MERGING CREATIVE DESIGN AND CAD LEARNING ACTIVITIES IN A PRODUCT DESIGN PROGRAMME

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ABSTRACT
Traditional learning and teaching methods for creativity differ from those used in a scientific context. Although the creative process can benefit from a certain level of prescription and structural constraint - with time allocated to research, problem definition, conceptualisation and idea development - flexibility and fluidity are necessary for creative innovation. In contrast, the more linear and rigid pedagogies associated with science and engineering education facilitate efficient learning of subjects such as those based on software packages, manufacturing and materials theory or mechanics. This paper describes the development of a project which aims to establish constructive links between the learning outcomes of a creativity-based module and a virtual modelling module. An action research approach was taken to develop links between the learning activities and outcomes in each module. A timeline is also presented with specific reference to the stage at which the engineering brief is given to the students and the two disciplines are merged. Through this exploratory case-study, a framework for the synthesis of creative and scientific product design modules is demonstrated. In addition, generic recommendations for the development of cross-disciplinary project briefs in product design education are provided.

Keywords: Multidisciplinary, collaboration, creativity, CAD

1 INTRODUCTION

1.1 Background

1.1.1 Requirements of Graduate Product Designers

By its very nature, product design education is a cross disciplinary activity. During the undergraduate education of product designers, they are introduced to concepts and techniques from a variety of disciplines. Typically, this is initially done on a discipline-specific basis. At later stages of a programme students will generally be exposed to more open-ended learning activities which require them to demonstrate their skills in a variety of areas. An important aspect of the structure of a product design programme is the stage at which the various disciplines are merged to best match the pedagogical needs of the student. If this occurs too late in the programme or not at all, the result is a segmented learning experience which fails to address the key needs of merging the creative and engineering aspects of design. Attempts to merge the disciplines at too early a stage invariably detract from the learning of key skills and principles in each discipline-specific area. The need for students to engage in various disciplines, and also to combine their learning in each, is supported in the literature. Kurowski and Knopf [1] outline the necessity to effectively combine product design students' natural creativity with the use of modern CAD tools:

> *"A successful product designer must combine natural creativity with the systematic use of structured design methodology and modern computer-aided design tools".*

In Rensellaer University, the Product Design and Innovation (PDI) program aims to prepare students to successfully invent and develop new products. This interdisciplinary design programme was described by Bronet et al [2] as having three dimensions: the technical, the aesthetic and the social. They also identified an emphasis on creativity, the imaginative application of new technologies and materials, and the social and political dimensions through design. Yang et al [3] examined the required competencies of industrial design practice and the effectiveness of existing educational efforts. Results from this study displayed the wide variety of roles and environments in which designers must be comfortable operating.

The conclusions of the above works support the hypothesis that design graduates need to be generalists, able to work on a variety of project types and in a variety of roles. Although contemporary literature advocates a multidisciplinary approach to product design education, Bronet et al. [2] also found that constructive experiences for students call for "a faculty that are themselves multidisciplinary and understand the associated issues". However, they go on to suggest that these traits are not always evident in academic institutions "where accomplishments and recognition in one's own discipline is what is often most prized". This paper posits that there is a gap in the literature related to good-practice guidelines for the cross-fertilisation of teaching activities during the early stages of multidisciplinary design programmes.

1.1.2 Links between CAD & Creativity

Since the introduction of CAD technologies in the 1980's, elements of design education and practice have been revolutionised. In practice, CAD has been found to affect the creative process both positively and negatively. Musta'amal et al [4] conducted a cognitive psychology study into the links between CAD and creativity through the observation of creative behaviours. Results from their research contradicted the oft-held notion that CAD is not a creative designing tool. They found that while creative behaviour was noticed in all users of CAD, those who expected to use CAD throughout the design process displayed more creative behaviours than other users. Robertson and Radcliffe [5] examined the impact of CAD tools on creative problem solving in engineering design. They noted that although CAD can enhance the *visualisation and communication* of ideas, a detailed CAD model can express an "illusion of completeness that tends to discourage creative thought". *Circumscribed thinking* [5, 6] refers to the idea that the generation of design ideas may be constrained by both the functional limitations of a CAD package as well as the forms which are most easily modelled. Essentially, designs generated with CAD tools may not match the designer's capacity for imaginative concepts. A contrasting problem can manifest when a designer assumes too much creative freedom as a result of their expert CAD skills and so are tempted to add superfluous complexity, thereby wasting resources. *Bounded ideation* is another barrier with which CAD can obstruct the creative process. In their case study, Robertson and Radcliffe found that the "mundane nature of drafting on a computer, exacerbated by technical problems and software bugs, is a distraction from the actual process of designing, and especially from idea generation and creative problem solving". *Premature design fixation* [5, 7] is another phenomenon. This relates to how the addition of details to CAD models discourages design changes; Robertson and Radcliffe found that virtual models can suffer from a sort of "inertia" so concepts became frozen rather than undergoing further development iterations. These ideas advocate CAD as a useful tool during the detailed stage of designing, but suggest that sketching and discussion are initially needed for successful ideation.

