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ON MAKING: ISSUES OF 3D REPRESENTATIONS IN DESIGN EDUCATION

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ABSTRACT
Digital design practices can be used to enhance students' agency in the generation, manipulation, and understanding of three-dimensional form. This paper examines the value of digital practices by contrasting the opportunities offered by digital modelling with those offered by more traditional, sketch-based strategies.

Keywords: Digital making, 3D representations, materiality, technical artifacts

1 INTRODUCTION
Product designers use a number of modes of representation when generating and evaluating three-dimensional form, traditionally these would have been concept sketches, in combination with physical mock-ups or rough sketch models. With the advent of digital technologies in design practice, however, these accepted modes of representation have now been augmented by digital alternatives in the form of CAD modelling and (comparatively) affordable rapid prototyping. Each of these various forms of representation, both traditional and digital, or physical and virtual, can be used to a greater or lesser degree in the assessment of appearance, feel, and usability of proposed designs.
The practice of design is becoming an increasingly digital one [1]. Effective 3D digital modelling software combined with powerful and cheap personal computing, as seen in the recent ubiquity of the laptop, has given designers what McCullough describes as the first, truly 3D sketch-book [2]. Personal experience of the first author as an architectural and product model-maker, a staff member (and now visiting lecturer) at the Royal College of Art, as an active user of digital design tools, and more recently from case-studies of design practice undertaken as part of PhD studies, reveals that digital modelling technologies can be used to support a re-evaluation of the role of making in design education. In addition to this, the case-studies mentioned above have also revealed a demographic change taking place in the practice of design. Younger designers, although taught in the accepted system, have often had to embrace digital practices soon after entering the workplace.

2 THE SKETCHING-PRECEDING-MAKING PARADIGM
It was the industrial revolution, and the concept of the division of labour, that first introduced the widespread need to represent three-dimensional designs on paper [3]. As a consequence the two-dimensional, paper sketch-book, and the sketching-preceding-making paradigm, became corner-stones of professional design practice and, in turn, design education for many years. Although the paper sketch-book has served designers well both it, and the sketching-preceding-making paradigm which grew out of it, could

be replaced by McCullough's conception of the 3D sketch-book (the personal computer combined with digital modelling software). The existing practice of mentally visualising three-dimensional form, attempting to represent that three-dimensional form in two-dimensional media (i.e. sketches, orthographic projections, etc.), and then attempting to create a three-dimensional physical representation from that two-dimensional representation has always been a fraught and imprecise process. The widespread acceptance of digital design tools has now made it possible to re-evaluate how form is generated in design. Not only is it possible for digital modelling to perform this 3D - 2D - 3D mediation automatically, as virtual designs are presented on-screen, but the inherent ability of digital modelling to uniquely and accurately record three-dimensional form, and the potentially infinite malleability of digital processes, mean that student designers can now be afforded greater agency in the manipulation, exploration, and an enhanced understanding of form in the round.

3 MODES OF REPRESENTATION AND FORM GENERATION

Different modes of representation are better at recording different things and the mode of representation used will affect the kinds of form that can be generated. Traditional (2D) drafting, by attempting to represent three-dimensional form on a two-dimensional plane, tends to accentuate the importance of side profiles rather than a more holistic appreciation of form. Drafting can only supply incomplete information about the form of an object, especially those composed of compound-curved surfaces. The form of this kind of object is approximated in traditional methods by sampling a very small part of it - taking sections through the object at more or less arbitrary points - and leaving the areas between these samples open to interpretation by interpolation. Digital modelling however, in addition to its role as a 3D sketch-book, can also be seen to supply a *unique* and usable record of compound-curved form. The digital notation of form is wholly interrogatable in a way that was impossible with previous methods. A physical artefact - a model or a mock-up - *may* uniquely record the form of a design but it is often extremely difficult, if not downright impossible, to extract information from that record. Different modes of representation can therefore be seen to be better at *reporting* different things. The need in product design to uniquely communicate the form of a product from the designer to a third party - to colleagues, clients, toolmakers or even, at a later date, back to the designer themselves has, in the past, constrained the kinds of form that are generated still further to those that can be readily (re)produced from profiles made up of straight lines and connected radii. As Pipes has noted about the forms used in Bauhaus designs:

> "It was not so much 'form follows function' as form follows drawing style." [4]

This idea of different modes of representation leading to different outcomes, and how the digital can open up new possibilities in the generation and understanding of form, resurfaced in case studies conducted earlier this year, in the words of two recent graduates from the Royal College of Art. First, a Design Products graduate from 2005:

> "…before I knew how to use 3D software, I limited myself in many ways - in how I designed, because I didn't know how to illustrate it, so I would design in different ways: I would not draw the curves that I really wanted…"

Next, a Goldsmithing, Silversmithing and Jewellery graduate from 2004:

> "I'm now using the computer as a design tool, because on paper you can't see something three-dimensionally from every angle; if you were to draw it out it would take a long time, and you wouldn't be accurate..."

