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A STUDY OF STUDENT LEARNING IN DESIGN PROJECTS

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ABSTRACT
Undergraduate courses in design engineering address both the form and functional design of products. This apparently simple objective belies some of the real challenges faced in educating students on such courses. These challenges tend to relate to achieving a balance in the consideration of form and functional issues in a manner appropriate to the product context being considered. This paper will describe a study undertaken at the University of Strathclyde that attempted to develop a better understanding of student learning with respect to this issue.

Keywords: design, group project, team working, conceptual design, prototyping

1 INTRODUCTION

The Department of Design, Manufacture and Engineering Management (DMEM) at the University of Strathclyde in Glasgow has offered degree programmes in design engineering at Batchelor and Master of Engineering level since the early nineteen nineties. These courses have proven to be very attractive to potential students and employers due to the blend of practical engineering, design, business and inter personal skills that they contain.

The courses place emphasis on achieving a balance between the consideration of form and functional issues in product design in a manner appropriate to the product context being considered. This apparently simple objective belies some of the real challenges faced in educating students on such courses. Furthermore, the challenges are dynamic as new technologies and support tools change the educational perspective on an ongoing basis. This paper will describe a study undertaken at the University of Strathclyde that attempted to develop a better understanding of student learning with respect to these issues.

2 RATIONALE

A review of student design engineering projects undertaken in DMEM over the past five years identified a number of characteristics and trends.

- An increasing focus on geometric modelling and rendering with a corresponding increase in the quality of rendered images;
- An increasing reluctance to explore product layout, component configuration or to conduct appropriate analysis or modelling;
- An increasing tendency to select a product concept for further development without due analysis, rationale or exploration;
- A decreasing focus on and quality of layout and detailed engineering drawings;

- An increasing tendency to work in a serial fashion with little iteration or concurrent use of methods, tools etc. e.g. physical modelling, analysis etc;
- An increasing tendency to focus on form rather than function in concept sketches e.g. concept sketches often do not show how mechanisms operate and tend not to be annotated.

The overall trend appears to indicate that students are increasingly placing more emphasis on form related issues to the detriment of function – in extreme cases to the extent that no evidence is provided as to how a functional product might work. There also appears to be an increasing tendency for students to follow a singular path towards a design solution without due exploration and reflection. We do not believe that these characteristics are purely those of our students, as anecdotal and paper based evidence tends to suggest that similar trends can be identified across a broad spectrum of courses in the UK and Europe. [1][2]

Consideration of these issues and others were the rationale behind the development of a third year level (penultimate year of a four year BEng course) class entitled Integrating Design Project aimed at strengthening and developing students' design project based skills, particularly from a functional perspective.

~~3~~2 INTEGRATING DESIGN PROJECT

3.1 Approach

The main aim of the Integrating Design Project class was to consolidate and develop design project based skills and also to integrate and apply knowledge acquired from other level three classes (mechatronic design, component design and design analysis). In addition, the project targeted particular weaknesses in the students' approach to projects that had been identified in previous years, namely;

- Proof of concept
- Student reflection and design rationale
- Use of information sources
- The storage and retrieval of project information
- Critical appraisal skills
- Working to a timescale

In the earlier course years students are introduced to design project work through formal and studio based classes. The third year was, therefore, considered to be an appropriate time to consolidate and develop these skills before the students embarked on their major final year individual and team based projects.

Project work is undertaken in the department's design studio, where the students work with tutors in an informal and supportive environment. Students are encouraged to take ownership of their project work and are responsible for driving it forward to completion.

3.2 Class Format

The Integrating Design Project class takes place over the full academic year. This consists of two twelve week-long teaching semesters. The class involved the students in two projects, one undertaken as a part of a team of four and the other individually, and concerned them in the design of predominantly functional products. Both projects were tightly structured with clear objectives set for each week. The idea was to keep the

students moving briskly through the design process encouraging critical appraisal and reflection on the way. In this manner it was hoped to keep them focused on the tasks required.
The two projects may be described in outline as follows;

Project 1 (first semester)

Topic:	Domestic Can Crusher
Format:	Teams of four (ten teams)
Focus:	Proof of concept, use of modelling/prototyping, information management and utilization
Given:	Project brief, statement of market need
Outcome:	Proof of concept model and evaluation of suitability of concept

Project 2 (second semester)