1.2 Aims and Objectives

This paper describes work in DIT's product design programme which is aimed at establishing links between modules at an early stage in the student's development while not compromising the teaching of key principles of engineering and creative design. The work is focused on the teaching of the creative design process and virtual modelling to second year students. The link between the modules aims to primarily encourage creativity in the early stages of conceptualisation, while demanding that the student develops the ability to apply the rigor of a full engineering design process.

1.3 Pedagogical Background

This paper is centred on the development of two twelve-week modules in DIT's product design programme. For clarity, semesters are thirteen weeks long, with twelve teaching weeks and one review week. The first of these modules is focused on creative design and the second is focused on virtual modelling.

1.3.1 Applied Creativity in Design (ACID)

This is a studio based module which aims to foster creative design thinking. Students are supervised as they work through two practical design projects. They are introduced to and tasked with research exercises, they generate and develop concepts and they build prototypes. The first project asks students to solve an environmental issue by selecting a material from a company's waste-stream and developing a consumer product using that material. The second project sees them develop a specified consumer electronic product for a particular brand. Students work individually and in small teams throughout the projects to identify problems and develop solutions. Examples of class exercises include brainstorms, visual reference and other secondary data collection and analysis, role-play, group critiques, sketching, sketch model-making and prototyping. The purpose of the module is to cultivate the student's ability to act as designer and solve a wide range of problems using a creative thought process.

1.3.2 Virtual Modelling (VM)

The second module is focused on virtual modelling skills. This is performed using two industry-standard modelling software packages. The first of these is Rhinoceros (Robert McNeel & Associates, Seattle, WA, USA) which specialises in free-form Non-Uniform Rational B-Spline (NURBS) modelling. The second is SolidWorks (Dassault Systèmes, S. A., Vélizy, France), a parasolid-based solid modeller which utilises a parametric feature-based approach to create models and assemblies. In the VM module students learn the uses of these systems. Rhinoceros is used to give students an appreciation of the methods that can be used to develop freeform models and applied in the manipulation and redesign of models so that they more closely capture the original conceptual sketches developed by the student. SolidWorks is used for the communication of final designs, including the generation of more regular geometric shapes and fixtures, and production of assembly models, and manufacturing, assembly and customer drawings.

2 METHODOLOGY

Reeves et al. [8] suggest that research concerning technology pedagogies in higher education too often seeks to determine the effectiveness of a delivery medium, rather than the teaching strategies and tasks themselves. This paper describes the iterative development of an integrated brief using an action research methodology. Action research is a practical yet systematic cyclical method that enables educators to investigate their own teaching and their students' learning. Each cycle is comprised of reflection, planning, action and observation stages [9].

Lecturers from the VM module and ACID module worked together in order to facilitate a multidisciplinary experience for the students. The seven-week brief for ACID tasks students with team-based and individual exercises involving primary and secondary research, brainstorming, experience prototyping [10], sketching and model-making. They are also required to create technical drawings of their final design, a prototype and a presentation. The VM brief requires students to develop a strategy for producing 3D models at part and assembly levels. They must build a product assembly from individual part sketches, reflecting and developing routes to produce the required CAD geometry. They must then apply part finishes and produce drawings and rendered images of their final models.

3 RESULTS

Below, Figure 1 describes three cycles of the action research process. Each year's reflection, planning, action and observation is synopsised. Figure 2 then shows samples of the students' work from the most recent project iteration.

