INTEGRATED PROJECTS: POSITIONING DESIGN AS THE UNDERLYING INGREDIENT TOWARDS INTEGRATING SUBJECT AREAS WITHIN AN UNDERGRADUATE PROGRAMME - A CASE STUDY

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ABSTRACT
This paper provides a case study on how design as a process can be used as an underlying foundation to link and integrate several subject areas. The paper discusses the process in which learning outcomes from different subject areas are identified and the creation and execution of an 'integrated project' is delivered to students in order to improve the students' understanding these outcomes, both individually and holistically. Assessment of the learning outcomes of the course before and after the introduction of such an integrated project is presented as well as a detailed account of the results and experiences of both the students work and academics observations. Also, observations on increased students' engagement is highlighted and lessons learned are documented. The case study was a mini-project given within the 'Introduction to CAM' course, which is typically a course that does not cover other subject areas as part of its curriculum. The main subject areas covered for the integrated project case study included but were not limited to: geometric modelling, CAD, NC manufacture, machining, industrial design, entrepreneurship, and project management; all under the umbrella of a design process to design and build an artifact. Both a quantitative and qualitative approach is used to analyse the outcomes of such an integrated project and the results are extremely encouraging.

Keywords: Design activity model, bezier curves, NC machining, integrating projects, learning outcomes

1 INTRODUCTION

A university teaching engineering in present times has two responsibilities: (i) to equip the students with sound knowledge in both engineering science and technology and (ii) to teach them how to use the knowledge gained in design. Integrating Project within courses aim to combine the knowledge chunks gained from the courses the student has already studied and those from the current course to solve given design problem. Pugh [1] rightly observes that "*Contrary to much common opinion projects per se do not achieve the necessary integration. Projects can still be diffuse and unintegrated. The design activity model and structured methods are those that make it operational and integrate diverse people and knowledge into effective decision making on critical issues*" He further argues that '*Design is an amalgam of specialist inputs, and the design of an artifact that is not based upon such an amalgamation does not exist; It is the picture on the box, that matters as well as the individual pieces of the jigsaw*'. Elaborating on this, two issues can be observed: (i) several specialist inputs or knowledge components (the pieces of the jigsaws) are required for any design and (ii) the overall objective of that design or the holistic view (the picture on the box) is different from design to design and hence different knowledge chunks (jigsaw pieces) are needed for different designs. The research question therefore is 'whether positioning design as an underlying ingredient enhances the learning experience of students'. This paper reports on the learning experience the United Arab Emirates University students had through the integrating project in their Introduction to Computer Aided Manufacturing course.

2 THE PROJECT

The project was to design a memorabilia clock for UAEU consisting of three parts (i) a clock insert bought outside (ii) a body to house the clock insert and the name tower or logo and (iii) the name tower itself. The main design task is that of the body. In order for the students to feel the importance and grasp the holistic picture the students were asked to work as partners of a fictitious company making a bid. The brief given to students is described in section 2.2. The components that needed to be amalgamated in order to realize a successful conclusion to the project are illustrated in Figure 2.

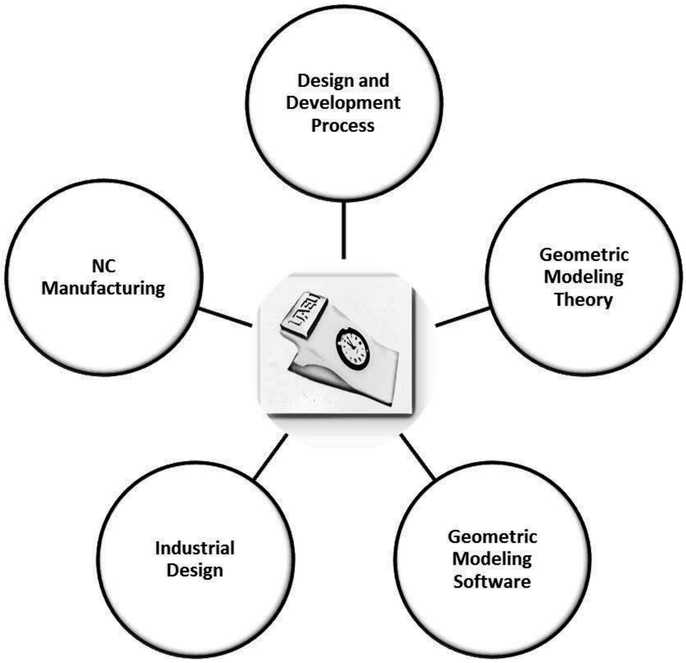

Figure 1. Component combination for a successful project

2.1 Objective and Learning Outcomes

The integration expected from this project was a combination of curve definition, use of high powered software for it, machining practices, NC manufacture and industrial design aspects under the umbrella of a design process to design an artifact. The project therefore did not involve knowledge chunks in structural analysis, heat transfer and the like.

The expected learning outcomes of this project were the (i) ability to grasp the formation of a project specific design activity model (picture in the box) (ii) identification and mastery of the knowledge components required (jigsaw pieces) and (iii) development and usage of structured methods (the details of the pieces). In the specific case of this project the brief detailed in section 2.2 was prepared and given to the students.

