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DEVELOPMENTS IN TEACHING APPROACHES "THE ROLE OF MODEL MAKING WITHIN THE UNDERGRADUATE PRODUCT DESIGN PROCESS"

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ABSTRACT
This paper examines the reasons for the use of model making as part of the undergraduate Product Design Process (PDP). It begins by discussing why model making is important to the activity of designing products, covering the exploration of 3D form, understanding of structure and process, scale, size, component mating, ergonomic consideration, communication of design intent and experimental learning.

In the second section it examines the different types of models produced and the ways in which they are manufactured throughout the PDP and within an educational environment. This section will examine hand modelling with "soft materials", crafting hard materials, prototyping using manually controlled machine tools, facsimile models using manually controlled machines, models and prototypes using "low tech." Rapid Prototyping (RP), models and prototypes using "high tech." RP and virtual modelling.

The paper concludes by presenting a case study of the UWIC model making method and using it to compare and contrast new and traditional processes within design education. It will discuss the place of hand modelling within a CAD/CAM driven process, the adoption of low tech CAM by non-expert users and the final project output in terms of a quality learning experience.

Key words: Computer supported design education, Model making, Skills, Product design, Transferable, Structure, Integration, Product design process, Learning, Curriculum, Education.

1 INTRODUCTION: MODEL MAKING AS PART OF THE UWIC PDP

Model making is considered an essential part of the undergraduate Product Design Process (PDP) at UWIC. It is first introduced at the concept sketching phase and takes place in parallel with traditional 2D concept sketching.

In 2003 Dyson stated: "It is important to get into 3D models as quickly as possible….a model can show you so much more than a computer drawing ever could" and these statements have found resonance in the authors' experiences. Myerson [1], reiterates the point, telling us that *IDEO* always produce tangible model at each stage of the design process, and Bloch [2] further elaborates on the topic from a marketing perspective. It is well established that Virtual 3D CAD models facilitate the exploration of 3D form, structure, process, and component mating and to some extent help to communicate design intent. However it is only when these virtual models are translated into real world entities that a true appreciation of scale, size and ergonomic consideration can be achieved.

Later on in the design process when the product is becoming more accurately defined and working prototypes are being explored there is an excellent opportunity for experimental learning. This was discussed at some length by Dyson [3] in 200X when describing the product design process he employed. He stated that “You make discoveries by testing the model and you learn to improve from your mistakes” and Velásquez-Posada [4] reinforces the merits of an iterative approach.

2 MODEL MAKING TECHNIQUES USED IN THE PDP

This section examines the different types of models produced and the ways in which they are manufactured throughout the undergraduate PDP at UWIC.

2.1 Soft Modelling

Sketch modelling is normally undertaken early on in the design process and allows the designer to explore the 3D form of an object that previously only existed as 2-dimensional sketches. These models are usually hand crafted from materials that are quite soft and easily and quickly formed. This has led to the common adoption of the term “soft” or “low fidelity” modelling and is an ideal medium for experimental learning as it is easy to work and requires little formal training.

An other important aspects of sketch modelling is that it facilitates the appraisal of scale and size and in particular allows the initial evaluation of ergonomic and semiotic issues related to the proposed designs.

Perhaps the most important role of sketch modelling is that it aids communication and is the first opportunity to fully explain the concept designs to the rest of the group and or teaching staff.

2.2 Hard Modelling

The next stage after the evaluation of the concept sketch models is usually concept development. This involves the development of the initial ideas in order to improve on them and attempt to more accurately meet the requirements of the brief. These models are often made of hard materials as the properties of these materials more closely match those proposed for the final design. These hard materials are generally more robust and often allow the development of finer details of the design that were not possible using softer modelling materials. In addition it may be possible to simulate such features surface finish, weight, and any moving parts or mechanisms such as switches or hinges.

Hard modelling is usually achieved using a combination of hand tools and manual machine tools such as band saws, milling machines, lathes etc. This type of model making therefore requires considerable training, experience and skill in the use of these tools in order to be successful.

2.3 Facsimile Modelling

Facsimile model making is often the final step in the model making process. The facsimile model should represent the final product design in as much detail as possible and should be almost undistinguishable from a manufactured product in appearance touch and feel.

Facsimile models were traditionally made using manual machine tools with hand finishing and normally required the skill and experience of an expert model maker to be successful.

A more modern alternative is the adoption of computer based rapid prototyping techniques for facsimile model making. These techniques all depend on the use of the information contained in a detailed 3D CAD virtual prototype of the proposed design to inform the rapid prototyping machine of what is to be made.

