

Innovative Teaching of Product Design and Development in an Engineering Management Program

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Innovative Teaching of Product Design and Development in an Engineering Management Master Program

Abstract: Engineering Management is a discipline that is not rigidly defined and the Master Programs attract students with different undergraduate disciplines. Students are attracted towards Engineering Management only at the Masters' level and it is difficult to incorporate all topics in the Masters' curriculum. Therefore a choice has to be made. Some programs give more emphasis for Product Design and Development course while some do not and this choice is often governed by the national requirements. United Arab Emirates University places great emphasis for Product Design and Development in their Master of Engineering Management. The students are from a variety of disciplines and a novel model for teaching the design process was introduced. The model consists of (i) teaching design models, methods, approaches and outputs (ii) using the techniques taught to design and build a new product and (iii) developing a design management strategy derived from their project experience. The results were very encouraging and this paper describes them.

Keywords: *Design Methodology, Problem based learning, Product Development*

1 Introduction

Design is the epitome of all engineering endeavours and is the life-blood of the manufacturing sector. Engineering managers have to be involved in the management of product design and development either as a part of a designing team or as a purchaser of a system that is being designed. But engineering managers come from different backgrounds and fields of specialisation in their undergraduate studies. For this reason there will be students, in a Master of Engineering Management program, who have graduated from a variety of undergraduate disciplines. The emphasis of an Engineering Management Master program differs widely among universities and in some programs the emphasis on Product Design is less while in some others it is more. United Arab Emirates University offers a Master in Engineering Management program where product design and development is a major course. The challenge for the curriculum design is to teach the design process and the outputs at various stages so that an engineering manager can provide effective leadership to a design office or team. A teaching methodology consisting of three parts has been developed and delivered to a cohort of twenty-three students, who are from different backgrounds including mechanical, civil, electrical, chemical and architectural engineering as well as information technology. The challenge was on the selection of a suitable project where they could easily understand the product and focus on the process only while designing the product. This paper describes how the course was delivered and how the students applied the knowledge on designing and developing a 'Reading Assistant'. It also describes what conclusions were drawn on the effectiveness of the method and what lessons were learned.

2.0 Engineering Management

Engineering Management is a discipline that is not rigidly defined and this is evident from a variety of Engineering Management programs offered by different universities. According to Gupta President, Institution of Engineers, India [1], Engineering Management is the process of planning, organising, staffing, leading and influencing people, and controlling activities, which have a Technological Component. American Society of Engineering Management [2], ASEM, defines it as the art and science of

planning, organizing, allocating resources, and directing and controlling activities, which have a technological component. Peterson and Humble [3] considered the total undergraduate and master student intake in 2004 and identified that the master's degree was the predominant with 75% of students. There are a variety of topics that are taught in Engineering Management programs and it is not possible to include all of them in a Master's program. Inclusion of one topic means exclusion of another. Thus the curriculum design including the course content for the master programs become even more crucial. The following sub sections look at the literature before homing on the methodology for deciding the contents of a Master's program.

2.1 Curriculum Content Among Programs

Cherbaka and Lavelle [4] identified 38 topics covered as the core curriculum in Engineering Management programs and the percentage of programs covering them varies from 2 to 96. Typical topics in the list are organizational and people management, project management, product development, leadership and design for manufacturing. A similar attempt by Peterson and Humble [5] report topics ranked according to credit hours in the top 28 universities having the largest student enrolment in Engineering Management. The list includes topics like engineering economics/finance, project management, production operations management, management of product design and statistical quality control. Collins and Youngblood [5] report another set of courses by evaluating seventeen prominent Engineering Management programs. This list includes engineering management, project management, production management, information systems and quality engineering. They also report that sixteen out of the seventeen programs considered 30-36 credit hours for the award.

