A TRADITIONAL APPROACH TO 3D PRINTING

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ABSTRACT
Since the 1980's Industrial Design has developed beyond the remit of the traditional realisation of the object or product. Design is seen as a user-centred problem identification and solution methodology which can be applied to several contexts or issues. However, there is still a need to be able to realise a manufactured artefact; skills increasingly demanded by industrial design employers. The knowledge of materials and how they are processed into components is paramount in this process. Also, in the last few years the possibilities for rapid prototyping and manufacture through 3D printing machines has become financially possible and creatively opens up new possibilities. Shapes which can now be manufactured were impossible a few years ago. The authors took a pragmatic approach which utilised the possibilities of 3D Printing to help understand the complexity of traditional manufacture through a design and build project. Whereas most student projects conclude with propositions, few are carried through to validation. Although the more engineering based programmes do build and test prototypes, complexities of design for manufacture are usually left unresolved. Students were challenged to design, manufacture and assemble a working model of an alarm clock. Each component has to be designed against an understanding of a material and production process and then prototyped on a 3D Printer. The final product was then assembled from these prototype components. Finally paper concludes that making is an essential part of the design process and that new technologies can enhance this empirical approach.

Keywords: Design method, construction, manufacture, rapid prototyping

1 INTRODUCTION

This paper outlines how the authors have used the new technologies of rapid prototyping (RP) and 3D printing (3DP) to help students connect the virtual world and real worlds through a design project for industrial design (ID) students. Within this construct (the project), students built on their prior knowledge of design for manufacture (DfM) through component design and product assembly. This also involved negotiating the compromises needed to realise a product through real materials and the processes by which they are manufactured. There was rigour in the realisation of the final working prototypes. Against this backdrop of a disconnection between design in the virtual environment and real manufacture the authors advocate utilising CAD and RP within design for manufacture or production [1].
The paper concludes with a reflection on the value of this project against the learning curve of student experience as training for the product design profession.

2 BACKGROUND CONTEXT

The challenge to design and build an alarm clock is an individual project constituting a 15 Credit Module (120 credits undertaken per year) in the first semester of the final year of a three year ID Programme. It builds on prior learning of the design process, a knowledge of manufacturing and the skillbase of CAD (Solidworks CAD Package). Through this project this paper explores, three current issues within design education:

2.1 How to integrate the new possibilities of Rapid Prototyping, 3D Printing and additive manufacture (RP) into the curriculum.

This is a complex subject as it originates within industry and includes questions on how these new possibilities will impact on the way we manufacture and consume products. Not only does RP facilitate the creation of objects which were previously impossible to make but it also alters the landscape of production possibilities, shape and quantity. Without tooling costs objects can now realistically be made as one offs and small production quantities rather than needing the economics of scale afforded to mass production. This in turn has posed new questions for designers, those of 'new visual languages', 'new production possibilities' and 'new economic possibilities through one off or mass customisation'. This is acknowledged and explored by Ford and Dean [2]:

The tool-less manufacturing flexibility of AM (additive manufacture) allows for more personal approaches to production such as mass-customisation, with outputs tailored to an individual's need or desire [2]

However they go on to note:

Almost any form imaginable can be reproduced by AM and production issues could potentially be ignored [2]

This is countered by Valamanesh and Shin[2] who see Digital Fabrication as a tool to replicate and explore complex components:

Digital fabrication provides realistic opportunities for representing, evaluating and redesigning complicated forms. It extends learning in a digital design environment since designers will be engaged with materials and machine processes similar to industrial production. [3]

Ford and Dean finally conclude:

What is clear is that it is not valid for designers to be encouraged to ignore 'traditional' design for manufacture processes at this point in time; they have to be introduced to the opportunities and constraints inherent in all levels of production. Teaching should not be restricted to innovative practice in the application of new technology but all appropriate methods, old and new. [2].

This paper attempts to connect the value of RP as a new opportunity for detailing design for manufacture.

2.2 Virtual and Physical Environments

Although RP generates more physical objects, the process is more aligned to the virtual rather than physical world. Objects are conceived within a 3D CAD virtual space rather than evolved within the workshop with physical models. 3DP emphasises the need to be competent with CAD skills and further alienates student designers from the physical world and traditional design methods. This need to work in and test within the physical environment is critical to both ID within industry and the training for it [4].