There are two fundamental methods of creating rapid prototypes these are “material on” and “material off”. Technologies based on the material on approach include Stereo lithography, Fused Deposition Modelling, Fused Material Sintering etc, whereas the material off technologies are all based on the use of computer controlled machine tools.

3 CASE STUDY: GLUE GUN

The paper concludes by presenting a case study of an undergraduate level-2 “glue gun” design project that compares and contrasts new and traditional processes within design education.

3.1 The traditional UWIC PDP

Figure 1 shows the “traditional” UWIC PDP (in a simplified form) and represents the process that has been used on the undergraduate programme for the past decade or so.

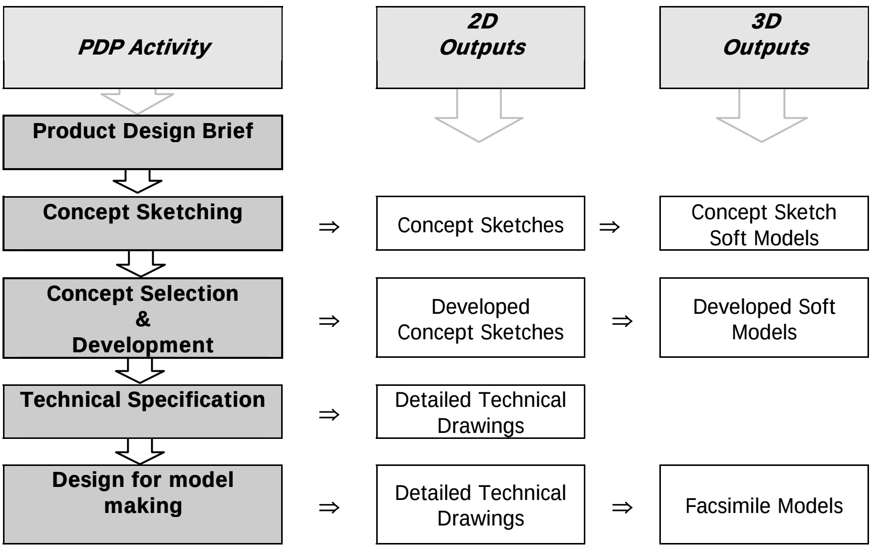


Figure 1: A simplified version of the “traditional” UWIC PDP showing typical 2D & 3D design outputs for each activity

The process follows the well-established pattern of concept sketching in both 2D and 3D, followed by concept development, technical drawing and facsimile model making. All of the model making undertaken during this process is achieved using hand tools and/or manual machine tools.

The concept sketching and concept development stages (Figure 3&4) are relative quick and easy to achieve and for a project like this would typically be achieved over a two week period.

The technical drawing stage involved converting the developed sketches and models to technical drawings to BS8888 (figure 5). This process was quite challenging and exacting and typically took a further two weeks to achieve. These drawings were necessary firstly to fully define the product in terms of design for manufacture and secondly so that the drawings cold be used to help design the facsimile model.

The final stage of this design process is the manufacture of the facsimile model. However before this can take place an intermediate design activity of converting the design for manufacture drawings into a set of "*design for model making*" drawings needed to take place. These design for modelling drawings were necessary because of the techniques available for model making are typically very different to those used in mass manufacture. This process typically took several days and required significant input from the very experienced model makers on the technical support team of the Product Design Programme.

The final stage of actually making the facsimile model using traditional model making techniques was very time consuming and typically required several weeks and significant professional model making support to achieve.

3.2 The computerised UWIC PDP

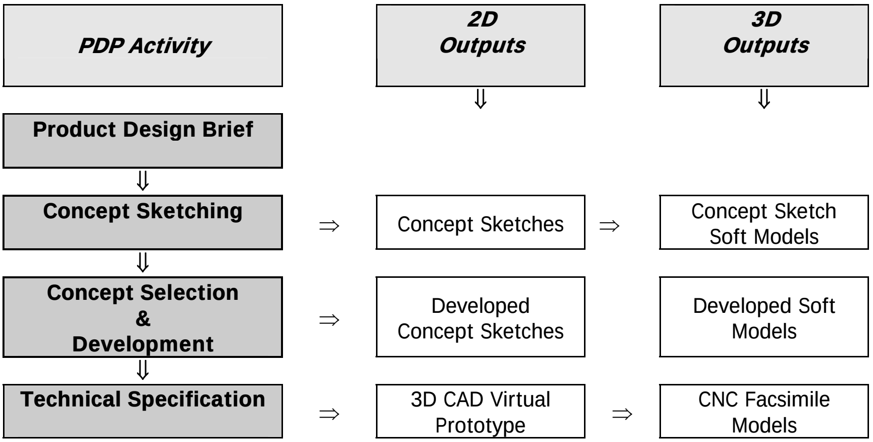
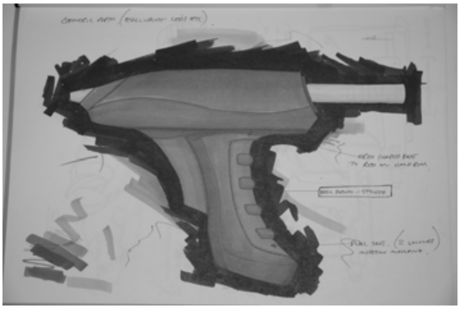


