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READING ASSISTANT: HANDS-ON EXPERIENCE WITH SYSTEMATIC DESIGN

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ABSTRACT
'Product Design, Development and Marketing' is one of the key courses in the Engineering Management Program at UAE University. The course was aimed at enabling the students to fully comprehend the various stages of the design process and the interim outputs that are produced and needed to be produced in a systematic design process. Systematic design process with design models and methods was taught in lecture classes. A carefully chosen design and build project was undertaken to cement the learning. Reading Assistant, a tool assisting readers to have access to multiple open books with ease, was designed and built as part of the course. It followed a systematic design process consisting of five stages namely Requirements, Product Concept, Solution Concept, Embodiment and Detail Design. In the process customer requirements were recorded, specifications were drawn, alternative concepts were proposed and a preferred one was chosen, embodiment was developed and the detail design was completed. The design was analyzed and proven before its committal to manufacture. Manufacturing was considered at every stage of the design process. Several interim outputs were produced during the passage from idea to completion. The project described here is the work of one of the seven student groups from a class of 24 students. This reinforced the structured path that has been followed in the design and development of the product. The course has given a first hand experience in the systematic development of a product and taught a large number of theoretical and application lessons.

Keywords: Systematic design, design teaching, product development.

1 INTRODUCTION

Master of Engineering Management Program at UAE University has Product Design, Development and Marketing as one of its main courses aimed at enabling the students to fully comprehend product and concurrent process development from concept to completion. 'Product Design and Development'[1] was used as the prescribed text. Design models and methods were taught in a series of lectures with appropriate examples. A project has been carried out to gain a comprehensive firsthand experience in the design and development of a product from concept to completion. Reading Assistant is a tool that enables a reader to have a direct access up-to six standard books in open position. The entire class of 24 students participated in the Design and Development project grouped in seven groups. *HEX III*, the product developed by the authors' group is intended to be useful to Researchers, Students, Physicians, Lawyers, Libraries, etc. in such a practical and innovative way that provides easy and fast access to multiple books saving the reader time while keeping the table top neat and clean. The product was developed using a systematic design process that has five stages namely Requirements, Product Concept, Solution Concept, Embodiment and Detail Design[2]. It enabled the students to have definite starting and finishing points together with interim milestones for the entire project from the inception. Also it made the planning of the work more efficient. The course taught a number of design methods[4] that could be used at various stages of the design process and the project gave the opportunity to use some of the chosen ones. It has given confidence to students to start a design project and steer it towards a successful completion. This paper starting with a brief literature survey describes the course, product, learning outcomes and the learning experience of the students.

2 LITERATURE SURVEY

A Design Model describes the sequence of activities or stages that transforms an abstract set of requirement into the definition of a physically realizable product. Cross[3] states that descriptive models

outline the activities that typically occur in designing while the prescriptive models attempt to prescribe a better or more appropriate pattern of activities. Systematic Design breaks down the design process into a sequence of stages and handle each stage in detail so that no one stage is overlooked and the entire process is transparent and repeatable. Systematic Procedure had been proponent as an urgent need to improve on traditional ways of working in design because of increasing complexity of modern design. Cross[3] defines the design methods[4] as "any procedures, techniques, aids or 'tools' for designing and they represent a number of distinct kinds of activities that the designer might use and combine into an overall design process". Jones[4] in the sixties started the focus on design methods with his book outlining thirty-five design methods including Brainstorming; which aims to stimulate a group of people to produce many ideas quickly, Synectics; which aims to direct the spontaneous activity of the brain and nervous system towards the exploration and transformation of design problems, Removing Mental Blocks; which aims to find new directions of search when the apparent search space has yielded no wholly acceptable solution, Morphological Chart; which aims to widen the area of search for solutions to a design problem. Developing and refining new design methods is an ongoing research activity to help overcome the difficulties of modern design problems.

3 THE COURSE

The course started with a comprehensive overview of the objectives or what the students have to achieve at the end of the course. An existing simple product, a portable concrete mixer, was introduced and the societal need of it was described. The need was then translated into specifications in a brief fashion. Main purpose functions were then shown. Concepts of the product available in the market were identified and the parts tree for a chosen model was shown. Make/buy decisions that had to be taken were pointed out. This quick walk through of the development process gave the students a reasonably good idea of the process. Design models were introduced after this citing many different examples. Design methods[4], the tools and techniques usable at various stages of the design process followed the design models. Brainstorming, Ideation, Morphological Analysis, Decision-Matrix, Pugh's[6] concept selection, and parts-tree analysis are some examples of Design Methods taught in the Course. Approaches to conceptual design were described and the detail design was divided into two parts. The professor explained that in the first part called Detail Design every component needed are identified and put in place. In the second part called the Detailed Design all the necessary engineering considerations are identified and detailed analyses are carried out in these areas to prove the soundness of the design. The outputs at various stages were explained and the professor emphasized the importance of defining the needed outputs right at the beginning. In the development of the Reading Assistant project the following outputs were considered:

Table 1. Shows the anticipated learnt output for each design stage of the overall design process

Stage	**Anticipated Output**
Initiation of Project	Brainstorming, Targets sets, Time Schedule
Extraction of Mission Statement "Design Brief"	Carefully listening, Constructive Thinking
Establishing Needs	Evaluation of needs, its importance and Needs Metrics Matrix
Product Concept	Functions Analysis, Function Diagram
Solution Concept	Morphological Analysis, SCREENING / SCORING Matrices
Embodiment	Parts Tree, Make/Buy decision
Detail Design	Bill of Quantity, Drawings of all parts included
Detailed Design	Engineering Stability[7] Calculations
Manufacturing	Technical on-hands skills
Marketing	Roles Distribution, Marketing 4Ps
Project Close-Up	Results and Conclusion, Lessons Learnt

4 THE PROJECT

4.1 Methodology

The prime task at the beginning was to understand the project in full and making a comprehensive plan with interim outputs and milestones. A lot of handholding and collective work with the whole class were needed at the beginning but once started the students groups went independently in their own ways. The project started by interacting with customers, which included Professors, Research Students, Lawyers, etc. and carefully listening to their voice. Their verbatim was recorded and later translated into needs. Metrics that could deploy the needs were identified after this. Chosen needs were then referred back to the customer to ascertain their relative importance. The design team then established a function tree and conciliation between the function tree and the needs was used to draw the specifications. Conceptual solutions were then proposed systematically and Morphological Analysis was used to structure the thought process. Three different design concepts were proposed. Hand sketches followed by dimensioned CAD drawings and 3D modelling were produced and carefully discussed for each design extracting the pros and cons of each design.

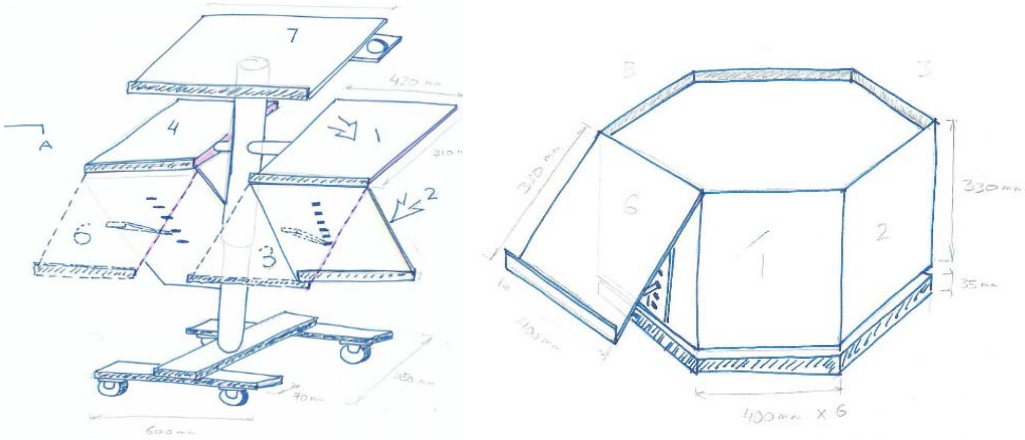

Figure 1. Hand Sketches of some proposed designs

Figure 2. 3D modelling of proposed designs

Most preferable design was chosen based on SCREENING/SCORING method. The process then proceeded to the embodiment design stage. In this stage the Parts tree was established, Make/Buy decisions were carried out and specifications for the parts to be bought were drawn. Decisions were made on the choice of material for the parts to be made. In the detail design stage the product was defined completely - including smaller individual parts and all dimensions required to make the product. AutoCAD[8] was the software used to define the detail design. The last step remaining was to prove that the design is safe and optimal by identifying and carrying out the required engineering

analyses. In the case of *HEX III* stability of the designed product was the main analysis needed. The design was thoroughly checked and proven to be safe before manufacturing the product was started.

4.2 Actual Product

HEX III is a wooden hexagonal tool consisting of six adjustable angle-reading panes that can be retracted in place enabling convenient reading angle. Each of the six reading panes is equipped with page holder that kept the book open while switching to another one. The reading panes are attached to a hexagonal upper body at the centre through hinges and can rotate freely through the entire 360^{o} allowing quick and easy access to any book with ease. The overall reading body height is adjustable providing the reader with a unique ability to read while sitting or standing. Five mobile caster wheels that provide easy mobilization of the tool support the upper body. The caster wheels are lockable type that provides the tool with stable positioning. The tool was provided with independent freely rotating LED spotlight at the top providing the reader with better vision whenever required. Moreover, the top surface can provide significant area for the reader to take notes or write comments. The tool is intended to have a coffee cup holder in the next phase. It also will provide deck for charging mobile phone, listening to music, viewing i-Pads, and some other interesting features providing reader with most comfortable means. Figures 3 and 4 show the product.