Whilst designing in the 3D digital environment allows for a faster and possibly more fluid process, we still have the need for the real object as seen in the 'real' world……..

………This 'hand's on' approach can be used to finalise any design problems that may arrive during the digital environment, one such example is scale or fit. [4]

There are now instances where students (and professionals) are proposing designs, which can only be realised through RP and do not understand the complexities of production, scale, materials and techniques. Some students have never translated or evolved designs from the virtual CAD environment into realisable objects in the 'real' world. This could lead to a detachment of ID from the manufacturing base where it originated. The business model for design [5] which correctly assumes that ID can, amongst other benefits, deliver value in manufacturing, needs designers who understand the practical as well as the theoretical.

The authors also note that some candidates for degree programmes in design do not come equipped with a natural intuition of how things are made, structures, materials and strengths. We live in a world where a failed product is discarded rather than repaired. People do not take products apart to repair them and a fundamental knowledge is being lost to students (and others). In contrast, the virtual world through the computer is a natural environment to them. They are Digital Natives as defined by the Oxford Dictionary:

a person born or brought up during the age of digital technology and so familiar with computers and the Internet from an early age [6]

We are dealing with Generation Z [7] as students do not explore in the real world in the way they are fearless in the virtual world. The project outlined below is an attempt to link the two worlds and re-engage student designers with the third physical dimension.

2.3 Dealing with a crowded curriculum.

In many instances projects deal in methodology and design thinking often culminating in design propositions outlining a concept, physical presence and interaction. Although valuable, an understanding of manufacturing detail is being reduced or marginalised. Although Universities have become strong on the breadth of investigation and Design Thinking, students often lack a depth of knowledge, in this instance of detailing for manufacture. The UK Design Council describes this interdependency the T of Design, Figure 1.

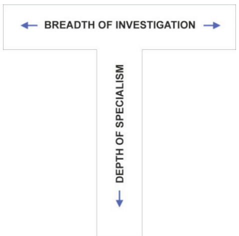

Figure 1. T shaped Design

"The stem of the T is the depth of knowledge in their specialist subject while the horizontal cap of the T represents the breadth – their ability to make their method, skills and thinking work in a different context." [8]

The project also connects to the Design Councils Double Diamond design process, Figure 2.

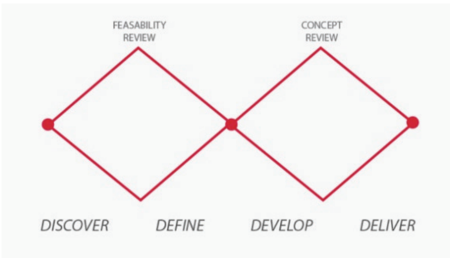

Figure 2. Design Councils Double Diamond Design Process [9]

Many design programmes focus on the 'Discover' and 'Define' elements of the process, encouraging imaginative, user-centred solutions to social or product issues. The core of this project is located in the Develop and Deliver phases of the Double Diamond Process. Emphasis is given to the realisation of an assembled product so resolution of manufacturing and assembly details are critical to a successful outcome.

The project outlined below reconnects the physical to the virtual as a process or design methodology. It addresses the points outlined above with particular attention on 2.2 and 2.3. The project explores the interplay between real and virtual, traditional skills and new possibilities. It achieves this by incorporating and valuing 3DP as a mechanism to replicate complex 3D components.

3 OUTLINE OF PROJECT

As a final year project it was an opportunity for students to demonstrate the management of a project from initial design responses to the construction of a working prototype. One Learning objective, relating to this paper, was to explore and understand the relationship between the design concept and physical reality, in a design process from sketchbook through to simple 'proof of principal' models and then from detailed CAD models through to working prototypes.

3.1 The Brief

The individual task set to final year students was relatively straightforward:

You are required to design an alarm clock. This is a design and development project, which has a technical bias. The PCB and electronic components are available as part of a kit that should be purchased from the University. You should design an innovative solution to the alarm clock, which will *enclose the electronics. You will also assemble the PCB for inclusion in a working prototype that demonstrates innovative design, product function and component detail.*

The task was rooted in a traditional aspect of ID, that of encasing technology. The electrical components were given and the only leeway allowed was that the students decided which components would go on a PCB and which could be satellites to it. This immediately introduced an interesting compromise between innovation and practicality. Being too creative would mean significant modification to the board making the product difficult to realise and possibly impair functionality. Leaving the components without change could result in poor user interaction. Students dealt with the external attributes, aesthetics and interface while resolving the internal component layout including design and specification of the case system (parts). With the later they were required to 'print' these on a 3DP machine. The number and size of these parts was defined within the brief; a maximum of six components to be made by RP. This limitation was logistical relating to the number of students and available resources but also taught students to work within limitations. The processes were restricted to Polyjet and Fused Deposition Modelling Technology.

