Session 3425

Engineering Design and Common Household Devices

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Abstract

Most design is redesign. Some might suggest this is an overstatement, while others may say all design is redesign. An engineering manager at a large appliance manufacturer told me, "Some engineers, fresh out of school, think they are going to be working on innovative, far out, projects and are disappointed when asked to work on a redesign of one our standard products". One component of our junior level methodology course is and individual project is aimed at redesign of a simple appliance. Simple appliances are accessible, familiar to the students, embody engineering science, and demonstrate the complexity of design for apparently simple devices. Each student selects a different appliance in a blind draw. The devices are found around the house and range from a hair curler to a car jack. The initial problem statement is "Improve the performance of a _____."

A series of assignments, from the first assignment aimed at understanding the operation of the device to the final assignment aimed at developing a preliminary design, are completed in parallel with the lectures. These assignments are submitted as draft reports. The students correct and compile these draft reports into two formal reports, a design proposal and a preliminary design report.

The use of simple appliances provides the students with exposure to the design elements of an existing design, the opportunity to apply of a systematic design approach to improve a product, and experience in formal report writing. The individual project, combined with traditional assignments, tests and a group design project provide a complete design learning experience.

I. Background

Nature of the Course - Common household devices are used as an individual design assignment in a junior level course, *Introduction to Engineering Design*. The course is interdisciplinary in nature and is taught to all engineering disciplines in our program. The assignments on individual design projects closely follow the lecture schedule. This individual design assignment counts as 20-30% of the grade in the course. In addition to the individual assignment the student

participates in a group design project that counts as 25% of the course grade. The balance of the grade is determined by two tests and a final examination. Topics include the design model, project planning, teamwork, problem clarification/needs analysis, conceptual design, decision making, materials, manufacturing processes, assembly and joining, human factors, and potential problem analysis. There is an emphasis on written and oral communications in the course.

Design Model – The design model for the course is similar to a traditional phased approach, such as the one described Pahl and Beitz.[1] The first phase of the design process is the problem clarification/needs analysis. The main emphasis is on understanding the problem and developing design requirements. The next phase is the conceptual design phase. The conceptual design includes functional analysis, concept generation, and selecting a concept. These phases are followed by the preliminary design or design layout, the detailed design, and final design phase. This paper focuses on the first three phases.

The approach taken to the design model is a functional approach. Design can be considered as a transformation from a functional description to a physical description. The model suggests starting with the customer inputs to the design process, generation of a functional description, transforming the functional description to a physical description at the conceptual, layout, and finally the detail design level. The emphasis on function requires an understanding of function from the customers' point of view (what does it do?) and from a technical point of view (what functions must be performed to accomplish the customers' functions). The functional approach deviates from the traditional model described above in that the functional analysis is performed in the problem clarification stage.

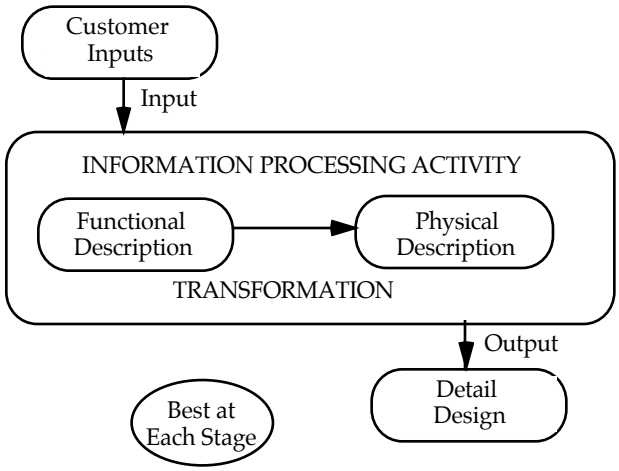

Figure 1: Design as a Transformation Process

Household Devices – The use of common household devices started over ten years ago with the use of a steam iron as a demonstration tool. The iron was dismantled and parts and subassemblies were used to relate different aspects of design including the relationship to engineering science. The historical development of the iron and the relationship between the iron and society were discussed. The use of small household devices was expanded and assigning individual devices to each student was a way of giving individual take-home examinations. The

individual device is now the vehicle for the students to experience all aspects of individual design projects and to tie those aspects together into formal reports.