2.2 Curriculum Requirements by ASEM

The coverage of diverse topics prompted ASEM to define Engineering Management and regularise the coverage. They formulated a certification program for Engineering Management courses. Requirements for certification by ASEM [6] are as follows:

1. A balance between qualitative and quantitative courses.
2. At least one third of the curriculum is management and management related courses.
3. Courses designated 'Engineering Management' are in the academic catalogue
4. Courses must be related to technology driven organisations
5. The curriculum must require each student to demonstrate command of written and oral communication skills in English
6. Courses must relate to knowledge workers in a global environment
7. Each student is required to perform a capstone project or thesis using analysis and integration of Engineering Management concepts
8. A minimum of one course in probability and statistics
9. A minimum of one course in engineering economy
10. Two courses in quantitative analysis

2.3 Influencing Factors in Engineering Curriculum Design

Traditionally curriculum, the organised set of content and activities, is the means by which universities achieve the teaching objectives. Reviewing the literature Sivaloganathan [7] identified the influencing factors for Engineering Education as (a) country's requirements (b) attitudes and skills that are required by engineers for being effective in the field (c) areas of employment open for engineering graduates (d)

attributes specific to developing countries (e) attributes specific to developed countries (e) accreditation requirements and (f) international developments. Out of these attributes specific to developing countries is a special one. Grayson [8] also identifies part of the difficulty that arises due to the fact that advanced technologies are introduced into the developing countries in their current fully developed forms. Students from such countries lack the experience of participation in the development and growth of these technologies from initial concepts to their present form. They lack the heartaches of failures, Eureka moments of overcoming them, and the techniques used in the overcoming process, which are all important for a designer. These experiences are the building blocks for introducing new technological advances into old products and processes. Thus exposure to applications of basic engineering principles in the form of artefact studies becomes a fundamental need of the curriculum in a developing country. On the other hand the requirements on the curriculum in a developed country are to bring in the latest advancements in the scientific principles and the manufacturing technologies. The problem is further exacerbated in developing countries that aspire to grow faster and reach the developed country status. They have to embrace both exposure to basic engineering principles as well as the application of advanced latest technologies.

2.4 Methodology for Program Design

ABET [9] identifies the Program Constituency as the starting point of the design of a program. The University consults the program constituencies and formulate the 'Program Educational Objectives'. These are then deployed as 'Student Outcomes'. The university then designs the courses and the student outcomes are further deployed into 'Course Outcomes'. The university devises the course content or activities, which provide the learning experience to the students to achieve the intended course outcomes. Assessments are carried out at various stages and students who reached the pre-defined standards become graduates. They then go back to the constituencies and serve the community. Now the evaluation starts in a big way. As Barbara Walward [10] puts it "Assessment tells how an individual student performed with respect to many student outcomes, while Evaluation tells that, while students are strong in X and Y they are weak in Q and R. That detailed information tells the department what to work on". This is schematically shown in Figure 1. While this procedure is reasonable for programs with an identifiable constituency from the inception, it may not be suitable for programs developed in regions where the program title itself is not widely known. In such situations a "Design and Debug" approach can be taken. The university entrusts the task to a learned faculty member to make an initial draft of the program. The draft document is then sent to identifiable international experts for evaluator comments. This consultation process goes through iterative cycles until a consensus is reached. The document is then submitted for approval through the various committees.

