The DATA Lecture

The Current and Future Role of Modelling in Design and Technology

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Introduction

When I was invited to give the DATA lecture at the National Exhibition Centre I was given the option of proposing the topic. Although being a great supporter of the importance of both electronics and information technology as vital areas of children's education, I decided to use this opportunity to raise the debate and promote the importance of modelling in design and technology. In particular, this lecture will cover those methods of modelling that children and adults use when they are designing. I support the idea that modelling is at the heart of the subject and, as Bruce Archer proposed way back in the 1970s, that modelling is the language of designing. New ways of modelling continue to be developed as a result of the IT revolution and three, namely CAD/CAM, rapid prototyping and virtual reality, will be reviewed. Evaluation is required to determine how effective those IT modelling techniques are that are currently being used in schools and what the impact of these new forms of modelling may be on design and technology in schools in the future. We need to consider what, if any, changes need to be made to what and how design and technology is assessed in the light of these developments. We as educators need to identify whether children will benefit from using these new forms of modelling and, if so, how should they be used by pupils as they prepare for adult life?

The examples provided are mainly in the areas of resistant materials, electronic products and systems. It should be noted, however, that modelling is, of course, of equal importance for all areas of design and technology.

This paper reviews different forms of modelling, their roles in designing and identifies that one of the key skills pupils need to develop when designing is to be able to select appropriate models for developing, testing and/or communicating ideas.

Current context for design and technology

Gradually, over the last 40 years, and at an increasing rate, there has been a growing awareness of the importance of good quality design. Often led by the Design Council, industry has gradually begun to appreciate the importance of good design, not only in terms of appearance but in all aspects of products including their ease of use, reliability and more recently, sustainable design issues.

Linked to this is a recent revival of a recognition of the importance of innovation for the well being of the future economy of the country. Design and technology in schools is one area in which children can be educated to be more innovative. The development of modelling skills, including cognitive modelling, can be argued are key factors in increasing creative ability.

A new version of the National Curriculum Orders for design and technology was published in 1999 followed by supporting schemes of work published by the QCA. It is encouraging to see in the new order the requirement for pupils to develop thinking skills and evaluation skills. Clearly design and technology should be able to play a major part in developing thinking and evaluation skills since they have always been fundamental aspects of this subject area. In previous National Curriculum Orders for design and technology there has been little emphasis on the key role of modelling. The QCA Schemes of Work (1999) also encourage modelling in some schemes. For instance, in QCA Key Stage 3 Schemes of Work, unit 8F 'Pupils should learn: to design directly in 3D using low cost, quick to use materials without preliminary drawings.' p 4.

Never has there been such a wealth of resources for teaching design and technology both for the pupils and their teachers. Examples of organisations that have produced materials over the last few years are the Design and Technology Association (DATA), Department for Education and Employment (DfEE), examination boards, industrial companies, institutions such as the Institution of Electrical Engineers (IEE), Nuffield Design and Technology Project, Royal College of Art (RCA) Design and Technology Project, Technology Enhancement Programme (TEP) to mention but a few. Many, such as the Nuffield Design and Technology Project and the RCA Design and Technology Project, support the role of modelling in their materials.

Another aspect of the current scene is the recent rapid advances that have been made in computing power and design related software. Today, thanks to a number of initiatives, pupils can have powerful CAD/CAM modelling packages such as Pro/DESKTOP on their computers at school that only a few years before could only be afforded by industry. Standard packages such as Microsoft Excel are readily available which can be used for mathematical and graphical modelling in design and technology.

There is a growing research culture in higher education in design, and design and technology education. Those involved in research and curriculum development in design and technology around the world are able to share findings through conferences such as IDATER at Loughborough University

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Figure 1: An example of Lucy Holland's work, winner of the Stuart Pugh Design Awards 2000.

and through a range of journals such as DATA's *Journal of Design and Technology Education*. The DfEE's Best Practice Research Scholarships (£3000) to encourage teachers to be involved in research are a welcome addition in helping to build a research culture in the design and technology teaching profession.

Designing and making

While this lecture is about modelling used when designing, it is very important to note that in no way does that mean that the importance of making in design and technology should be lessened. So important is making that it is worth just quoting a short extract by Roberts and Baynes (1998) on the value of making in human development.