II. Assignments for Common Household Devices

The students are responsible for a series of assignments on the household devices that parallel the lecture. The assignments have two purposes. The first is to collect the information necessary to complete the problem clarification, conceptual design, and preliminary design phases of the redesign problem. The second is as an exercise in technical writing; that is, producing a design proposal and a preliminary design report. Each individual assignment is treated as a learning exercise and a draft of a section of one of the two reports. They are reviewed for both content and format. The grading emphasis is on the two formal reports. The individual assignments are outlined below.

Background information - The first design assignment is to describe the device and the operation of the device. A written report describes the device including a labeled sketch, discussion of various models (including both powered and non-powered if both are available), and an operational description. The students are required to have a minimum of three sources of information. The students are encouraged to visit retail outlets and explore the variety of forms of the product, talk to users, and procure the actual product. The students are expected to gain some insight into the technical operation of the device and the relationship of the operation to engineering science.

Customer Point of View - The second assignment is aimed at gathering information from the users point of view. The student identifies the customers and focuses on the end user. The student "walks through" the way the user operates the device, defines the what operations are performed (user functions), and how these operations are measured by the customer (customer attributes). The customer attributes are most important since they are the criteria that will be used to evaluate and select alternative redesigns. The customer attributes are divided into "musts" and "wants". The student talks with others outside the class to determine the relative importance of the customer's wants using a paired comparison. The student's individual device is compared to similar devices for each of the customer attributes in a benchmarking exercise. Published information, such as Consumer Reports, can be used for this exercise. The student's report focuses the customers' attributes and opportunities for improvement.

Technical Point of View - The third assignment is to look at the product from a technical point of view. The report includes the functions, the engineering characteristics, the key design issue, the boundaries, the design objective and a set of design goals. The technical functions are an expansion on the customer functions. The primary function from the customer's point of view is the task function. From this task functions the functions that must be performed to perform the task function are identified (basic functions). The other functions are supplementary functions. These are the functions that enhance the product, ensure dependability, ensure convenience, and please the senses. The functions are organized into a FAST (Functional Analysis System Technique)[2] as a means of organizing the functions and as a way to ensure all relevant functions are included.

The functions are used to identify engineering characteristics. These characteristics are related to the function. For example, when we consider the function "move device" requirements associated with movement include; speed, distance, direction, and position. How fast is the device moved? How far? What direction? These are associated with movement whether the movement is a hair dryer, a computer mouse, or automobile.

During this process it is desirable to identify a key issue or the crux of the design problem. This issue, defined by functions or requirements, may be the issue that makes obtaining a solution difficult or one that affords a unique opportunity to be creative. The boundaries defined both the areas to be addressed and the areas that will not be addressed.

Design Proposal - The proposal is a formal written document that includes all of the information in the outline shown below. The proposal should be written to the person or organization funding the work. The summary should include a detailed project objective. The student also is responsible for identifying specific goals e.g. to relocate the temperature control to a more ergonomic position that will achieve the overall objective.

Outline for Design Proposal

Summary (10%)
- *Design Objective -describe the overall objective of the design effort*
- *Goals - specific goals to meet the design objective*

Background Information (25%)
- *Description of Device*
- *Physical Description (including sketch)*
- *Operational Description*

Customer Needs (25%)
- *Problem Definition*
- *Customers*
- *Operating Factors*
- *Customer Attributes*
- *Wants and Needs*
- *Relative Importance*
- *Benchmarking Existing Products*
- *Opportunities*

Technical Needs (25%)
- *Define Design Functions*
- *FAST Diagram*
- *Engineering Characteristics*
- *Key Issue*
- *Boundaries*

References (5%) Minimum of three

Timeliness (10%) Submitting design assignments and proposal on time.

The background information should show an understanding of the current state of the device including a physical and operational description. The section on the customers' point of view should demonstrate an understanding of how the customer uses the device, the desired

performance attributes, performance relative to competitors and opportunities for improvement. The review from the technical point of view should demonstrate an understanding of the function of technical components, the engineering design characteristics, the relationship between these characteristics and the customer attributes, and the identification of the key design issue and boundaries.