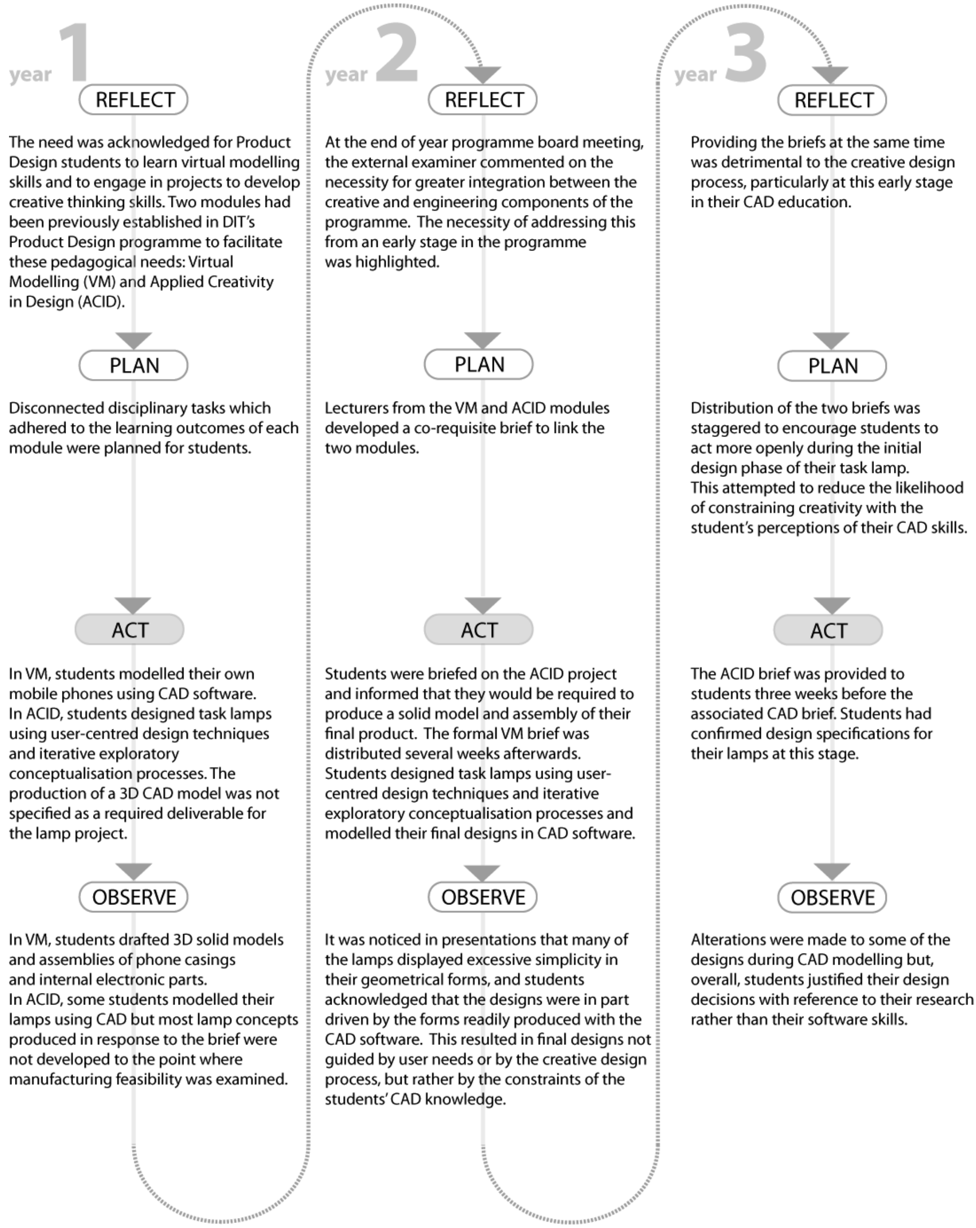

Figure 1. Development of the merged project

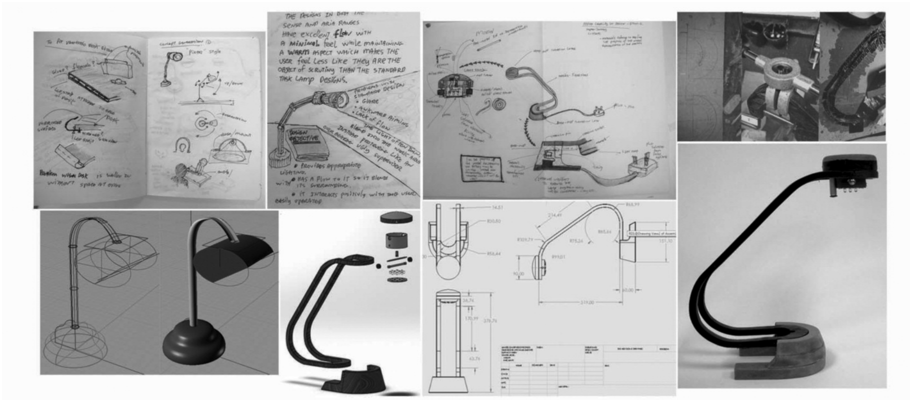

Figure 2. Samples of project output

4 CONCLUSIONS

The substantive findings from this action research suggest that it is beneficial to encourage students to initially engage in research and traditional paper-based conceptualisation and sketch model-making. Once design specifications have been formulated, students can then be tasked with modelling their designs with CAD software. In the initial manifestation of these modules, no explicit link was specified between the two learning activities. As the merged approach was developed, it became clear that limits of both the software's functionality and the novice students' skills in using it could limit the creative designs produced in the conceptualisation process. For this reason, it is deemed crucial that students are not aware early in the project process that they will be required to produce a CAD model for the product. Staggering the distribution of the two briefs was found to facilitate the optimum student engagement in each module, and therefore, the most successful demonstrations of the creative design process in the final concept presentations. Figure 3 depicts a suggested timeline for linking a CAD-based module and one focused on the creative process. An outline for a twelve-week semester is shown. It is important to clarify that this model is not a proposal for professional design practice as it does not acknowledge design changes that may become apparent during Finite Element Analysis (FEA) or tooling design. Rather, the model below is a recommendation for merging CAD-based and creativity-based modules during the early stages of a product design student's education.

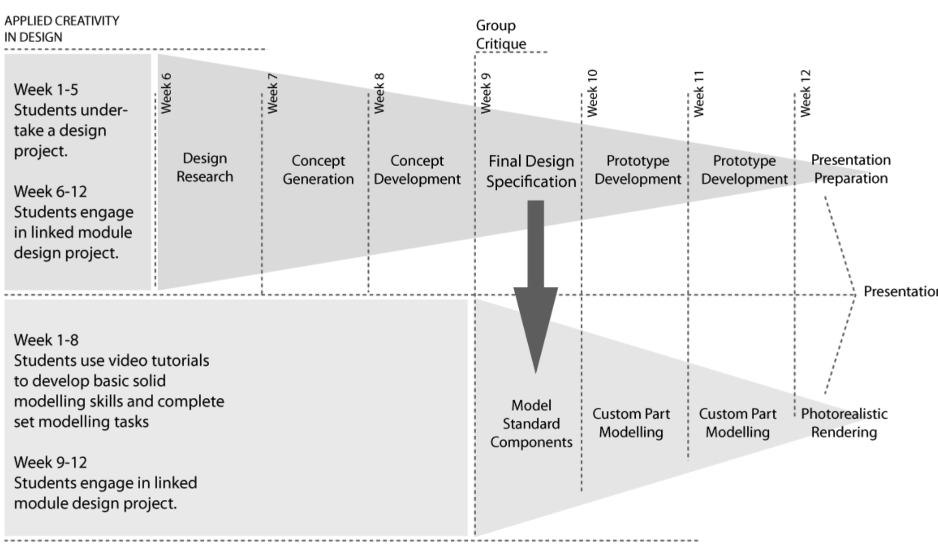

Figure 3. Proposed timeline for merged project

4.1 Recommendations for the synthesis of creativity and engineering modules

Below is a list of recommendation stemming from this work for linking such modules.

