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Innovation in Engineering Education at ITESM

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Abstract

Engineering Education at ITESM is being transformed since several years to active learning strategies, as Problem Based Learning (PBL) and Project Oriented Learning (POL). One example is the Course M-99-235 Product Design and Analysis that is being offered for the Master Program Manufacturing Engineering based on the POL Strategy. This course is focused on enhancing the creativity and inventive skills of the students and their ability to create new innovative products. Students work in teams solving real world design projects from manufacturing enterprises on a contractual basis. The students are provided with tools and methods that efficiently and effectively support the design process. It is intended to have an approach of the design process that may be easily learned due to its logical structure and to the enhanced capability of students/designers for achieving better solutions for challenging design projects.
The approach that has been used for several years is based on the integration of Parametric Analysis and Quality Function Deployment (QFD) during the specification/planning stage; the Theory of Inventive Problem Solving (TRIZ) and "Classical" Design Methodologies as Morphological Matrix at the conceptual design stage, and 3D-parametric computer aided design tools at the embodiment design stage.

Key-words: Innovation, Design Education, Design Methods

1. Introduction

Engineering Education at ITESM is being transformed since several years to active learning strategies, as Problem Based Learning (PBL), Project Oriented Learning (POL) (Martín-Pérez, 2002). One example is the Course M-99-235 Product Design and Analysis from the Master Program Manufacturing Engineering, as from the Master Program Leaders for Manufacturing, based on the POL Strategy. This course is focused on enhancing the creativity and inventive skills of the students and their ability to create new innovative products. Hence, this course claims that creativity can be taught (Tornkvist, 1998). The course honors the ABET program criteria for Accrediting Engineering Programs, especially for manufacturing and similarly named engineering programs (ABET, 2003).

Students work in teams solving real world design projects from manufacturing enterprises on a contractual basis. The enterprises assign experienced representatives to follow up the projects. The principles of reinforcement through feedback and motivation in the process of learning and learning by doing are stressed here trough (Entwistle, 1987), (Dewey, 1966).

2. Objectives

Main objective of the course is to provide the students with tools and methods, which efficiently and effectively support the design process stimulating their creativity. It is intended to have an approach of the design process that may be easily learned due to its logical structure and to the enhanced capability of students/designers for achieving better solutions for challenging design projects.

3. Scope of Work

The product development process may be defined as the complex system of activities that are derived from market opportunities and produce the information required for bringing new or enhanced products to manufacture. The course offers the possibility to analyze how modern ideation tools may be integrated in a product development environment for helping designers finding solutions to problems arising during the conceptual and embodiment design stages looking to increase design effectiveness and productivity. Therefore the course also serves as a laboratory where research work may be undertaken looking for the effect of integrating different design tools and methodologies to increase design effectiveness and to enhance creativity.

4. Methodologies

The approach that has been used for several years is based on the integration of Parametric Analysis (Pugh, 1991) and Quality Function Deployment (QFD) (Terninko, 1997) during the specification/planning stage. The Theory of Inventive Problem Solving (TRIZ) (Altshuller, 1995) and "Classical" Design Methodologies as Morphological Matrix (Zwicky, 1966) are applied at the conceptual design stage and 3D-parametric computer aided design tools at the embodiment design stage.