2.2 Project Brief

With emphasis on delivering a 'product' students were presented with the following Project brief:

> *"Following the traditions of big universities United Arab Emirates University wants to produce some memorabilia. A table clock has been considered with several other ideas and has been selected as the most appropriate one. It consists of a suitably designed stand onto which a clock insert is fixed. The manufacturing process considered for the stand is a 2.5D profile milling followed by the drilling of a hole and gluing a tower for the University Logo. The university wants to make 1000 pieces of this. It wants to contract this job out. You are a group of*

mechanical engineering graduates just graduated from UAEU and are in the process of forming a product design and manufacturing company. You want to have this contract to launch your company. But the competition is very high. Several companies are bidding for the contract. Make a bid on the specified format given."

Each group was asked to submit the following together with a convincing presentation.

1. An Innovative name of the group with an explanation of the name not exceeding 50 words
2. Plan of their development process
3. Conceptual sketch by each member of the group and the selected concept. The reasons for selecting the chosen concept also should be given.
4. Fragments of the profile into curve segments and the identified control points using CorelDraw software
5. The equations of the Bezier Curves
6. The NC Code and evidence of running Simulation
7. Produced Profile, hole and the name tower
8. Description and comments about your learning experience

3 DEVELOPMENT PROCESS

From the inception the students realized that the project needs knowledge components on the design process, geometry, use of CAD software, industrial design considerations, and manufacturing in general and NC manufacture in particular. From the theory of Bezier curves they understood the flexibility offered by it but one group started with combining circular arcs together in their design (See Figure 2 (a)) and realized that their design has lost flexibility. They abandoned the concept and used Bezier curves instead and they had more prospective in shaping the curves. Their model is shown Figure 3(a).

The development process followed by all eighteen groups of students went through several stages. They first divided the product into three parts, the body, the clock and the university logo. The body has to reflect the characteristic character of the university while housing the clock and the tower for the logo. Thus the design task focused mainly on the housing which was constrained to be manufactured by 2.5D milling. Firstly, each group started by three conceptual designs to reach the ingenious design. The concept selection was one of the most important decisions that have been taken by each group during the development of the product. One concept was chosen for further development. The sketch was then broken into different curve segments that are easy to model in the second stage and transferred as the node points of the individual curve segments to the computer software CorelDraw. In the software, the lines connecting the node points were converted to Bezier curves and their control points were obtained. Each group had several curves and started establishing the equations of their respective Bezier curves using matrices. Having thus finished the design process NC programs have been developed where a 8mmØ slot drill tool was used in milling to cut the body from a rectangular Nylon block of size 35mm x 48mm x 110mm. All groups kept the design heights as 48mm. Drilling the 35mmØ hole for the clock insert was the next step where the work piece was fixed so that the area housing the clock was horizontal. The last step was the production of the name tower with dimensions 43.5mm x 20mm x 3.5mm and gluing it to the body. Using 'Techsoft' design software and the milling machine the logo of UAEU was engraved.

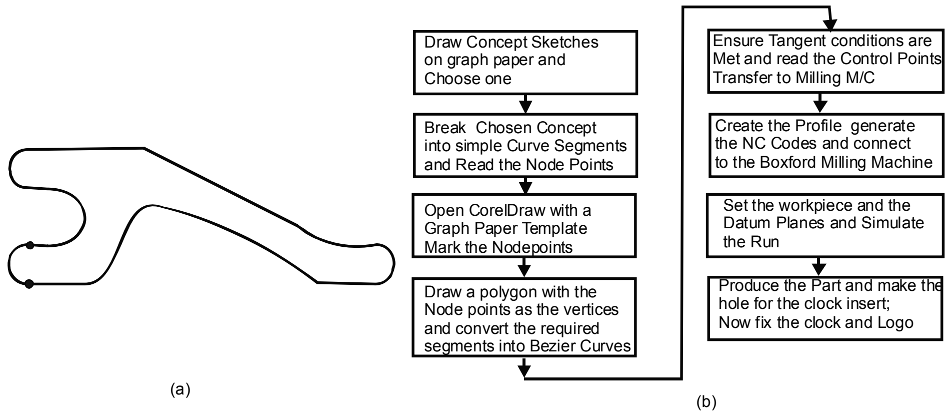

Figure 2. Design process model flowchart

4 OBSERVATIONS AND CONCLUSIONS

This course has been running for several years, yet in previous years, it focused predominantly on introducing computer aided manufacturing basics to the students and such an ambitious project was not offered. Furthermore, the output of practical tasks in previous years was not only much simpler but final Course Assessment Forms and feedback (filled by both the course instructors and students) had repeatedly shown a lack of full understanding of even the basic CAM material by a significant portion of the students. Previous assessment had shown that understanding parametric curves was not fully grasped by students and that the NC codes was simple information obtained from existing texts and no real understanding on developing their own NC information. By offering a CAM only project in the past, students had failed to grasp fundamental aspects as well as the intended scope of the course. However, by offering students this integrated project, the first and foremost observation was that the students' need to know the full extent of the work. The process model presented to them alleviated many potentially problematic issues.