> 'Making' is recognised by anthropologists, cognitive scientists, psychologists and educationalists as one of the most fundamental aspects of human beings. Every known human society has used making as a way of shaping its environment. But making is also crucial in personal development not only because of its practical usefulness but also because it interacts creatively with other aspects of intelligence.
>
> In child development, making is so fundamental that there is a danger of it being taken for granted. In fact, all children depend on handling materials and working creatively and experimentally with a variety of tools in order to attain basic knowledge about the world. Making is recognised by anthropologists, cognitive scientists, psychologists and educationalists as one of the most fundamental aspects of human beings.

In a period which lays much stress on literacy and numeracy, it is all the more important to present the case for 'children making' as forcefully as possible. (Pt B: 2)

One of the advantages of three dimensional (3D) sketch modelling, which is discussed below, is that it involves the pupil or designer in making.

Modelling

This section looks at what a model is, why modelling is an important issue to address for design and technology educators, why modelling can be considered the language of design, what the relationship is between modelling and designing, why models are used and what forms of modelling are available.

A model is a representation of something which exists, or in the case of design and engineering, something that could be produced. A model has only some of the attributes of what it is representing. Different types of models can represent different attributes and some can demonstrate particular attributes better than others.

There are many types of models and these include two dimensional (2D) such as sketches and drawings, physical three dimensional (3D) such as 3D sketch models or mock-ups, 3D appearance block models, mathematical models, computer models and cognitive models, that is, imaging in the mind.

An example of a range of modelling that can be used when designing is shown in Figure 1. It is the work of Lucy Holland, a prize winner at the Stuart Pugh Design Awards in 2000 organised by the Institute of Engineering Design. The display shows examples of development sketches, 2D modelling, two 3D sketch models and a 3D scale model.

Models can also be categorised into three different types according to whether they provide a visual representation, a diagrammatic form or abstract code:

- iconic models – those that represent an aspect of a product by looking like that aspect e.g. a drawing or 3D model of a kettle handle, symbolic. Sketching, card, foam, clay and wooden 3D models are all forms of iconic models.
- analogue models – those where diagrams, using symbols, are being used to represent a system or product. In addition to the map another example is an electronic

Figure 2: Pupil's 2-D sketch modelling (age 13) Uppingham Community College.

circuit diagram where say a capacitor in the circuit diagram looks nothing like an actual capacitor.

- symbolic models – these are models which use an abstract code to represent aspects of an existing or possible product or system such as a mathematical model to represent some aspects of a new bridge.

Although this lecture is about modelling in design and technology, it is worth considering the extent to which everyone uses modelling in their everyday life. When we read a book we imagine, i.e. cognitive model, the scenes and the people described in our minds. When we listen to the radio we have images of the people talking or the characters they are acting. Geographers create maps, 2D models, and models of weather systems. We are all aware that the famous model of the London Underground gives no idea about how to go from place to place above ground but is excellent for finding the way about the underground system. Scientists, such as Newton, created models of the universe both mathematically and through 3D moving models. Chemists produce models of chemicals and chemical reactions and biologists produce models of systems such as population growths of particular insects. Economists produce models of economic systems and teachers use models to try to explain concepts, say that of an electron, to help children to learn. Clearly modelling is a vital way of communicating ideas and information in many disciplines, not just within design and technology and engineering.

There are very good reasons why modelling in design and technology should receive much more attention. The first is that modelling is fundamental to designing. From the initial idea in the mind, when a designer is briefed, all the way through to the working prototype, the designer's ideas are in the form of models. These can range from images in the mind to 2D sketches (Figures 2 and 3), 3D mock-ups, computer models and engineering drawings. All of these models have some aspects of the final product or system missing or different be it colour, mass, size etc.

The second reason for raising the issue of modelling is that there appears to be a reluctance among undergraduates and pupils to use 3D sketch models to help themselves to develop ideas.

