The Experience of the Discipline “Product and Process Design” in a Production Engineering Undergraduate Course
(004-134)

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Abstract
This paper describes the experience of the discipline “Product and Process Design” in a production engineering undergraduate course in the Polytechnic School at the University of São Paulo, Brazil. Its contents aims at teaching the concepts and knowledge involved with product development, production processes, functional interfaces (marketing, sales, accounting, etc.), including tools employed to support the design process. Teaching activities involve classes, workshops and lectures by professionals from industry. Six partial reports are considered as a project is being developed in addition to a final project briefing. One of the main disciplines deliverable is a first generation of a prototype that the students developed along the course. At the end, competitive projects are selected by academics and practitioners and the best projects are awarded by Procter & Gamble. The discipline has been conducted for more than 10 years with successful projects from which three of them were applied for patent.

INTRODUCTION
Many industries that developed new products acknowledge the importance of hiring freshman engineers with a strong background on product and process design. On the other hand, educational institutions should consider teaching product and process design in order to prepare engineers on this capability. Engineers need to carry out the laborious working of converting ideas into drawing that could be used to manufacture the product. Therefore, there is an urgent need to bring understanding this capability to the engineers.

In this sense, this paper describes the experience of the discipline “Product and Process Design” in a production engineering undergraduate course in the Polytechnic School at the University of São Paulo, Brazil. Its contents aims at teaching the concepts and knowledge involved with product development, production processes, functional interfaces (marketing, sales, accounting, etc.), including tools employed to support the design process. The discipline is part of a curricula of a five-year production engineering undergraduate course. It is delivered during one semester (approximately twenty weeks). Its main objective, besides to teach product and process design, is to integrate various concepts from other disciplines such as: industrial costing accounting, factory design, introduction to mechanical design, introduction to manufacturing, quality assurance and control, etc. Teaching activities involve classes, workshops and lectures by professionals from industry. The discipline centers around the concepts of critical parameters of a design. It enables effective processing of conceptual ideas while providing the vehicle to continually conduct the design through the whole process.

The paper has been structured as follows. Section 2 contains a brief review of the literature related to product design. This review is focused on the subjects delivered in the discipline. Section 3 describes the main discipline body of knowledge and presents the monitoring reports used to conduct the course. Section 4 presents some examples of projects recently conducted. Finally, section 5 draws the final considerations of this work.

RELATED LITERATURE
The Oxford dictionary describes design as “conceiving a mental plan for; making a preliminary sketch, picture”. Other who are closer to the discipline have described it in more detailed terms. Hollins and Pugh (1990) described “total design” as a “multidisciplinary iterative process that takes an idea or market need forward into a successful product”. The authors also note that design does not end with production but with product disposal. Middendorf (1990) define design as “an iterative decision-making activity whereby scientific and technological information is used to produce a system, device or process which is different in some degree from what the designer knows to have been done before and which is meant to meet human needs”. Some points that are unquestionably about design are (Fox, 1993): it is creative; it is a multidisciplinary process; it seems to need to be iterative; it is evolutionary; and it serves human needs.

The literature on product design is rather broad. The development of a product usually follows the sequence of idea generation, investigation, design formulation, product production, and market launch. In addition to this process, analytical techniques and methods should be introduced to support
the design process. For instance, the results of a survey in the UK industry suggest a number of methods used in product design (Araujo et al., 1996). In fact, during the past decades, various of those methods have been widely discussed. They can be found either in specific publications (e.g. Akao, 1990; Taguchi, 1993) or compilations (Pugh, 1991).

Many techniques for product design have been described in the literature and all of them will contribute to some extent to a more effective design process. Actually, there is no single method or process described in the literature that can do it alone, but a combination of methods and techniques and good management can make a significant improvement in the way products are brought to market. Using those methods coupled with new technologies with an effective operations management will enable industries to compete globally and deliver quality through design. This can be accomplished through an effective training and education of professional people by including design in operations management and engineering courses. One of these experiences are described next.

**BODY OF KNOWLEDGE OF THE DISCIPLINE**

The discipline considers a wide body of knowledge relatively to product and process design. Its contents involve but it is not limited to the following topics:

- Benchmarking
- Brand development
- Costing systems
- Creativity
- Design for manufacturing and assembly
- Design for six sigma
- Design process
- Distribution channels
- Engineering specifications
- Failure mode and effects analysis
- Functional analysis
- Market segmentation
- Methodology for new product development
- Quality function development
- Packaging
- Patent application
- Process Planning
- Raw material selection
- Value engineering
- Viability study
- Voice of customer

A product are usually developed considering the following possibilities:

- Needs not yet fulfilled by a product;
- Necessities barely fulfilled by a product (considering user needs);
- Needs fulfilled by a product using technology and design out of date;
- Needs fulfilled by a product with high costs;
- Needs fulfilled by an imported and expensive product.