The given examples of modes of representation: sketches and physical models from traditional design practice, and CAD drawings and digital geometry from the newer digital practices, are actually one and the same thing. They function in the design process as technical artefacts [5] i.e. as externalized forms of internal representations (of the imagined design). By externalizing and recording the form of a design, technical artefacts are used as a way to reduce the mental load on a designer's evanescent, short-term memory. They can be thought of as a way of clearing a space in the imagination.
Both the internal representations of a design (in the imagination) and its external representations, whether physical or virtual, are part of a design's materiality, that knowledge of a design which is available to the senses; its 'reality' as perceived in the mind [6]. The materiality of a design exists whether or not this sensory input comes from physical or from virtual sources - materiality is not always synonymous with physicality. Rapid prototyped objects however, as physical instances of digital representations, can be seen as the converse side of the same coin: as the physical output of digital designs they can be used to assess those tactile and functional qualities of designs which are unavailable from on-screen representations.
The digital can be seen as just another tool, an addition to the toolset of non-verbal representations, and of 'Designerly Ways of Knowing' [7]. However, there are clear advantages in the adoption of digital tools, not just in time saving and avoiding unnecessary mental fatigue, but also in designers' enhanced understanding of their designs as three-dimensional forms.

4 A RE-EVALUATION OF MAKING IN (DIGITAL) DESIGN

Learning by doing, a legacy of the Bauhaus, has been a part of design education and practice for at least a century now, and making things, the production of technical artefacts, has always been a valuable part of the generation of form in design. Digital making, by the same token, is also engaged in the production of technical artefacts, both virtual and physical. However, not everything digital offers the same degree of affordance for form generation. Many digital modelling programs, derived from 2D CAD, are essentially electronic paper: they continue to work within the drawing paradigm. Feature-based, parametric solid modelling, however, does offer an alternative approach that can be thought of as design-through-*making* rather than design-through-*drawing*. Programs such as Solidworks and Pro/Engineer, used throughout professional practice, approach form generation in a way that is closer to traditional craft practice, using digital equivalents of the kind of marking-out and shaping processes to be found in physical making. This concept of design-through-making, rather than design-through-drawing, was used in the following example to build up an exploratory accretion and subsequent modification of a set of digital features. No drawing was made of this example object before commencing work on it.
Feature-based modelling begins, unsurprisingly, with a 'base-feature', and the example object (Figure. 1) began as an extruded block. The three images in this figure show the effect of the initial shaping processes. The second and third steps (Figure. 1) in this image are particularly important to my argument as they reveal how the apparent bulk of the object has been reduced by the radii. Front and side elevations, taken from either

of these steps, would have been indistinguishable if standard orthogonal views had been used.

Figure 1. The initial stages: two profile cuts and two full-round radii are applied to a virtual block

The malleability of the digital affords greater opportunities for experimentation here: anything that has been done digitally can be just as easily undone, as became apparent during the further refinement of the form of the example object (Figure.2). At this point the main focus of interest in making the object shifted to the area of the edge profile at the top of the block, an edge that was created solely by the intersection made by 'cut' features with the main block, rather than a pre-determined, pre-sketched outcome. The shape of this edge was repeatedly adjusted by going back and forth in the feature 'tree', modifying the profiles that generated the intersection, and assessing the effect of those modified cuts on the shape of the edge. The way the appearance of this edge changed as the view of the object was rotated was an important factor here, being able to take a virtual walk around the object was an integral part in deciding how the design would progress.