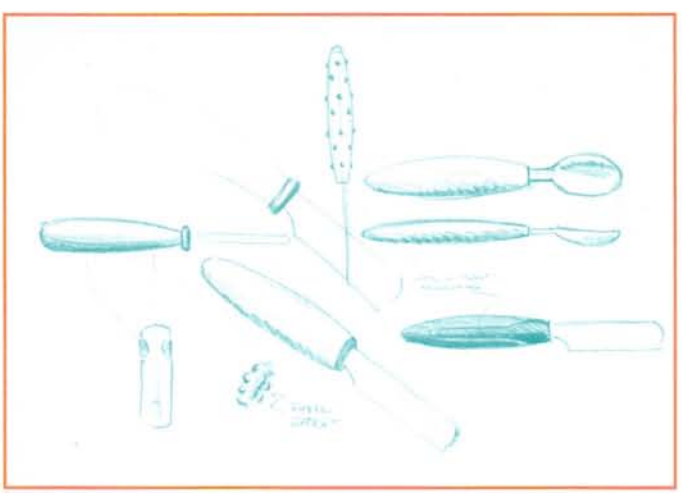

Figure 3: Professional 2-D sketch modelling by Mark Evans.

Modelling in the mind has limitations. The most obvious is that it is impossible for anyone else to share the ideas. It is also difficult for most people to develop their ideas significantly just in the mind. A third difficulty is the ability to test and evaluate the model just in the mind. It is for these reasons that other forms of modelling are used, to help to communicate to others, to assist the designer to manipulate ideas, to be able to test aspects of the design and to evaluate these aspects. What the designer requires is to be able to represent the ideas developed in the mind quickly and at low cost in a form which s/he and others can see, evaluate and develop further. Normally the initial models or images in the mind are recorded and worked on using 2D modelling, namely sketching. While some would argue that sketching is the key method for designing, it has limitations and although it is a very important modelling tool for designing, in some cases its importance may be overstated. Time and again it has been observed that undergraduates have been unable to generate new ideas while using sketching but once they move into 3D sketch modelling their ideas start to flow again.

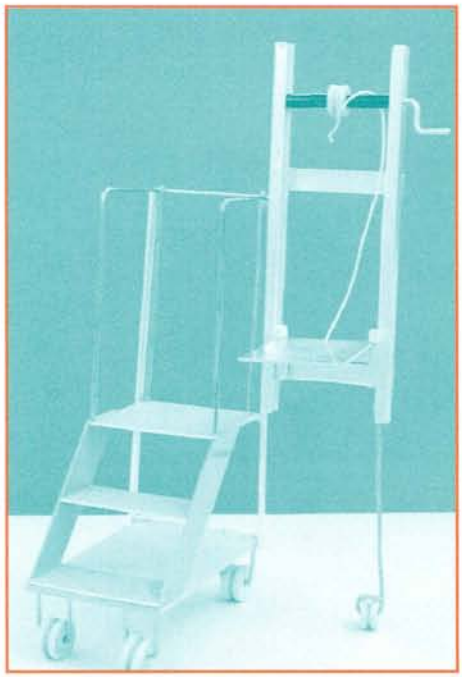

Figure 4: Pupil's 3-D sketch model by Lucy Holland.

In this country there appears to be a reluctance for pupils and undergraduates to use 3D sketch modelling. The author is currently researching, with Professor Ken Baynes and Krysia Brochocka, into whether this is in fact the case and if so why? This became particularly interesting recently when reading a paper by Malcolm Welch (1998) about his research into the way Canadian children designed in design and technology. He found that the Grade 7 pupils went immediately into 3D modelling when designing. In a follow up to this study Welch, Barlex and Lim (2000) found that even when they included teaching of modelling through 2D sketching first, the pupils still went straight into 3D modelling initially. Now the pupils may be using the most effective way for them to develop ideas, but it would be interesting to know if there is a difference between the approaches of Canadian and British children and if so, why? Is one method more successful than another? Is a balance between the two approaches the most successful? Do design and technology teachers push 2D drawing too much to the exclusion of 3D sketch modelling? The author would be very interested to hear from teachers and researchers who have views and/or experience on this topic. What is clear is that there is scope for a large amount of research in the area of modelling including comparative research.