The Brief had defined stages and deliverables as follows:

1. *Concept work including sketch drawings, foam models, CAD models and photorealistic images illustrating at least 3 concept alternative designs, trial printouts of components for evaluation. The designs should be innovative and their style must reflect the intended market. One must be selected for development into a detailed design.*
2. *A document or storyboard demonstrating how the user interacts with the product.*
3. *A fully developed CAD model of your chosen product design communicating the detail design of the enclosure, including PCB location features, button and display interfaces and design for manufacturing details.*
4. *CAD models (of each individual for 3D Printing).*
5. *A working prototype of your chosen design with the PCB assembled into the prototype enclosure.*
6. *High quality visualisation images of your chosen design for presentation.*

4 CONTEXT AND PURPOSE

As part of the design process, students were also allowed to experiment with parts prior to obtaining 'sign off' on the final design. This experience was essential in integrating 3DP into their design method. The use of accurate parts informed the design process in a time efficient way. Emphasis was placed on modelling the intricate details in CAD. This demanded resolving the 'minutiae' and was constantly a revelation to students, as it demanded both rigour and investment in time. By contrast, once modelled in CAD, producing 3D objects is 'rapid', hence the earlier term of rapid prototyping for the technology. These parts have to be realistic to a commercial manufacturing process not just replicable with 3DP. The 3D prints were used to emulate high volume manufacturing processes. The project challenged students to detail their components to a quality where the data could be used for production tool manufacture. Once printed, the parts needed to be finished. This required an attention to detail during cleaning, sanding and painting. Once complete, the components were assembled into working prototypes. This final aspect of assembly was important as students realised, through hands-on assembly, how effective or efficient their design detailing has been.