The project ran over a period of about eight weeks but the sense of overwhelm and fear of failure disappeared after the second week upon going through the steps of the design process. All groups commented that without the design process model in place, they would have been completely lost and would have been unsure on where to begin. The idea of an integrated project to the students was also one received with excitement especially when they realized they were going to make a complete product from concept to realization within a short space of time. The students spent a lot of time and effort to choose very creative names showing that the product has raised their passion. The list of documents required in the submission helped them to decide the tasks in the design process. Figure 2(b) shows the typical design process model followed by most of the student groups. Although the students' followed the design process, the reason for the enthusiasm was not for the model itself. This was seen as a useful guide for them to achieve their 'real goal'. The real involvement of the students came with the conceptual sketches. Each group was motivated to win the contract and the competition was evident. They wanted some kind of symbol to recognize the youth of the country and their strength. Several good sketches were produced by the students. Many sketches had around 12 sections and had some kind of twist in the final design. Learning CorelDraw to produce the sketch to obtain the coordinates of the control points would have been difficult and needed many classes. But the urge to finish first and to go to the manufacturing in CNC made them to learn CorelDraw quickly. The students were required to show the equations of the curve segments to start manufacturing. This made the students to learn and understand Bezier curve thoroughly. NC manufacture had the same effect.

All in all the students had the benefit of the design process model or the picture on the box. By treating this project as a 'mini design' project and following a design process model, it was observed that the students always felt grounded and that they knew what was needed to realize their product. The striking point was that everyone was enthusiastic and all students had a product at the end. The students became emotionally attached to the project. They saw the flexibility of Bezier curves and the power of the software. It also enabled them to dig deeper into Geometric modelling theory that in previous years was simply not done by the students. The final Course Assessment form represented this in a resounding way on both the achievement of the outcome in Geometric Modelling and CAM but also other areas that were not included in previous years. All in all, the project achieved its objective, the integrated application of the intended knowledge chunks.

The results can be summarized as those shown in Table 1.

Table 1. Observation Summary

Observed Behaviour	Observation
Use of design model	Used as a guide and a means to an end. Without understanding the design model and process, students felt a bit lost initially and a sense of fear and overwhelm. As soon as they understood 'what they had to do', these feelings dissipated
Enthusiastic Participation	Competitive nature of the project really enabled the enthusiastic participation and the need to study more, Naming, sketching, CorelDraw and CNC machining
Command on Bezier Curves	Students from previous classes tended to select the simplest form of Bezier curves to generate the equations. Here the complexity of the curves was led by the desire to make the 'best' product. This forced the students to better understand the theory needed to generate the required curves they imagined their part to be.
CNC Programming and Simulation	The diversity of subject areas kept the students interest and for them set 'mini-milestones'. They were excited to progress to the next stage and wanted to make their part before the other student groups.
Creativity	Creativity was abundant, primarily due to the spirit of competition and enabled the students to look at geometric modelling theory from a different perspective; one where they saw a real use for the equations. Students mentioned several times that it was one of the first times they saw complex mathematical equations implemented in real life.

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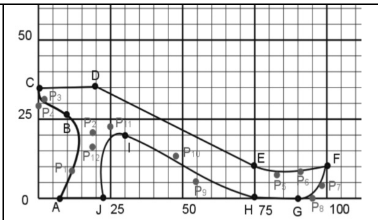
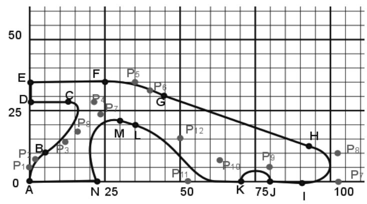
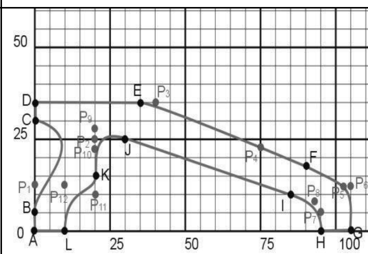
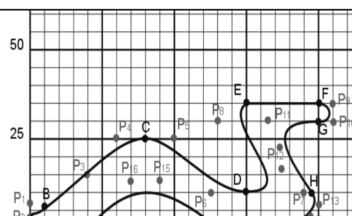
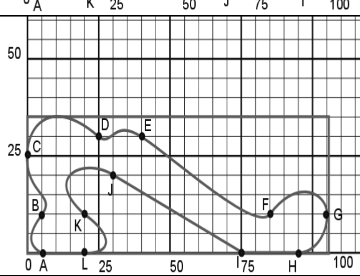
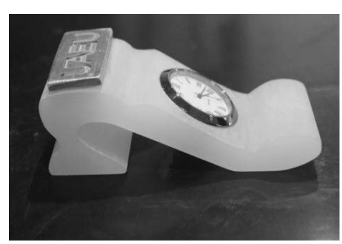
Victory Group (a)		
Infinity (b)		
Mechanical Maestros (c)		
Techno-D (d)		
Creamy Wave (e)		

Figure 3. Corel draw sketches and final models