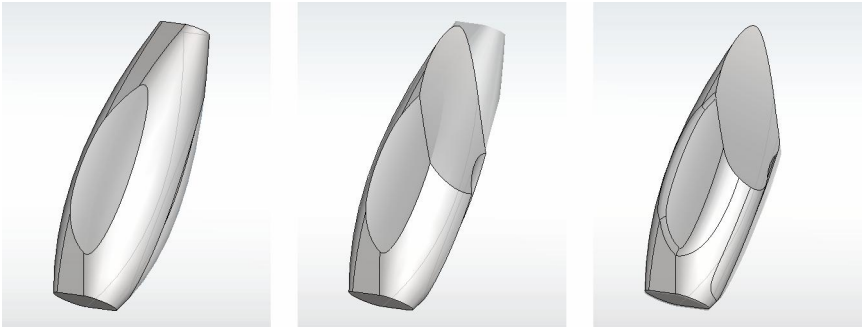

Figure 2. Refining the outer form of the block with two vertical cuts and a further perpendicular one

Once again, orthogonal views would have been of little use, and sketching would have been unable to describe this particular aspect of the design. A traditional sketch-based approach could not have been used in this case to develop the design further.
As stated earlier, the form generation process used here involved going backwards and forwards through the list of features that define the form (the feature tree) in a non-linear fashion; modifying earlier features in the light of later decisions. In addition to

modifying features it is also possible to simply move a feature's position in the feature tree and, by re-ordering the sequence in which features are applied, it is possible to generate unforeseen results which would have no analogue in any 'real-world' process. The particular digital design process used here was solely confined to removing material, digitally carving the form out of the initial block. By the same token, material could just as easily have been added for a fabrication based approach, or both approaches could be used in combination.

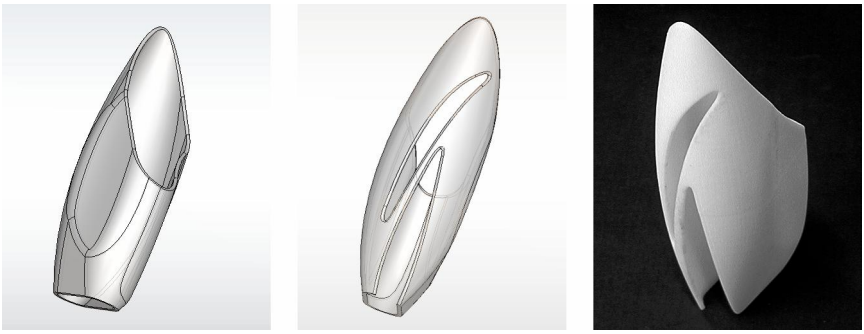

Figure 3. Shelling and finishing touches. Finally: a physical instance of this particular digital design

Following the final shelling and detailing processes the virtual object was converted into an STL file, which was then used to make a physical object via the fused deposition modelling process.

Often, when making, you have to start somewhere just to get an idea of where you actually should have started from. When making a physical artefact many of the processes involved are irrevocable: once a piece of wood has been planed there is no way to un-plane it, which tends to inhibit freer experimentation with form. The digital, however, makes it possible to back-track to a preferred departure point without the necessity of starting again. It can be seen to enhance agency in the generation and manipulation of form, especially so in more organic designs where traditional strategies for representing form would struggle.

Practice has not been good at describing how models have been used to generate form in design. Making, however, can remain at the core of design education, although a new consciousness is required of what it means in a digital design age. The incorporation of digital tools may not only offer a suitable means of developing the communication and creative skills of student designers, but may provide the only viable means of doing so.

5 CONCLUSION

Why should we change design education? If we are now part of a digital age this should be reflected in our approach to design education: if we have a better understanding of the ways in which the digital is already being used, and how those practices may be improved further, we will be better able to assist students in their manipulation and understanding of form in design. With the advent of the digital the accepted practice of 3D – 2D – 3D mediation, as part of the sketching-preceding-making paradigm, is now open to re-examination. Current design education practice seems to have become blinded to the ideals of the Bauhaus spirit by insisting on the *details* of Bauhaus practice. The Bauhaus ideals themselves emerged out of a recognition that design education should change to mirror changes taking place in the outside world. As

traditional design practices were no longer appropriate the Bauhaus decreed that new designs should be created from first principles only, rather than by following precedent. The irony of this situation in 2006, of course, is that precedent now includes the Bauhaus itself.

Digital practices afford greater scope for experimentation than traditional methods and, as Rapid-Prototyping looks set to become Rapid-Manufacture in the foreseeable future, design students should be encouraged to use digital representations, both on-screen and physical, to enable them to function fully as designers on graduation. Digital practices can add new possibilities in the generation of form, to allow these new possibilities we should not artificially limit them by insisting on the practice of sketching first. With the widespread acceptance of digital practices it is now possible for student designers to be involved in making form, rather than just drawing it, from the outset.

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