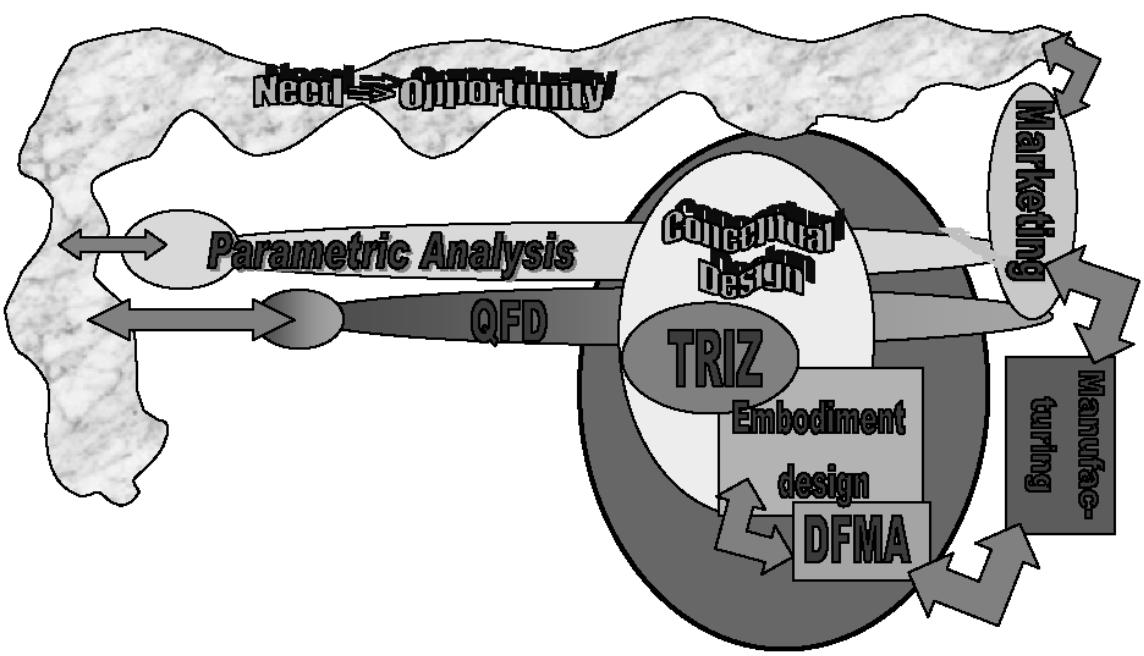

Figure 1 Conceptual map of the product development process

This approach is intended to contribute create the groundwork for integrating product development tools and methods that may also be easily learned due to its logical structure. In Fig. 1, a diagram of the conceptual map that supports this approach is shown.

Building the Teams

The first step of every product development project is the creation of the team that will be on charge. In a company environment, the team members are mainly chosen based on their expertise and abilities. In an academic environment, the team building involves different considerations. Commonly the students meet the first time at the initial course day and the professor and assistants do not know the most of them yet. In such a situation, a suitable method for building the teams and assigning projects is perhaps more critical. Several activities and methods for accelerating the knowledge of every student with each other and to the professor and assistants regarding its background, past experiences and personalities are required.

The assignment of the projects occurs on a concourse basis. The students are asked to consider for which projects they suppose to have advantage. They are then requested to fill a questionnaire related to their background and experiences, which is then used for a self presentation. During the presentation, the peers look for possible teammates. Students are given a week to build their teams and to present a concourse exercise to persuade the resting students and the instructor that they have build an adequate team to successful carry out the project for which they are competing.

The test of Myer Briggs

Since several years, it has been determined to use the test of Myer Briggs (MBT) to help students gain a better knowledge of their personalities and skills. Instead of making the tests before the creation of the teams, it has been decided to make the tests after the teams are already built. It has been shown that the tests results help them feel more confident, competent and committed to experiencing success, as here through they identify the role team members are best suited to play. Furthermore, it is suggested to use existing literature on how to handle with the different MBT during team work (Hipple, 2002). Although it is very difficult to measure the effect on the team's performance, it is evident that since these tools have been introduced the course atmosphere has improved and the conflicts among teammates are better managed.

Assigning the projects

Assigning the projects occurs on a consensus basis. Commonly agreement for assigning the projects is achieved during the second week but in some critical cases, during the third week assignment is yet being analyzed. Although these analyses delay the decisions, it has proved to be important to continue going deeply before taking decisions. The sense that the projects are assigned on a rightful basis improves the team performance and preserves the fun on the projects.

Specification/planning

During the first project/course module Parametric Analysis followed by QFD are applied to the specification/planning stage. However, students are asked to extend its employ through the whole recurrent product development process as due to the amount of time and work needed both tools should not be accomplished as a simple stage of the project schedule. It is rather recommended to perform QFD and Parametric Analysis in a continuous way, as part of the enterprises' culture in order to gain competitive advantage in the market without affecting the product design schedule.

As part of the Parametric Analysis, students are invited to use the INTERNET with advanced search engines to gather information of similar products. Commonly students perform this assignment in 2 weeks. The information is then structured in tables and graphics showing the most important correlations. Fig. 2 shows an example of parametric analysis performed in a past project.

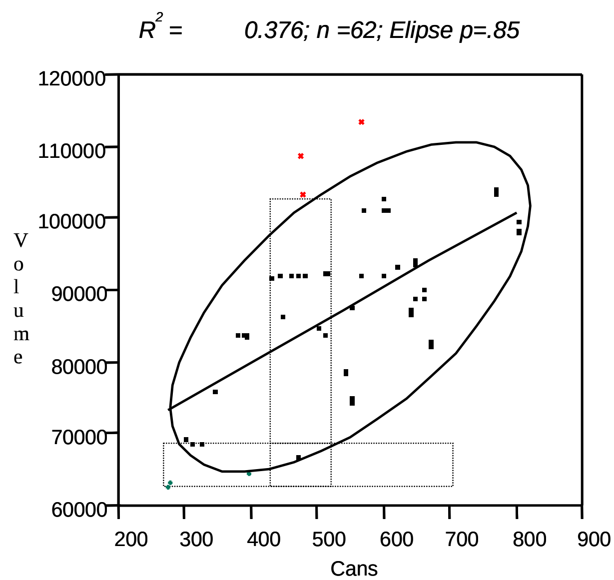

Figure 2 Parametric Analysis Volume vs. Number of Cans in Vending Machines

Terninko (Terninko, 1997) describes the primary purpose of QFD as to identify the most important issues and parameters of the products and to link priorities and target values back to the customer before the new product design process is started. The QFD process is summarized in the diagram called the House of Quality (HOQ). Filling the diagram with data is a cumbersome and long process that requires considerable time and effort. Therefore, the students are advised that in the short time available during the academic semester it is only possible to have a first draft of the QFD. Nevertheless, the positive influence of the contact with customers of former products or with potential customers of the new products is invaluable for product design students.