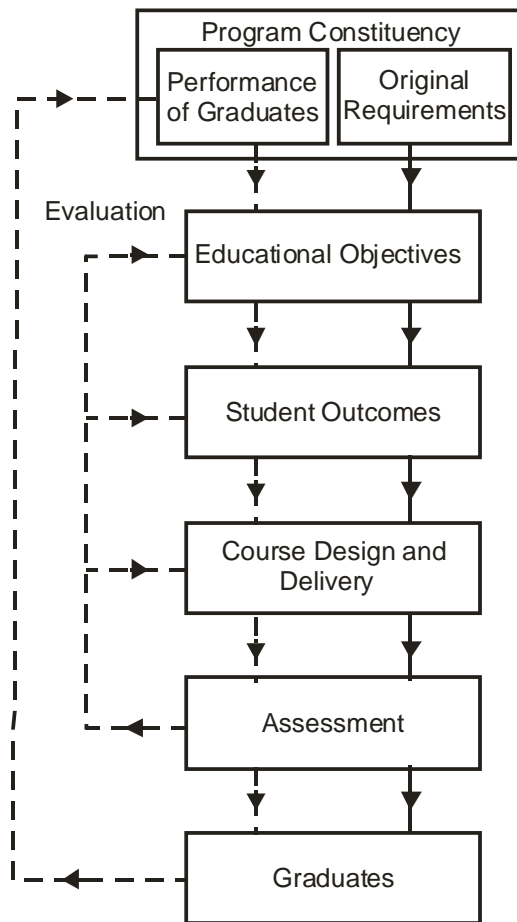


Figure 1: Program Design and Maintenance Methodology

3.0 Engineering Management Program at United Arab Emirates University

United Arab Emirates University (UAEU) is the first and foremost comprehensive national university in the United Arab Emirates. Founded in 1976, UAEU is a comprehensive, research-intensive university enrolling approximately 14,000 students. As the UAE's flagship university, UAEU is committed to offering a full range of accredited, high-quality graduate and undergraduate programs. UAEU works with its partners in industry to provide high calibre graduates and research solutions to challenges faced by the nation, the region, and the world. UAEU's academic programs have been developed in partnership with employers, so the graduates are in high demand. UAEU alumni hold key positions in industry, commerce, and government throughout the region.

The College of Engineering and the College of Business and Economics at UAEU jointly launched the Master of Engineering Management (MEM) program with sixteen 2-credit hour courses in 2006. This program is the synergic integration of engineering and business skill sets that equip students with the technical expertise, leadership and the insight needed to excel through the many facets of the fast-paced world of technology. In general, MEM program enhances knowledge building in engineering process and project management, quality engineering, and operations

research, and combines it with leadership, financial and management accounting, decision techniques and supply chain management from the business side. This equips the graduate with the knowledge and skills necessary to lead engineering teams and complex projects. In this program, Product Development and Engineering at large is enhanced by engineering process, project and quality management and complemented by leadership skills, decision techniques, supply chain management, and financial and management accounting techniques. It has been developed within the context of UAE and the region. The educational objectives of the program are to provide graduates with:

- Knowledge about management of existing and emerging technologies.
- The management decision-making skills.
- The professional leadership and management skills
- How to carry out cost estimates, financial, and economic analysis
- How to integrate quality, HSE, and other engineering considerations in technology management.

At the beginning of the program, the sixteen 2-credit hour courses allowed the coverage of a wide variety of topics, which were meant to address the needs of the industry at large. However, after five years the college decided to streamline the program while also maintaining the program's competitiveness and value to the students and community at large. This also meant focusing on smaller number of courses that were identified as core needs of the program and more beneficial to the graduates and industry. Therefore, the sixteen 2-credit hour courses were reduced to eleven 3-credit hour courses. This was also in line with the College of Engineering's plan to unify the credit hours of all graduate courses as 3-credit hour courses, which allowed the students in any of the College graduate program to take relevant courses from other programs. This was based on the recommendations from the faculty members and executive committee members of the master programs as well as the college administrators. Moreover, the College implemented a set of core courses for graduate students in common areas such as math, statistics, analytical and numerical simulations and Environmental Impact Assessment. Students from different graduate programs in the college may attend the same courses, thus reducing the number of offered sections, which reduced the teaching load and optimized the use of available resources and facilities.

Courses including Managerial Economics and Maintenance Engineering were removed from the MEM program, a few courses (Project Management for Engineers and Project Planning & Control; Action Project 1 and Action Project 2; Marketing Management and Product Development) were combined, and the content of some courses were modified to change them from 2-credit hour to 3-credit hour courses. Five of the eleven courses from the new curriculum are taught by the College of Business and Economics and the College of Engineering teaches the remaining six courses. Product Design is at its infancy in the country but it is a very much needed knowledge and skill even to evaluate designs and to manage design of large projects with international suppliers. In line with UAE's aspirations to be at the forefront in the international arena Product Design and Development was taken as a core provision in the Engineering/Technology side, thus taught by the College of Engineering. With these changes, the college believes that the MEM program has been strengthened with the 3-credit hour courses. The number of students has also increased as a result of these changes as shown in Figure 2. The numbers for the

Spring 2013/2014 intake have not been announced yet. It is expected that the number would exceed 45.