The product development is then conducted considering those possibilities and by applying the topics earlier mentioned. As the development is carried out reports should be issued to describe the design activities, results from each development stage as well as the decisions made based on technical and market needs and the literature on product design. There are six reports for monitoring the development of the discipline according to the topics as well as to the product development cycle. The reports mainly embrace:

**Report 1** – Fulfilling user needs (market segmentation and customer requirements, differentiation study, macro functional analysis, definition of commercial strategies, etc.).
Report 2 – Market price determination (initial product sketch and market research, commercial benchmarking, etc.).

Report 3 – Concept development (detailed functional analysis and concept selection, material specification, packaging definition, storage, handling and distribution channel requirements, etc.).

Report 4 – Detailed design (engineering specifications and blue prints, technical documentation, bill of materials, design failure analysis, etc.).

Report 5 – Process development (process planning, machine and tools selection, quality control definition, process failure analysis, etc.).

Report 6 – Economic evaluation (cost and price assessment, comparison between product price and market price, value engineering analysis, etc.).

Each report are delivered every three weeks. A feedback document is issued for each report in order to review its contents for the final project brief. As the product are being developed, a prototype is constructed mainly considering product attributes with regard to i.e. dimensions, functionality and, in most cases a simulation of its operation. The projects are developed by two or, maximum, three students.

In addition, lessons can also be learnt through previous developed projects. The best projects of each year can be consulted at a technical library. Students can borrow previous project reports and adapt their contents to the current product being developed. Generally, typical projects include: educative toys, games for persons with disabilities, games for learning foreign languages, etc.

To motivate students, best projects are awarded by Procter & Gamble in the end of each year. Top ten projects (selected by the lecturers based on the grade) are sent to professionals from Procter & Gamble (usually people from marketing and product development) in addition to two more lecturers, associate professors, or professors. Then, a ranking is established with best six projects. Those are presented in a special occasion followed by the award ceremony and a cocktail. It is worth mentioning that this is not a technical presentation (in fact, all projects are ‘conventionally’ presented at the end of the course using MS Power Point). Although this presentation includes technical issues it is more an advertisement to ‘sell’ the product. Some of those product development projects are illustrated at following section.

EXAMPLES OF DEVELOPED PRODUCTS

Table 1 shows some examples of projects recently developed.

Table 1 – Examples of Product Development Projects.

<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerojet</td>
<td>Mini toy airplane with propulsion</td>
</tr>
<tr>
<td>Compact pet</td>
<td>Mechanical device to reduce the volume of plastic bottle aiming at recycling</td>
</tr>
<tr>
<td>Easy ice</td>
<td>Gadget to apply ice for physiotherapy treatment</td>
</tr>
<tr>
<td>Flitop</td>
<td>Tennis shoes that can be changed to slippers</td>
</tr>
<tr>
<td>Magic bottle</td>
<td>Bottle with instantaneous heating through a chemical exothermic reaction</td>
</tr>
<tr>
<td>Safety kitchen</td>
<td>Protection equipment for stove to prevent children accidents</td>
</tr>
<tr>
<td>Sensitive game</td>
<td>Touch game for persons with visual disability</td>
</tr>
<tr>
<td>Tube</td>
<td>Tooth brush with tooth paste and dental floss in the same gadget</td>
</tr>
<tr>
<td>Weicher article</td>
<td>Game for learning articles in German</td>
</tr>
</tbody>
</table>

As can be seen in Table 1, recently developed products are quite diverse. They involve different technologies, materials as well as manufacturing processes. There are a prototype for all of them, which simulate product concept and functionality. Figure 1 shows an example of a winning prototype of a project developed in 2005 (called “tube”). It is a tooth brush that includes tooth paste and dental floss, conveniently developed for travelling, camping, etc. Most parts are made from plastic (high density polypropylene). The engineering drawings for all components were developed as well as the respective manufacturing process, including process flow, equipment, tools and dies, quality control...
devices. All specifications were based on a given volume production obtained through an estimate in the market (based on a market research conducted in a specific segment and niche). Throughout the product development a number of methods and tools have been applied, including FAST (functional analysis system technique), FMEA (failure mode and effects analysis), QFD (quality function deployment), value engineering, benchmarking studies, etc.

Figure 1 – Example of a Prototype of the “Tube”.

**Final Remarks**

The discipline takes a new look at what design really is and proposes an approach which make changes in the way students learn about design. It is worth mentioning that it considers not only technical aspects of design but also a comparison of alternatives of concepts, materials, equipment, manufacturing process, and so on. This surely contributes to operations management with regard to new product development.

The discipline defines the process design, treating it in a broader sense from concept to manufacture. In addition, the student identifies and applies some of the methods and techniques required to deliver quality products and establishes a process (including a set of reports and a feedback) that help to monitor product development throughout its cycle. As the production engineer expands its horizons, it enables to bring knowledge on how to develop a project. The course has resulted in a truly multi- and inter-disciplinary environment contributing to the students knowledge on product and process design. It has been conducted for more than 10 years with successful projects from which three of them were applied for patent.

**References**