Topic:	Domestic Bread Maker
Format:	Individual
Focus:	Concept development, detail design, use of layouts, appropriate use of engineering/analytical concepts.
Given:	Product design specification and a given product concept
Outcome:	Detailed product layout and supporting information

The class was run for the first time in session 2003/04. Being a new class it was desirable to monitor student development and the success or otherwise of the learning approaches adopted in meeting the class objectives. A member of staff from the University's Centre for Academic Practice was, therefore, included as a part of the class support team. The ongoing evaluation of the class was undertaken in a discrete manner so as not to distract the students from the focus of each project. Data relating to student activities was gathered using both quantitative and qualitative methods. This evaluation was critical in providing both staff and students with feedback as the projects progressed and in giving an overall appraisal at project end.
The class support team consisted in total of eight members made up as follows; two class coordinators, three subject specialists, and three support staff addressing class IT, evaluation and information management requirements. The intention was that the team would act as coaches, facilitating rather than teaching design project skills and knowledge. [3]
The class met twice per week in the design studio with members of the class support team being on hand to liaise with and guide students. Short introductory presentations of up to thirty minutes were held on average every two weeks to introduce the project focus for the succeeding weeks and to provide general feedback on progress. In the bread maker project subject specialist staff led these presentations, reviewing the appropriate background material and providing guidance on its application in the projects. In this manner efforts were made to ensure that the students progressed the projects as required and resisted deviating from the given brief or design specification. This was something that we had learned from past experiences that students tended to do, resulting in time and effort being expended on aspects outside the class objectives – often resulting in the final project outcome lacking the required level of detail.

3.3 Project Information and Support

To help guide the students, templates were used throughout the projects as a means of recording project progress and summarising project information - a project template was issued for each of the key stages in each project. The templates enabled staff to steer the projects and, therefore, the students in the direction required, ensured steady student progress, and facilitated explicit recording of progress and as a consequence enabled improved feedback from the class support team. [4]

The templates also meant that in some cases a final submission would not be required. For example, during the can crusher project, teams were given three templates of a fixed format to record their design concepts. Each template, once completed, comprised an image of the concept, a text description, keywords and references to the key information resources used in the development of the concept. The purpose was to create a uniform hand-in and to save student effort on formatting. Students appreciated this simplicity, as it offset the extra effort required in documenting their design work. When brought together at the end of the project, the templates also formed the basis of the overall project report.

The practical nature of design work means that there is a great deal of investigation, sketch work, model making and group discussion. Much of this activity contributes to the crucial 'experiential' element of an educational design project. Unfortunately, much of this information is not recorded and therefore is not reflected upon in a formal manner. Indeed, many students do not appear to recognise the value of these aspects as a part of their educational experience.

As a part of the projects efforts were made to capture at least some of this tacit information electronically and then to store it in a digital domain for future reference by both staff and students. To allow this to be done with the minimum of disruption to project progress the DMEM design studios were furnished with digital cameras, scanners, electronic whiteboards and equipped with ready access to wireless networked laptop computers. This was seen as preferable to establishing 'media rooms', which attempt to document the design process in its entirety but at the expense of realistic working conditions. The laptop computers were also used by the students for general computer-based work, information searching and presentations. [5]

All the class and project information was stored within a digital environment. The software environment used was TikiWiki, a web-based piece of groupware [6]. This environment allowed staff to post information to students and for students to store their project information within their own electronic workspace. Through the use of TikiWiki (posting project documentation, requesting project hand-ins to be uploaded etc.) it was possible to encourage the students to document their design work as it progressed, providing benefits in terms of their critical reflection with the minimum of interruption to their design work.

The students also had access to the DMEM product development laboratory equipped with model making equipment and materials. They were encouraged to model and test their concepts physically as a part of the concept development process in addition to modelling them virtually.

4 OBSERVATIONS

The class as a whole was considered to have been successful in developing the students' project based skills and in addressing many of the issues identified in section 2 above. As one would expect, however, not everything was as successful as had been hoped. There were many lessons learnt and some new insights gained by the support team.

These will be reflected upon and the class modified as appropriate for next session. Some of the key observations for the class are discussed below.