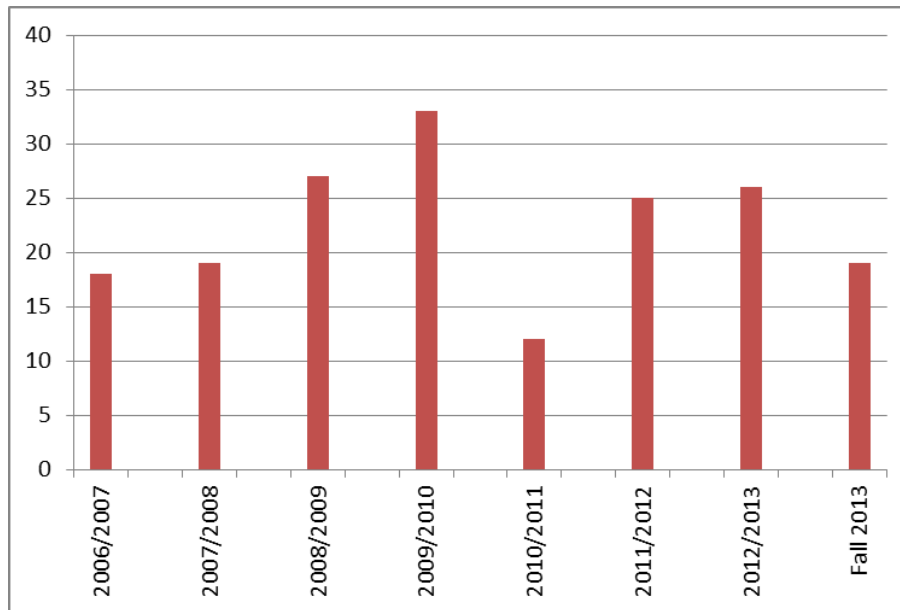


Figure 2. Student Enrolment in MEM Program Since Establishment in 2006.

Currently, the MEM program comprises eleven 3-credit hour courses and is run over two years or four semesters. The award of Master of Engineering Management degree requires the attainment of 33 credit hours with the average GPA greater than or equal to 3.0. Students can join the program in September or February in each year and can complete the program in two years. Each course is delivered in eight weeks on a one day per week basis with classes starting at 5.00 PM and finishing at 9.30 PM. The MEM program has established a constituency with its alumni, who have been actively involved in promoting the program by giving presentations and helping organize its activities such as orientations, guest lectures and various events.

So far, admission to the MEM program has required a bachelor of science degree from a university recognised by the UAE Ministry of Higher Education and Scientific Research, a minimum GPA of 2.5 out of 4.0, and proficiency in English with a minimum score of 500 in TOEFL or 5.0 in IELTS. Plans are currently underway to get accreditation by the UAE Ministry of Higher Education and Scientific Research based on the Commission for Academic Accreditation (CAA) standards. As such the admission requirements will become higher with minimum GPA of 3.0 out of 4.0 and minimum score of 550 in TOEFL or 6.0 in IELTS.

4.0 Product Design and Development Course within the MEM Program

Product design and development is an important course in the MEM program because companies are involved with design, either as its consumers or producers. Engineering managers have to involve in the management of product design and development either as a part of a designing team or as a purchaser of a system that is being designed. Design process is often described as a stage model or activity model. The stage model often is static with specified number of stages to include design

brief, specifications, conceptual design, embodiment and detail design while the activity model can incorporate several design methods such as quality function deployment and morphological analysis and will vary in size in accordance with the size of the project. Teaching the process would be relatively easy if the students are all graduates from a specific discipline of engineering. Finding examples to reinforce the understanding of the tools would also be easy. However the admission policy for the program permits graduates from all branches of engineering and science disciplines to enrol. The challenge therefore lied with the choice of examples and the project. Considering the above the teaching methodology was divided into three parts: (i) teaching the design process consisting of design models, methods, approaches and outputs (ii) using the techniques to design and build a new product using the methodology and (iii) developing a design management strategy derived from their project experience.