Figure 3. General Overview of Product HEXIII

Figure 4. Multiple Books in open position.

5 EVALUATION AND THE LESSONS LEARNT

This section evaluates the work and then describes learning outcomes and learning experience of the students. The product chosen was new but there was no technical difficulty in understanding the product irrespective of the undergraduate educational background of the students. This careful choice of the project made it easy for the students to fully engage and contribute from the beginning. The

design process including the design models and design methods were covered in lectures prior to the introduction of the project and it was a smooth transition from a passive listening and grasping to active using what has been learnt and, searching and finding further knowledge and information that are needed to do a good work on the product. The group of students used to meet regularly to edit, measure, calculate and discuss different design parameters during the short period of the course, which lasted for only eight weeks. In hindsight, it can be seen that this had developed the overwhelming intention to steer the project into success. The project itself was a challenge needed to be overcome which in-turn raised the sense of responsibility in all participating students to produce the best that everyone can add. The different groups of students had dramatically enjoyed manufacturing the product relying on their own technical experience they had gained during the undergraduate technical workshops courses. Nevertheless, groups met some challenges they believe had suppressed the efficiency of the overall project; for example, the planned period of the course was too short and congested to accomplish the required tasks in less than eight weeks. This resulted in eliminating some interesting features that was planned to be included in their tool. The lack of material, tools and equipment required to manufacture the product internally had resulted in coordinating with outsourced suppliers and workshops to carry out certain parts of the tool. The team lacked a professional ability to design the model in animated 3D, which was planned at the early stage. Conflicts in students prospective and roles was inevitable but was absorbed effectively after a team leader had been assigned within the group who could run the process and steer the team to a common-base. The work had met with rises and falls which were successfully overtaken only after cooperation between all team members and their faith and belief in their product to be eventually a success. The students believe that they have fully accomplished the objective of the project and the tool had reached a successful industrial opportunity.

5.1 Learning Outcomes

At the end of project assessment, the entire class had informal gathering and chat. The general consensus was that course had provided us the first hand-on knowledge and experience in the systematic process of design and product development. The learning outcomes from the students' point of view can be grouped into two categories (i) design specific and (ii) transferable skills as outlined below:

Design specific outcomes include

- Comprehending the different stages of design process, which have to be fulfilled regardless of 'what the product being designed', was. Systematic design process has been instilled as a fundamental concept in the students' minds.
- Development of a habit of focusing on all surrounding tools, machines and equipment to see if they can develop the current product for better use and smarter utilization as a life-experience, is a lasting outcome of this course.
- Learning the art of brainstorming as one effective method for troubleshooting and problem solving.
- Realizing how the engineering science learnt in the undergraduate studies can be put into action in general and specifically learning the principles of stability[7] calculations and how to stabilize any object under different load conditions.
- Learning how to set target and final specifications of any product design.
- Learning the general operations of AutoCAD and 3D Max as a secondary benefit.

Transferable skills based out comes include

- Learning the art of professional technical reports writing, negotiation, supporting arguments, paragraphs and assignments writing methodologies.
- Team leadership, roles distribution and team spirit were the essential skills gained through the learning experience of this project.
- Learning to work in harmony and collaboration; the students learnt how to deal, interact, discuss, negotiate, respect and effectively share views and opinions while thriving for the best answer to design needs.
- Learning how to hold effective self-driven meetings and how to invest the short available time to come up with a considerable achievement.

- Learning how to cooperate between team members and how to discover the strengths of each member to complete given tasks effectively which had been reflected in overall work integration as per very short time frame and huge load schedule set at the beginning.

5.2 Learning Experience

At the beginning, when the project was announced, groups of students were sceptical about being able to steer the project into a successful end. The fear and suspicion was enormous; bewilderment was more frequent but, nevertheless there was a dominating faithful intention in everybody's mind to play his/her role effectively. The amount of courage and trust that had been given to students by the professor was tremendous and he dramatically helped in overcoming many challenges met at the early stages. The group of students spent many sleepless nights working hard on their project in patience amidst of work and family commitments. They were confident that by doing so they would steer the project into a success. They learnt the art of Brainstorming, Coordination, Cooperation and Integration between each other. They learnt how to control Conflicts, Anger-Management and Tolerance. Time Management was an essential life-experience they learnt which affected their personal and career life positively. Every interim achievement was giving lot of confidence. On top of all these a lasting confidence and self-belief that each member of the team can embark on a new design project and steer it towards a successful completion was getting built.

6 CONCLUSIONS

The team members learnt the systematic design process and its constituent components the design models and design methods. Their knowledge was consolidated by the applications of the knowledge in the development of a reading assistant called *HEXIII*. In the process the students have learnt many practical lessons. The experience has given the team members confidence and self-belief that they can lead and manage product development projects. They were satisfied that their product meets the customers' requirement with which they started. In addition they are positive that their design is unique and can succeed in the market.

As a concluding remark, it can be said that working on a Product from concept to conclusion reinforces the theory taught in a more emphatic way.

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