4.1 Project 1 – Can Crusher (team)

Proof-of-Concept Models: Several of the proof-of-concept models didn't prove anything. The 'guilty' teams had in general become focused on the 'building' of their models rather than proving that the concept worked. Some teams noted that they had found difficulty in proving the concept via the model due to the build materials being different to those intended for the final product. In many cases, however, this difficulty was due to a lack of thought in planning the model for the purpose of evaluating a particular feature or function. Some students were more interested in the aesthetics of the model as opposed to the function they were trying to prove and how to 'prove' it. Encouragingly, several teams used initial 2D models to inform and explore their concept before moving to a 3D model. One team had two 'working models', and discussed how the second had developed from the first noting what they had discovered (learnt) in the process.

Analysis: In general the teams struggled to identify and undertake an appropriate level of analysis. For example, only a few of the teams had calculated the required force for operation and few could establish the mechanical advantage of the levers, gears, etc they had chosen.

Learning from Experience and Reflection: A discussion and feedback session was held after the final project presentation. It was clear from the discussion that most teams had seen the project as a positive experience and had already taken stock of what they would do differently in undertaking such a project again. During the presentations the students had had to demonstrate their proof of concept models to the rest of the class. This was also seen as a positive experience allowing staff and all students to discuss possibilities for improvement. One team that had used their model particularly well to develop their thinking and gain a better understanding of how mechanisms worked noted how they learnt a lot from building the model – "…thought we had finished the model but there was a lot more we had to refine."

The most successful teams were those that had reflected best. One team was aware of a lot of issues that they hadn't resolved and were clearly thinking about how to resolve them. Only one team seemed to be reluctant to learn from the whole experience, defending their chosen concept rather than being receptive as to how it could be improved.

Project Reflection on Video Presentations: The final presentations were recorded on video and placed on the TikiWiki site. All teams were then able to compare their performance with that of their peers. The presentations on the whole were commendable but it was interesting to note that all teams tended to convey their design work as a sequential process, with little reference to design rationale or iteration. There was also a strange reluctance to use their models as a part of the presentation.

Information Management: The teams were required to source, generate and store information in a manner that allowed easy retrieval as required throughout the project. The TikiWiki software proved to be a suitable platform for this activity with most students experiencing little difficulty in its use. The students coped well with the challenge of sourcing information from various online resources and then storing the relevant data within TikiWiki. Some teams did, however, demonstrate a reluctance to review and use the stored information to best advantage in later project stages. As the project progressed the nature of the information requirements changed, from marketing and product information at the project start to technical reports and component information during concept development. Most teams demonstrated a weakness in sourcing detailed technical information from online sources, highlighting the need to enhance the students' information searching skills – this was addressed through dedicated class sessions held during the bread maker project.

4.2 Project 2 – Breadmaker (individual)

The breadmaker project focused on the development of a given product concept. It was split into five different 'packages' - familiarisation and initial layout, component selection and design, material selection and casing design, mechatronic design, and final layout. The students worked on each package for two or three weeks recording the outcome of each in a template. At the time of writing the project is about to enter the final layout stage. The following is a summary of observations to date.

Initial Layouts; Surprisingly, a high proportion of students struggled with the concept of producing an initial layout of the bread maker from the information provided (key dimensions and components, overall arrangement). This seemed to stem from them being uncomfortable with the number of variables involved and the need to leave, at this stage, certain aspects of the layout undetailed. Some students took comfort in the aesthetics of the bread maker and started to detail the external aspect of the casing. This was in fact contrary to the guidance provided that placed emphasis on the internal arrangement and functionality of product

Some students developed their layouts manually (Figure 1) others on computer. Interestingly several of those who followed the computer based root became tied up in 'solid modelling for modelling sake' resulting in some layouts being completely meaningless, for example modelling power train elements but not showing them in situ.

Recording of project data; Storage of project data did create some difficulties. As in the can crusher project, students were given an area on TikiWiki to store all their project information. Some students were storing large CAD files and scanned images in their digital repositories and then experiencing difficulties in retrieving them due to excessive download times. This highlighted an unexpected need to develop the students IT skills in this respect. Students, however, did like using Tikiwiki as it provided an easy to use tool for file storage and information sharing accessible on or off campus.