Conceptual Design - The next assignment, after the design proposal is accepted, is to develop three different alternative solutions that include an operational description and a sketch. The development of alternatives should include generation of ideas, using functional synthesis[3], for the various functions, grouping of ideas, and finally development of the alternative solutions. The alternative solutions should be reasonable and at least one of the solutions should be considered novel (not necessarily a completely new concept but a concept that has not been applied to the particular product).

Decision Making - This assignment is to select a conceptual design for further development. The students present a decision rationale for each of the customer attributes. The rationale is based on Issue Based Information System (IBIS)[4] where and issue (customer attribute) is selected, a position (which alternative best meets the criteria) is selected, and arguments are made to support or object to the position. The students use the IBIS method to rank the three alternatives for each customer attribute. The ranking and relative importance of the attributes are used in a decision matrix. The students should identify and act on possible modifications to the original alternatives. The selected alternative should be an improvement on the original iteration on the conceptual designs.

Three other assignments are completed to examine additional areas to improve the original design. These areas are materials and manufacturing processes, ergonomics, and potential failures.

Materials and Processes - The students review the materials used to make the product, the processes to produce the product, and the joining and assembly techniques. Students are asked to recommend a material/process substitution including a rationale and to consider reducing or eliminating fasteners and/or reducing the number of steps in assembly.

Ergonomics - The next assignment is based on an ergonomic evaluation of the product. A suggested improvement in this area is also part of the improved design. The students examine the four types of the machine/user interactions for the device and make suggestions for improvement. These include occupy space, power source, as a sensor, and as a controller[5].

Potential Problem Analysis – The potential problem analysis is a qualitative evaluation that emphasizes the potential failure modes, effects of the failure, causes of failure and potential preventative action or controls. The students examine how the current device addresses potential problems and makes suggestions.

Preliminary Design Report - The preliminary design is based on the development of concepts, selection of a conceptual design, and the investigation into the material and processes, ergonomics, and potential problem analysis. The preliminary design is completed in more detail than the conceptual design. The preliminary design includes a layout drawing of the design and

discussion of the subassemblies involved in the design. Physical and operational descriptions are included. The student is asked to review how the design is an improvement over the original product. An outline for the preliminary design report is included below.

Outline for Preliminary Design Report

Summary (in paragraph form) 20 points
- *Objective*
- *Goals*
- *Summary of preliminary design*
- *Discussion of improvements over existing design*

Alternative Generation 20 points
- *Idea Generation Procedure (examples in Appendix)*
- *Presentation of Alternatives*
- *Sketch*
- *Operational Description*

Selection of Conceptual Design 20 Points
- *Decision Making*
- *Summary of Decision*

Preliminary Design – (Greater level of detail) 20 Points
- *Physical Description*
- *Operational Description*
- *Layout Drawing*

Discussion of Improvements 10 Points

Submitting Design Assignment and Proposal on Time 10 Points

III. Discussion

The individual project to redesign an existing device has evolved over time. It started as a demonstration, developed into a way to give individual take home examinations, and eventually reached its current state where the exercise is a centerpiece of the design course.

The individual project ensures that each person experiences the complete design process in addition to his/her participation in a group project. The hands-on experience with a common household device provides a concrete example for each design concept. Most students find the exercises helpful to understanding the lecture material. Students also find redesign to be difficult. It is difficult to come up with novel ideas for existing products. The students indicate that they would prefer to choose their own project and this may be tried in the future. The students also indicated that they would like to spend more time in class working on the project.

The emphasis on the formal written reports serves two functions. It treats the initial assignment as a draft and gives the students an opportunity to improve both content and the writing. Recently the university approved a new general education requirement that includes discipline based writing and requires multiple drafts. This assignment will be in partial fulfillment of that requirement and will have to be modified to include more than one draft. Placing the grading emphasis on the two formal reports can be a positive motivator in that the student can continue

to improve the content and style from the draft. Emphasis on the formal report grade can also result in a less than complete effort on the first draft.

Overall, the assignments have a positive impact on students learning engineering design. The use of simple appliances provides the students with exposure to the design elements of an existing design, the opportunity to apply of a systematic design approach to improve a product, and experience in formal report writing. The individual project, combined with traditional assignments, tests and a group design project provide a complete design learning experience.

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