | |
| Initial Calculations | | | | |
| Develop Engr Draw. | | | | |
| Develop Parts List | | | | |
| Identify Calculations | | | | |
| Oral Presentation | | | | |
| **Final Design** | | | | |
| Select Components | | | | |
| Design Components | | | | |
| Perform Analysis | | | | |
| Cost Estimate | | | | |
| Engineering Dwgs | | | | |
| Write Narrative | | | | |
| Submit Final Report | | | | |
| Final Oral Pres. | | | | |

Fig. 2. Schedule of semester activities.

After reviewing the projects, students rank the projects in the order that is of most interest to them. Using this information, teams are formed based on student project interests, aptitude and the leadership skills they bring to the course. The leadership skills are further developed throughout the course of the project. Project mentors include a representative from the sponsor and one or more faculty members.

*Establishing needs and generating ideas*

Every design or redesign action takes place because a need exists and has been identified. After needs are defined the specifications are generated. Specifications are classified in three categories: Functional Requirements, Design Requirements and the Design Criteria. The functional requirements are general in nature and identify WHAT the design is required to do. The design requirements specify how it is to be done and provides actual values for some of the constraints (e.g. horsepower requirements, type of electric service, etc.). The design criterion addresses the 'guidelines' within which the design must conform. Typical issues include safety, cost of the system, ergonomics, aesthetics, materials, performance, size, etc. The criteria or guidelines within which the design must fall are presented by Pugh [3]. The safety criteria are identified as having paramount importance. When the specifications are identified the teams must define the deliverables. This is the first step in the schedule of semester activities as listed in Fig. 2.

## CONCEPTUAL DESIGN

The conceptual design phase is arguably the most critical and most important part of the process. It is in this early stage of the process where the greatest flexibility exists and corresponds to the lowest cost impact for design changes. It is also the phase that students struggle with because it requires design synthesis and not

| CRITERIA | WEIGHT | CONCEPTUAL DESIGNS (PROPOSED CONCEPTS) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Concept A | | Concept B | | Concept C | | Concept D | |
| | | R | V | R | V | R | V | R | V |
| 1. | | | | | | | | | |
| 2. | | | | | | | | | |
| 3. | | | | | | | | | |
| 4. | | | | | | | | | |
| 5. | | | | | | | | | |
| 6. | | | | | | | | | |
| 7. | | | | | | | | | |
| 8. | | | | | | | | | |
| 9. | | | | | | | | | |
| 10. | | | | | | | | | |
| TOTAL | | Sum | | Sum | | Sum | | Sum | |

W = Weight – Indicates the relative importance of the criteria
R = Rating – Indicates the performance of a given concept with respect to each criterion.
V = Value – The product of the weight (W) times the Rating (R).

Fig. 3. Weighted rating chart.

closed solutions. As part of the conceptual design process each individual on the team generates three conceptual designs. These concepts are based on knowledge obtained in prerequisite courses such as theory of machines, design of machine elements, mechatronics, etc. It is expected that students will be familiar with mechanisms like power screws, hydraulic and pneumatic cylinders, and general torque transmitting components.

The initial concepts are presented through both sketches and a narrative of how it will work and major design characteristics. Team members perform a decision analysis on their designs as correlated with the design requirements and design criteria developed under the specifications [5]. A decision analysis chart (weighted rating chart) is shown in Fig. 3. This is presented here for those that may just be implementing techniques in the product development process and are not familiar with this method. Other decision analysis techniques such as controlled convergence [3] have been used at the discretion of the faculty mentor and professor. Other popular methods are presented by Pahl-Beitz [4] and Marples [6].

Individual team members assemble to discuss their designs and decision analysis. It is from this communication that the higher rated designs are further scrutinized and a team decision analysis is performed. Frequently this will result in a hybrid design that incorporates ideas from several designs. The results of the team collaboration are presented to the sponsor for feedback at an oral presentation. Included with this presentation is an outline of the deliverables. Frequent communication with the sponsor is a key to meeting the goals for the project. Based on sponsor input and team decisions one design is carried forward with several others placed on hold for contingency purposes. A Gantt chart (similar to Fig. 2) is prepared which provides a schedule for the activities for the term.

## PRELIMINARY DESIGN

The concept that has been agreed becomes the focus analysis and the final design. This phase has been known as the Preliminary Design Phase but more appropriately could be called 'the embodiment phase'. Pahl-Beitz identify that 'during the embodiment phase, when the layout and form design of the more or less qualitatively elaborated concept is first quantified, both the objectives of the task and also the general and task-specific constraints must be considered in concrete detail [3].

In this phase the materials to be used as well as the geometry are more clearly defined. Early in this phase a detailed drawing is generated without dimensions that articulates the relationship between individual components. One function of this drawing is to itemize the parts required for the final design. It is from this that the team determines the engineering calculations that must be performed to adequately analyze the design. Team members are assigned to perform the calculations and seek the most efficient method of obtaining the final components (original design and manufacturing or mass-produced components and systems). After the Gantt Chart is updated all of this is provided to the customer in the form of a written status report and an oral presentation. Frequently this is used as a method of performing a mid-course correction and assuring the deliverables will be met.

## FINAL DESIGN

The overall design, completed in the preliminary/detailed design phase, becomes the design on which engineering calculations are made. Detailed analyses that were previously considered 'design' (stress analysis, shaft design, heat transfer, design for manufacture, etc.) are performed in this phase. The importance of individual effort and accomplishment outside of team meetings is stressed. Engineering drawings are developed that will eventually be used by the sponsor or other student design teams. In many cases the sponsor implements some or all of the design. In other cases projects are carried over from one semester to another in which a design that was developed in one semester is manufactured in the next. The project concludes about 15 weeks after it was begun with a detailed final report and a one-hour formal presentation to the sponsor.

## FINAL REPORT

Nearly half of the grade in this course is based on the final report. The report is similar to a report required from project teams in industry. Dym and Little [7] present the importance and format of the final report (and oral presentations).

Final copies of the report are provided to the sponsor within a month after completion. The project is described in detail in a narrative section complete with figures. Here the team describes the need, specifications, conceptual designs and the final design. The format reflects the PRP and includes the manufacturing sequence, operating procedures, a cost estimate and engineering calculations. Conclusions and recommendations are provided which compare the results to the design requirements. Recommendations for further action for the sponsor or future design teams are articulated. Final grades are based on the report, team evaluations and individual assignments.

## ASSESSMENT

In order to affect continuous improvement, an assessment is performed throughout the course of the project. Since there are well-defined goals for the course, assessment measures must be implemented to assure that these are met. Industry and faculty mentors evaluate the oral presentations. Recommendations regarding individual and team performance are communicated to the students. Methods of improving the course procedures are also provided by the industry mentors and the students. At the conclusion of the project industry mentor evaluations are conducted to determine if the goals were met and if the outcomes were representative of those that would be expected in industry. The faculty member responsible for the course is charged with keeping a portfolio that shows the results of the student work.

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