Cognitive modelling

In design and technology, modelling is vital. As has been stated already, modelling is at the very heart of the subject. Right from the very suggestion of the need for a new solution, designers report beginning to model possible ideas in their mind. Such modelling is known as cognitive modelling, which Bruce Archer (1992) described as follows:

> The expression 'cognitive modelling' is intended to refer to the basic process by which the human mind construes sense experience to build a coherent conception of external reality and constructs further conceptions of memory and imagination. The expression 'imaging' is intended to refer to that part of cognitive modelling which construes sense data and constructs representations spatially and presentationally, rather than discursively and sequentially. (p 6)

Humans are able to design because of this distinctive capacity of the mind called 'cognitive modelling' which Bruce Archer argues is analogous with the language capacity and mathematical capacity. Modelling can be considered as the language of designing. One is able, when acting as a designer, to form images 'in the mind's eye' of objects or systems as they are or might be. These images may be manipulated and evaluated and continuously compared with the perceived requirements. As we are aware, the cognitive model can have texture, colour and sound as well as form. The image can be externalised, of course, through models in the forms of drawings, diagrams, 3D-sketches, models or mock-ups, prototypes as well as through language and notation.

2D sketch modelling

When a designer decides, or is requested, to design something, a possible solution in the form of an image, or model, appears to be often immediately generated in the mind. In order to capture or save that idea, it is helpful to record it on paper or in some other form. Freehand sketching enables the designer to record aspects of the idea in the mind quickly and at low cost in a form which s/he and others can see, evaluate and develop further. As S. Garner (1994), amongst many others has pointed out, one of the advantages of sketching is that through ambiguity or co-location of sketches, other ideas can be generated.

If sketching is an important modelling aid for designing then surely more research and curriculum development should be undertaken in how to develop pupils' and students' sketching skills which provide opportunities for ambiguity and hence an opportunity for creating new ideas? What age should learning sketching techniques be started and to what depth? Do pupils understand that one reason for sketching when designing is to assist in the generation of more ideas through the

ambiguity of the sketches and the juxtaposition of ideas?

It may be that pupils, in trying to produce the 'perfect' drawing of an idea in their mind, set on an A3 page with a perfect boarder, are restricting the opportunity for discovering new ideas because of the lack of ambiguity in the drawing. As Denton (1993) commenting on the effective use of 'design sheet' states 'They [teachers] may be failing to help children appreciate that there are different types of drawing and that these should be used in the appropriate place.' Have we been giving aspects of sketching the wrong emphasis in design and technology?

In a recent study by M. Suwa *et al* (2000) which looked at the cognitive processes of a practising architect's role of drawing, the authors identify a key implication for design education from their findings. Why not try, they suggest, encouraging pupils to see if they can find any features in their sketches which they did not intend when they drew them. Are any of these new features discovered in the sketch relevant to their design? A lack of skill in freehand sketching, it would appear, may be limiting one method pupils and students could use effectively for idea generation.

3D sketch modelling

3D sketch modelling, also sometimes known as a mock-up, is a quickly produced 3D model (Figure 4) which is made using readily available materials to quickly represent aspects of the 3D form of the product which might at this stage just be in the mind or in 2D sketch form on paper. Wood, plastic foam, Plasticine and card can all be used for this type of modelling so it can be low cost and can be produced quickly. Clearly many of the attributes of the product are possibly missing such as the correct colour and finish, the correct mass etc., but it does give the designer, the client, the user and/or teacher, a better idea of the 3D aspects of the final product. Experience also shows in practice that many of those not trained in design appear to understand the designer's ideas much more easily from 3D sketch models than rendered drawings and sketches.

There are implications, of course, to using 3D sketch models, especially in schools, because students need to learn techniques about how to design, make and develop such models. Suitable materials and making facilities also have to be readily available. Developing making skills through producing 3D sketch models may, of course, be very beneficial. A further consideration in schools is how such development can be recorded as evidence for assessment. How can design development through 3D sketch models be assessed? Space for storage of such models is difficult to find and often the models themselves go through many changes as new ideas are tried out.

Of all the different modelling techniques, 3D sketch modelling, or mock up, is possibly the one that is currently undervalued the most, particularly in schools and universities. This is so important because the use of 3D sketch modelling may be one of the most important techniques for innovation and the most cost effective method for the initial communication of ideas both to the designer him/herself, the client or users.

Now in industry, including design consultancies, 3D sketch models are used a great deal. Adrian Dartnall, a professional industrial designer, gave a typical answer when questioned about the use of sketching and 3D sketch modelling, stating 'You can only go so far using just using sketching'. Those who have seen the Dyson video for schools (2000) or who have read the article in Datanews (2000) entitled 'A Look Inside: Dyson' will be aware that the design engineers at Dyson use corrugated card and foam to model their early ideas. Companies making different products still use 3D sketch models but, if they are not injection moulded products, they may not use corrugated card. They might use wood or steel instead, whatever enables them to produce the most useful and quick economic models.