4.1 Teaching the Design Process

The teaching process started with the description of design as the process to create technologies using science that allow work to be done faster, easier, more thoroughly, consistently and economically. The concept of Design Process was introduced as the description of the sequence of steps taken by a designer in converting an abstract set of requirements into the definition of a physically realizable product or system. Examples showing the stages or milestones in the design process were discussed. With these the definitions were introduced. Fielden [11] defined engineering design as the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with the maximum economy and efficiency. ABET [9] defined Engineering Design as the process of devising a system, component or process to meet desired needs. Description of the stages the design process goes through is defined as the Design Model and a design model with five stages namely (i) requirements (ii) product concept (iii) solution concept (iv) embodiment design and (v) detail design was discussed in detail. Activities that take place at each stage and the outputs from the stages were also discussed. Design Methods were introduced as tools and techniques used at various stages of the design process. Design methods usable at each stage of the design model described were also discussed in detail. By this time the students had become familiar with the process and the terminology.

At this stage a general discussion on design was initiated. Two observations (i) the design problem is often ill defined and (ii) the design solution space is unknown, were identified as the characteristic characters of a design problem. The challenges faced by a design team therefore are to (i) define the design problem properly and completely and (ii) identify the region where the optimal and near optimal solutions lie and identify the preferred solution from that region. Partitioning the solution space into 'haves' and 'not haves' with respect to a property was discussed as an approach for reaching the potent region quicker. With respect to conceptual design several design methods including ideation through answering a set of questions, brainstorming, morphological analysis and analogy were discussed.

5.0 The Project

The objective of the project was to gain practical experience in design by applying the systematic design process consisting of design models, methods, approaches and outputs as learned in the course in a 'design and build' project. Twenty-three students were divided into five groups. The design brief development was discussed in the class. In this context the design brief was defined as the document given by the senior management to the design team for the development of a product. After a discussion title of the project, author of the document, product description, product concept, benefits to be delivered, position in the market including price, target market, assumptions, stake-holders, possible features and possible areas for innovation were identified as the key elements of a design brief. The product designed and developed is called a Reading Assistant and the description in the design brief is as follows:

The product is a simple, lightweight, and portable mechanism that enables users to easily switch between several books. It keeps all the current set of books in open position which facilitates note taking and eliminates the need for frequent opening and closing of books. The height of the presented book for reading is adjustable to the comfort of the user.

5.1 The Requirements

The essence of this stage is to understand the features that the customer wants to have in the product when using it in a measurable form and in an order of priority. Since the product is new the customer has to be given a good briefing before recording the requirements. In general the process starts recording customer verbatim. The design team then translates it into actionable requirements called needs. Some of these needs are mandatory while the importance of some may vary with the customer. Thus a chosen set of needs is referred back to the customer to obtain their relative importance. The need should be measurable so that its attainment can be measured and this measurable quantity is called a metric. Thus the requirements are presented as a set of prioritised needs with metrics and units to measure them. This is the output of the requirements stage. This was a difficult process for the students. Some students interviewed professors and research students while some students used other students as customers. Their collection of verbatim was discussed in class and a common set was agreed upon. From this point each group went in their own direction to establish the final set of prioritised needs and metrics.

5.2 Product Concept or Specifications

A product is designed to perform some functions and thus the functions are the outputs of a product. The objective of this stage is to define the functions or characteristics of the product with specific values and units that will satisfy the customer's needs established in the requirements stage. The first step in this stage is to establish the functions and structure them in some form. The students used affinity diagram method to first establish the function list and then form the hierarchical structure, the function tree. With the established functional sub-systems they carried out a preliminary morphological analysis to gain some insight into some solution path and the feasibility of the product. The developed morphological chart is shown in Table 1.