1. Lecturers from separate disciplines must initially become aware of the content and specific learning outcomes of the co-requisite module.
2. Regular communication between tutors during the project is necessary.
3. A pre-defined timeline structure for the project is initially necessary so that students can be prepared for the second brief. In the case outlined here, students must have their final design specification before they can advance to the detailed design/CAD stage.
4. When a software skill is one of the learning outcomes, the distribution of briefs should be staggered in order to best facilitate a fluid creative process.
5. Assessment procedures should match the specific learning outcomes of the individual modules. In this case, marks were awarded in the ACID module for research technique and analysis, concept generation and development, and presentation and communication. Marks were awarded in the VM module for part and assembly models, technical drawings and photorealistic product renders.
6. The linked project should be justified and explained to students. Reflective discussion should also be encouraged among the class in order to engender an appreciation for how CAD tools can best be used during the creative design process.
7. Lecturers should reflect together after a merged project is carried out in order to identify and suggest remedies to any issues.

This paper has described the iterative process of merging early-stage CAD education and a module based on creative thinking and conceptualisation processes in order to create a multidisciplinary experience for product design students. The literature shows that CAD can work synergistically with creative thought [4] but also that it can stunt creativity [5,6,7]. This piece of action research provides support for the argument that during early-stage product design education, traditional creative design techniques should instigate the design process, and only once a design specification has been formalised, should students advance to virtual modelling.

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