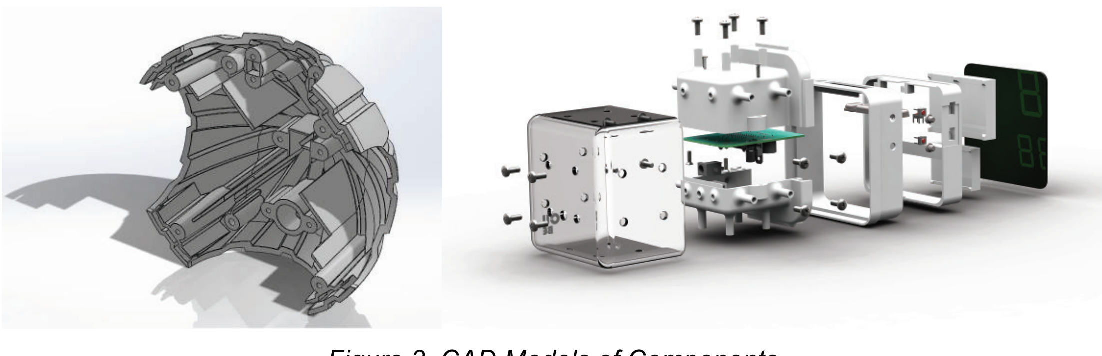

Figure 3. CAD Models of Components

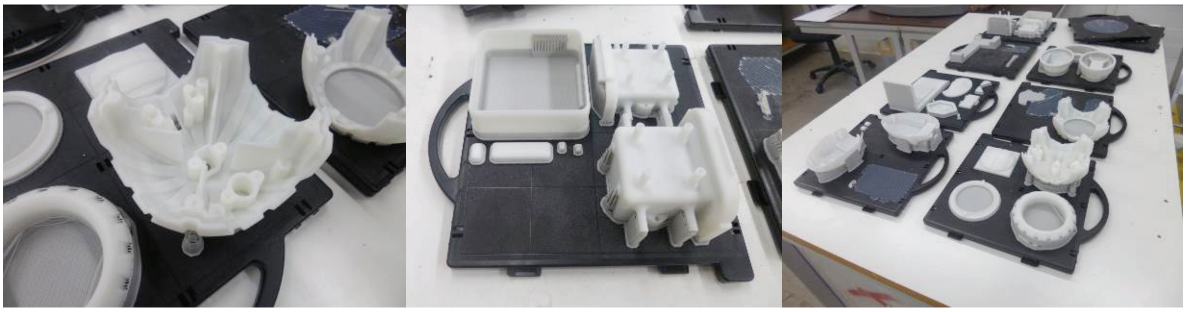

Figure 4. Printed Components from the RP Machine

5 CONCLUSION AND REFLECTION

Figure 5. Example of completed Alarm Clock

The aim of this project, and the degree programme, is to holistically educate all-round designers, that is those who understand both the breadth and depth of the T Design Model. A key purpose was to get the physical and virtual environments linked in both design process and students understanding of it. With the latter the project also challenged students to understand the complexities of assemblies, particularly plastic parts. This depth of understanding is valuable in a graduate's portfolio when making the transition from education to employment. In this there was not an acceptance that ID is not just clicking a button to print out what was on screen but an understanding of the value of both virtual and physical environments within the design process. Importantly students gained an understanding of when a process or skill is appropriate. They had to justify decisions on design detail before CAD files are 'signed off' by staff and sent to the 3DP machine(s). Within this they had to demonstrate an understanding of how a component is designed for a particular manufacturing process and material, predominantly injection moulded plastic(s). The project bridges the virtual world and real worlds using new technologies relevant to the students (Digital Natives and Generation Z) and the real world contexts, the design of products. particularly advances in 3DP, into the design process. It does not attempt to explore new shape possibilities provided by RP but re-iterates the technology as a realistic replication of traditionally manufactured parts (through, for instance, injection moulding and die-casting). It allows students to quickly and efficiently realise their designs as manufacturable propositions tempering virtual creativity with practical detail. Within this project students also become familiar with the intricacies of prototype manufacture utilising new technologies. One observation we have is that the project may be more appropriate earlier in the programme so the gained knowledge can underpin further work. The value of the project can be summed up by the following student:

'The alarm clock project was an excellent learning opportunity. The project helped me understand, in detail the process of taking an idea off the page into the computer and then making the working model. The task of taking concept idea and converting it to a CAD model with the capability of being

manufactured was an excellent and challenging experience, this design had to not only be faithful to the concept but also house the relative internal electronics and fit together. When the concept was completed on the computer, it gave me the best possible preview of how the product would look in the real world, This said the first time I saw the finished parts come off the 3d printer they were smaller than I had imagined. Because of the scale and size of a product being very difficult to define, prototyping is the best way to complete the link between the design on the computer and the way that it will look in the physical world to me the designer and other people.' (Michael Hardie, Final Year Student 2014).

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REFERENCES

[1] Leutenecker. B, Lohmeyer. Q and Mehboldt. M. Impart 'Design for Production' Knowledge by Application of Functional Prototyping. In *International Conference on Engineering and Product Design Education E&PDE13.* Dublin, September 2013.

[2] Ford, P and Dean L. Additive Manufacturing in Product Design Education: Out with the Old In with the New?. In *International Conference on Engineering and Product Design Education E&PDE13.* Dublin, September 2013.

[3] Valamanesh, R and Shin D. Tangible Ideation: How Digital Fabrication acts as a Catalyst in the early steps of Product Development. In *International Conference on Engineering and Product Design Education E&PDE13.* Dublin, September 2013.

[4] The Quality Assurance Agency for Higher Education. Benchmark Statements. Available: QAAhttp://www.qaa.ac.uk/Publications/InformationAndGuidance/Documents/ADHA08.pdf

[5] Design Council. The Value of Design Factfinder. Available: http://www.designcouncil.org.uk/sites/default/files/asset/document/TheValueOfDesignFactfinder_Design_Council.pdf [Accessed on 2014, 22 February].

[6] Oxford Dictionary. Available: http://www.oxforddictionaries.com/definition/english/digital-native [Accessed on 2014, 22 February].

[7] *Wikipedia*. Available: http://en.wikipedia.org/wiki/Generation_Z [Accessed on 2014, 23 February].

[8] Design Council. Available: www.designcouncil.org.uk/our-work/Insight/Policy/Sustainability/. [Accessed on 2010, 25 August].

[9] Design Council. Available: www.designcouncil.org.uk/news-opinion/introducing-design-methods [Accessed on 2014, 22 February].