QFD helps gaining competitive advantage by identifying the directions in which product parameters have to change for a better customer satisfaction. Hereafter mutual relationships among the new defined parameters values are identified. The positive relationships are synergies that occur among the new parameter values that enhance the product performance. Students are asked especially to identify negative relationships as conflicts, which may be typified as technical contradictions between the new targets.

Conceptual Design

Morphology is the science of relationships between ideas and actions, founded and developed by the Swiss (American) astrophysicist Fritz Zwicky (Zwicky, 1966). The resulting technique of creativity aims to replace subconscious mind driven and therefore arbitrary, random production of ideas by a more conscious, systematic approach.

Functional decomposition is the analysis of the activity of a system as a set of subordinate functions performed by independent subsystems, each with its own characteristic domain of application. Students start the conceptual design module from the morphological matrix combined with the functional decomposition of the design object as proposed in several Engineering Design Books (Ullman, 2002) and (Otto and Wood, 2001). The consequently generation of ideas for the different items is a proved useful method in product design as it stimulates creativity and helps to find new unexpected solutions through innovative combinations of solutions at the lower functional levels.

The Theory of Inventive Problem Solving (TRIZ) is a methodology that has proved to be a strong tool for helping to solve difficult technical problems that require inventive thinking. That means problems where one or more technical contradictions are involved and which do not have known ways or means of solution (Altshuller, 1995). Students are introduced to TRIZ during the second course module and are asked to use it combined with the morphological matrix to enhance its results. Students are asked to first clarify the TRIZ concept of Ideal Final Result in relation to their projects and then applying the Altshuller's Contradiction Matrix to the strong conflicts identified in their projects. The aim is to help them gaining a better understanding of the concept of technical and physical contradictions. Although the use of TRIZ in the product design process has yet to be better identified and established, several text books (Ullman, 2002), (Otto and Wood, 2001) are including TRIZ as a tool for the design process.

As a measure of achieved improvements, students are asked to make a comparative presentation of the results obtained before and after applying TRIZ tools and methods. Normally students recognize significant improvements accomplished. In Table 1, an example is shown for the development of a fuel-water separating device. The additional ideas generated with TRIZ tools are in gray shaded cells with bold letters. At the end of the conceptual design stage, Pugh concept selection is applied to choice solutions among the variants developed with the Morphological Matrix and enhanced with TRIZ (Leon and Aguayo, 1998) (Leon and Alvarez, 1999).

	Variants							
Functions	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Connect with pipe	Threaded coupling	Fast coupling	Embracer	With metallic belt	**Welded**	**Soldered**		
Sealing	With cardboard	With neoprene	With cork	With lead seals	**R.T.V**	**With SILICON**	**Ribbon**	**Vulcanized**
Warming	With electric resistance	With motor's cooling water	With escape gases	With flame	**Impeller**	**Laser**	**Infrared radiation**	**Eddy currents**
Separate free water	Decanting	Centrifugation	With a sheet	With filter	With a mesh	**Thermal shock**	**Ultra shall**	**Vibration**
Separate emulsified water	Coalescing	Centrifugation	**Ultra shall**	**Vibration**				
Extract contaminants	Butterfly valve	Pressure valve	1/4 round	**Pressure valve**				
Dispose contaminants	Throw away	Dispose	Evaporate					
Store contaminants	Steel sheet	Plastic container	Aluminum container	Glass Container	**Titanium container**			
Store fuel	Steel sheet	Plastic container	Aluminum container	Glass container				
Filter	Cardboard	Wire mesh	Paper	Thread	**Stone**	**Carbon**		

Table 1: Morphologic Matrix for fuel-water separating device

5. Results

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More than 50 case studies have been developed in the last 10 semesters, which range from consumer products as home appliances up to subassemblies of industrial machines. Modern ideation tools have been integrated in a product development environment for helping designers finding solutions to problems arising during the conceptual and embodiment design stages looking to increase design effectiveness and to enhance creativity. Therefore the course also serves as a laboratory where research work may be undertaken looking for the effect of integrating different design tools and methodologies to increase design effectiveness and to enhance creativity.

6. Conclusions

Although the time for learning and applying all the tools used is actually too short, the students manifest that this approach helps them in getting a better understanding of the products during the conceptual design phase. TRIZ has shown to be a strong tool for helping the teams facing difficult technical problems that requires inventive thinking. Prevalently students show enthusiasm in applying TRIZ tools and methods combined with the morphological matrix and declare to feel comfortable in using both methods in a combined way.

When asked which characteristic they perceive better in this approach students generally declare that the morphological matrix helps them to organize the conceptual design tasks while TRIZ methods and tools help to gain a deeper understanding in the problematic and to gain confidence in the proposed solutions, which are generally more innovative.

7. Recommendations

Although no metrics are yet available to measure the results of creative activity, some empirical studies are being conducted by researchers to answer this question. (Shah and Vargas-Hernandez 2003). New research is further required to clarify the outcome of this kind of systematic methods for idea generation in engineering design with the aim to measure its impact in ideation and innovation (Leon, 2001)

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