Once they identified the feasible routes they reconciled the customer needs, the function tree and the solution paths to draw the specifications. In this context it can be said that a metric and a value form a single specification and product specifications are a collection of individual specifications.

5.3 Solution Concepts

In this stage conceptual solutions are proposed, analysed and evaluated and an optimal solution is chosen. Robin [12] after analysing case studies from two prominent designers Dyson and Sanders states “*The basic concept of both Dyson’s innovations arose from a mental transfer of technology from one application to another. Sanders, on the other hand, tended to seek analogies between the problem he was trying to solve and products or components with similar functions*”. The students took two specific approaches and they were similar to those identified by Robin (i) developing something they have seen somewhere else and (ii) analogy. They all decided to stay away from developing a table or a big surface to keep many books and followed individual area for each book. The space was divided as moveable surfaces or fixed surfaces and all opted for moveable surfaces. Each group generated three or more concepts before analysing and choosing one according to a set of criteria drawn by the groups from the design brief.


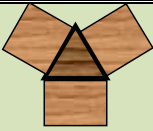
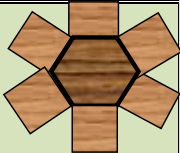
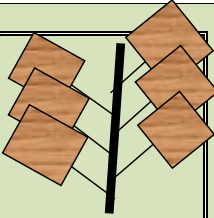
5.4 Embodiment Design

The embodiment stage is aimed at producing three main outputs (i) the parts tree (ii) make/buy decisions and specifications for the parts to be bought and (iii) the layout of the product. Many calculations and visualizations were necessary at this stage. Requirements from remote areas come out and derail the designs that are otherwise very good. For example the product should go through a standard door is a requirement that has become a limiting factor for some designs. Design for Manufacturing is a philosophy and mind set aimed at designing parts and products that can be produced more easily and it is applied heavily at this stage.

5.5 Detail Design

At this stage the entire details including material and dimensions of parts are defined completely so that the product can be manufactured. Often a CAE software is used to model the parts and assembly at this stage. This contains all the details needed for any analysis. Engineering calculations would have been carried out earlier at part and sub-assembly levels but now the complete product is available for analysis. Normally all possible analyses are not carried out. The worst-case scenarios are formulated and the necessary analyses are carried out to prove the viability and safety of the product. Two of the five groups used CATIA software to model the product and to produce the set of production drawings. Stability in the worst-case scenarios was considered and they ensured that the product was viable and safe. The finished products are shown in Figure 3.

Table 1: Morphological Analysis:

Book Support				
Working Area	Integral	Separate		
Mobility	Wheels	Lifting	Sliding	
Book position	Sliding	Rotating	Grabbing	
Height Adjustment	Individual	Assembly		
Reading Pane Movement	Sliding	Tilting		
Space for Accessories	Integral	Separate		
Stability	Wheel Base	Counter Weights		
Appearance	Shape	Arrangements of Panes		
Material	Plastic	Wood	Glass	Acrylic

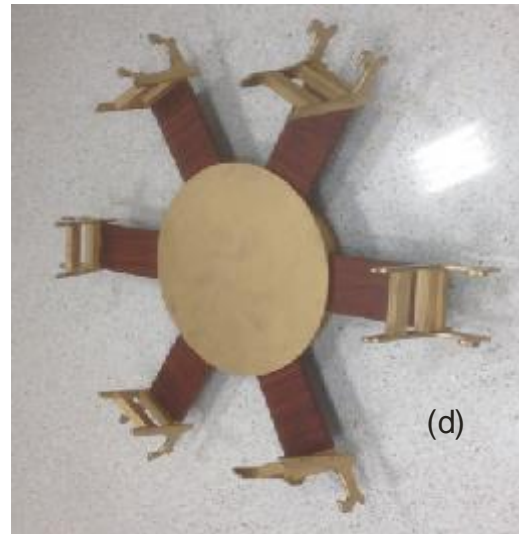


Figure 3: Finished Products from All Five Groups

5.6 Lessons learned for Managing Future Design Projects

The students followed a five staged systematic design process and produced eighteen intermediate outputs in six weeks. They are