Figure 2: A simplified version of the "computerised" UWIC PDP showing typical design outputs for each activity

Figure 2 shows the recently developed "computerised" PDP used at UWIC. The first two stages of the new process are actually identical to the traditional approach in that they rely extensively on the use of concept sketching and soft modelling (figures 3&4). Experience on the undergraduate programme has shown that even the most modern sophisticated 3D CAD package is no substitute for the traditional manual techniques. This view is shared by Muller [5] who said "During the thinking process, drawing skills are used as prime creative powers. The visual thinking process cannot, a yet, be simulated using computers. In this process the sensory and intellectual powers of the designer become one indivisible whole."



Figures 3: Concept Design Sketch

Figures 4: Extensive Soft Modelling

The next stage in the new computerised PDP is to convert the developed sketches and models to a virtual prototype in 3D CAD (Figure 6). This process is similar to the traditional BS8888 approach and is also quite challenging and exacting and typically takes one or two weeks to achieve. The virtual prototype produced at this stage fully defines the product in terms of design for manufacture.

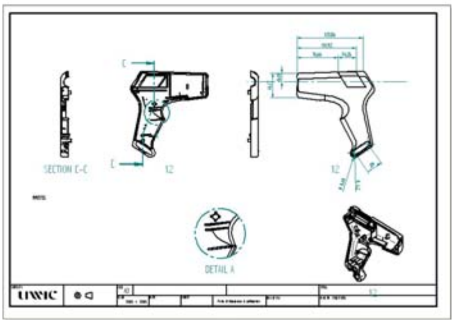


Figure 5: Detailed Technical Drawing

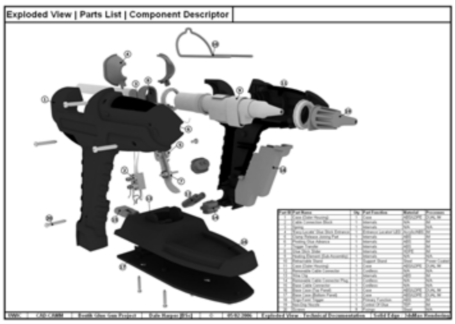


Figure 6: Detailed 3D CAD Virtual Prototype

The final stage of this new design process, like the traditional one, is the manufacture of the facsimile model. However in this case there is no requirement for an intermediate design for model making activity to take place. This is because the CNC based rapid prototyping technique that has been adopted can take the data from the virtual prototype and use to automatically manufacture components.

Disadvantages vs. Advantages of the Computerised UWIC PDP

It is normal to have both advantages and disadvantages when undertaking change. The main disadvantages of adopting the new computerised PDP are twofold. Firstly the capital investment required to equip a workshop with sufficient CNC machines to allow all students to adopt the new process is considerable and may not be generally available to undergraduate Product design courses. Secondly the initial learning curve for the academic and technical support staff to learn how to use the new equipment is quite steep, but once overcome the equipment is quite easy to use.

It is argued however that balanced against these disadvantages are the very significant academic and logistical advantages facilitated by the new process. One of these process-related benefits is that very detailed facsimile models can be made, changes applied in CAD and a new model made to the same standard within a short time frame. Thus allowing for the rapid iteration of high quality models advocated by Srinivasan et al [6].

Additionally the new process saves a considerable amount of time compared with the traditional one. Firstly it saves about two weeks by eliminating the design for model making step. Secondly the actual machining of the components is reduced from approximately 3 – 6 weeks down to approximately 3 – 6 days.

Another important advantage of the new process is that the skill level necessary to machine the parts is very significantly reduced when compared with the traditional craft-based PDP in that a level-2 student can learn how to use the CNC machines in a matter of hours by using a simple step-by-step guide created by the author.

Finally the model that is produced by the computerised PDP is much more accurate that any model produced by manual machining process as the dimensions of each part are effectively exactly the same as the CAD model.

Figure 7: A fully finished Facsimile Prototype

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