Sticking to the brief: As in the can crusher project, some students tended to expand or extend the project requirements often in a manner that avoided the main project deliverables. The project was designed to focus initially on the functional design of the product and to take the students through a structured development path. Some students, however, were particular drawn towards what they perceived to be 'easier' aspects even though it involved them in significantly more work. As an example, one student spent time in the early stages of the project developing concepts for the hinges on the bread maker lid whilst ignoring the need to detail the layout of the key functional components (motor, kneading blade etc.). One particular concern amongst the staff support team was how to encourage these students to recognize and focus on the key elements of the project without discouraging them from being creative when appropriate.

Design iteration: The component selection and design element of the project involved the students in detailing the arrangement of the dough kneading blade and associated power transmission from the motor. It involved them in selecting bearings, pulleys/gears, belts etc. and incorporating them into a feasible arrangement. Most students used analysis and selection procedures well to iterate the layout and make design decisions. Others, however, undertook analysis because it was expected and did not actively use the results to iterate towards an improved arrangement. These students also tended to feel negative about the fact that the layout changed or that there were several variables in the analysis. There are clearly issues with such students in moving from a highly structured design exercise with a single solution to a practical design project with several feasible solutions.

On the other hand, the highly motivated students readily appeared to understand the iterative nature of design but often put in more effort than was really necessary to produce a high quality project output through, for example, adding additional functionality. The class support team was reluctant to quell this enthusiastic approach even though the end effect was that, for these students, the project took more than its fair share of study time.

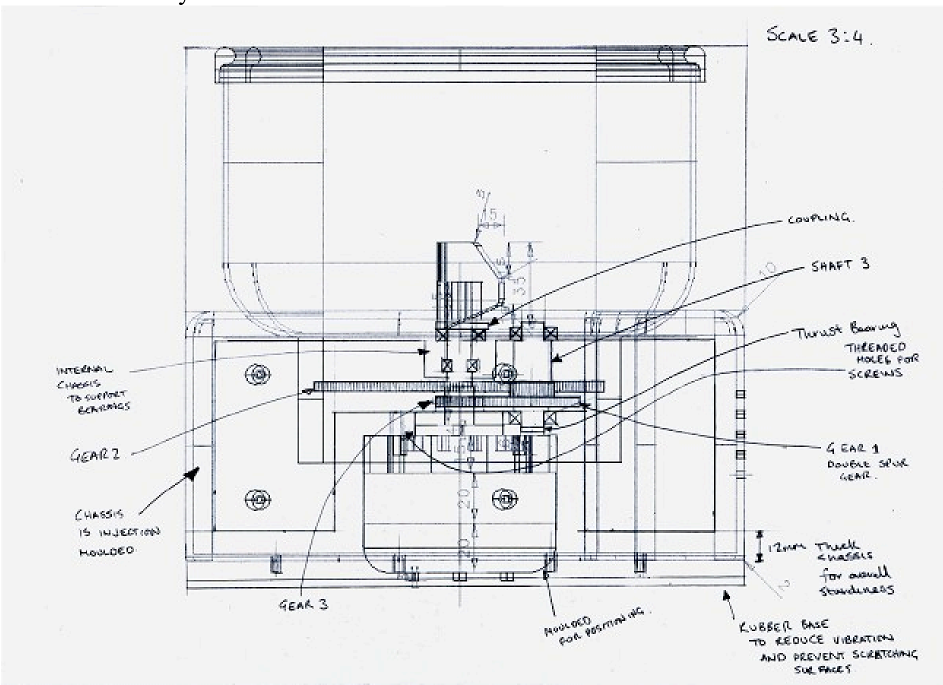

Figure 1: Example of part of a student layout

5 CONCLUSIONS

The Integrating Design Project class was run for the first time in session 2003/04 with the specific aim of addressing some of the deficiencies observed in student project work in previous years. The class has gone some way to addressing many of these deficiencies but as can be seen from the discussion above there are still a number of issues that need to be tackled in future years. It is believed that these issues are not unique to DMEM and the University of Strathclyde and that our experiences in tackling these problems will be of benefit to all design educators.

The project benefited from the combined efforts of a coaching and an evaluation team. The evaluation data gathered from the project has provided us with invaluable insights relating to both the students' learning processes and preconceptions, and the tutors' coaching styles. Of particular note was the students' difficulty in isolating the key functional requirements of a product and ensuring that these requirements were met. The data gathered from the project is being formally analysed and will assist in redesigning the structure of future projects and in developing tutors' coaching styles. The findings from this ongoing study, which we believe will be of benefit to all design tutors and coaches, will be presented in future papers.

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