- 1- The Design Brief
- 2- Customer verbatim
- 3- Customer needs with important ratings
- 4- Need metric matrices
- 5- Metrics and units
- 6- Function diagram
- 7- Product Specifications
- 8- Conceptual design
- 9- Concept selection and the selected solution
- 10- Embodiment design – parts tree
- 11- Make/buy decision
- 12- Specification and dimensions of items to be bought
- 13- Layout design
- 14- Raw material specifications for items to be made
- 15- Detail design – Preferably the CAD Model
- 16- Engineering Analysis / Detailed design
- 17- Set of Production Drawings
- 18- Building the product (Proof of product prototype)

Considering the above outputs, the students made the following observations in their description (aimed at design management) of the learning experience:

- i. The design model was a very useful roadmap that kept them focussed towards the end goal. It was very useful to have pre-planned intermediate outputs at the end of each stage.
- ii. A detailed design brief gives a good scoping of the project, which leads to the next stage namely requirements. The design brief also described the product details that were used to form the criteria for choosing the concept. Though the elements identified and provided in the brief was adequate for them to complete this project additional details may be required for specific projects.
- iii. Activities performed in the requirements stage in general and in particular the establishment of metrics were new to them. They found it a very useful technique and said that they would consult the operators and maintenance crew when they write specifications for equipment.
- iv. Blending the function tree and the prioritised needs to write the specifications was a topic that has been spoken about from the time of their graduation projects, but was never understood fully. This project has made them to realise how to do it.
- v. Establishing the parts tree was a new technique that the students found useful. This gave them a holistic picture and an estimate of the remaining work. It also gives the basis for cost estimation.
- vi. The detail design, though familiar with the courses in geometric modelling during the undergraduate studies, got a new meaning with this project.

The students in general said that the six points above would be in their mind when they work on strategies for new designs either as a consumer or producer.

6.0 Observations and Analysis

The first and foremost observation was the rapid growth of confidence among the non-mechanical engineering and science graduates based on the design model and the pre-defined interim outputs. As a matter of fact a group with no mechanical engineering graduates came up with the most creative and elegant product following the systematic design process to the letter. All groups needed handholding during the first two weeks but after that they worked almost by themselves with limited input from the instructor mainly as comments on evaluation and decision-making. The opportunity to work on a project from A to Z with everything under their control was one of the main driving forces.

At the beginning of the project it was decided to make observations on (i) organized structure and cognitive action (ii) scoping and information gathering (iii) consideration of alternatives and (iv) gathering basic data such as information, calculation methods, terminologies and typical values. But as the project progressed it was felt that the source that triggered the initial idea of the concept should have been recorded. As a consolation the students were asked to describe the source that triggered the idea for the concept.

Organized structure and cognitive action – This was evident in all groups mainly because the design model governed it and there were pre-defined interim outputs at each stage.

Scoping and Information Gathering – The project was too small to have a big activity here. However the students have understood the need for scoping and places to look for the required information.

Consideration of Alternatives – Each group has come up with at least three concepts. The criteria for choice however came from different corners. Attractiveness, original and different, elegant and a status symbol were some of the unusual factors included in the criteria. In short there was creativity in both the concepts as well as the selection methods.

Gathering Basic Data – This was a problem for non-mechanical engineering graduates. However once explained they did not feel about their shortcoming and proceeded as normal. They also had difficulty in handling CAD software like CATIA. These suggest that they should either plan to have members who as a whole possess all required competences or should hire consultants for specific services.

Sources Triggering the Concept–Each of the five concepts were triggered by different sources. Table 2 summarises the sources.

Table 2: Concept Triggering Sources

Concept	Triggering Source
a	The idea came from 'Hanging Toys' for Babies. These toys have items, often artwork, hanging vertically when they are stationary and go at an angle when the motor rotates them.
b	This concept is the development from the rotating displays of picture post cards in newsagent shops. They rotate about a central axis with cards displayed in cylindrical casings of various forms.
c	The idea was originated from a rubber plant which has large leafs connected to the trunk of the plant through a stem. The design was similar with rotatable stems.
d	This concept was developed from the rotating food server sometimes called the 'Lazy Suzie'. The mechanism could be put on a table or on a stand.
e	This team started with looking at the table and attempting to modify it with additional function-providing features. They considered the seated position of the user and tried to provide the books to the user from various ways.

As a course in the engineering management program the main outcome is the ability to formulate a clear systematic process for product development, which the students could use in their professional work. The main benefit is the ability to look at product design and development from a managerial point of view with the knowledge of the intricacies of the various stages of the product development process.

6.1 Conclusions

Analysing the literature and information in the public domain reveals that engineering management has a wide variety of topics included in the curriculum. Since all of them cannot be included in a program at the Masters' level a choice of topics has to be made. These choices have to be based on various criteria. Literature and ABET guidelines suggest the requirements of the nation or constituencies should be used. UAEU has started the Mater of Engineering Management program with international referees' comments and wider coverage. After running the program for five years and creating an alumni constituency the college rationalised the program with 11 courses with a total of 33 credits. The program has become more popular after the change and this is reflected on the rapidly increasing number of student enrolment.

Product Design and Development is a main provision of the Master of Engineering Management program. Students taking the program come from a wide variety of backgrounds. The challenge therefore lies with the delivery of the course content.

A delivery method with three parts: (i) teaching the design process consisting of design models, methods, approaches and outputs (ii) using the techniques to design and build a new product using the methodology and (iii) developing a design management strategy derived from their project experience, was introduced and observations were made. On the whole, all the students had an enjoyable and highly value added experience. The product was easily understandable and the students

could focus on the process. They could apply the course material straight away on the project and this made them feel confident about doing the project. Most of the students had the opportunity to see all the stages in the design and development of the project for the first time.

Students identified six points that would be useful to them in their professional life. They could apply them to manage design projects if needed. All conceptual designs stemmed from two sources: (i) applying something seen somewhere else in a different context and (ii) analogy. This observation can be beneficially used to choose projects for future student work.

As an overall summary it can be concluded that the model used to teach design and development was effective. However the success depends heavily on the identification of a suitable product for the design and development.

References:

1. Gupta A,K. Engineering Management, Chand Publisher New Delhi 2007.
2. ASEM http://louisville.edu/speed/industrial/Eng_Mgmt Visited on 23rd December 2013.
3. Peterson W. and Humble J., Engineering Management, *The Body of Knowledge as Defined by Coursework*, Proceedings of the ASEE Annual Conference 2007.
4. Cherbaka N. and Lavelle J., *Proposing an Engineering Management Program at North Carolina State University*, Proceedings of the ASEE Annual Conference 2009.
5. Collins T.R. and Youngblood A.D., Engineering Management Program Re-Evaluation, Proceedings of the ASEE Annual Conference 2002.
6. http://www.asem.org/ASEM_Docs/EM_Masters_Program_Certification_-_Academic_Standards.pdf Visited on 29th November 2013.
7. Sivaloganathan S. *Influencing Factors from the Literature for Engineering Education*, The journal of the Institution of Engineers Sri-Lanka. December 2003.
8. Grayson L.P. *The Design of Engineering Curricula*, UNESCO Studies in Engineering Education, United Nations, Paris 1977.
9. *Criteria for Accrediting Engineering Technology Programs, Effective for 2011 – 2012 Accreditation Cycle*, ABET Inc. 111 Market Place, Suite 1050, Baltimore, MD21202, USA.
10. Walvoord B. E., *Assessment Clear and Simple, A Practical Guide for Institutions, Departments and General Education*, Second Edition, Jossey Bass 2010.
11. Feilden G.B.R., Engineering Design, Her Majesty's Stationary Office, London 1963.
12. Robin R., Case Studies of Creativity in Innovative Product Development, Design Studies Vol. 14 No 4 1993 pp 423 – 443.