Now, if professional designers, with highly developed cognitive modelling skills, find 3D sketch models valuable when designing, how much more valuable are 3D models likely to be helpful to pupils who have limited experience of designing and work better with 'concrete' examples?

This may be true but there is a need to research into the effectiveness of 3D sketch models in schools and, as mentioned above, a pilot study is currently being undertaken at Loughborough University. From these findings, if the results are positive, further research will be needed to identify effective ways of introducing 3D sketch modelling for designing into schools.

However, research takes time and it is to be hoped that, in the meantime, teachers will either continue or begin to encourage pupils to produce 3D sketch models early in their designing. Pupils should be encouraged to record what they gain while producing the model, as well as from using it for evaluation and communication. Pupils could also be encouraged to think about what, in their own experience, has resulted in their ideas being generated. It would be interesting if teachers recorded their findings on the use of 3D

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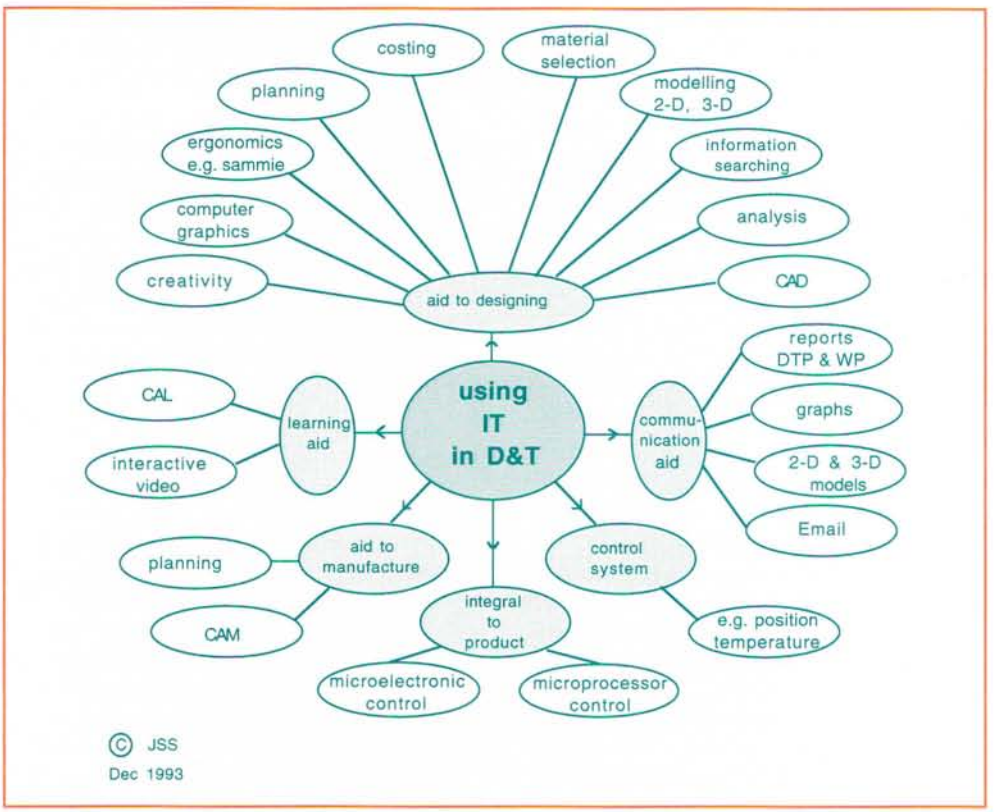

Figure 5a: Uses of IT in D&T (Smith J.S., 1993).

sketch models by their pupils and sought to publish their findings in the *Journal of Design and Technology Education*.

Modelling using information and communication technology (ICT)

The application of IT to designing has had a major impact on modelling of design ideas in industry and commerce. There is no doubt that ICT has started and will have ever more impact on designing, making and evaluating in design and technology in the future. In 1993 a DfEE invitation conference was held in Stratford upon Avon on information technology in design and technology. In the report of this conference, Smith (1993) produced a model, Figure 5a, which was produced to identify areas of IT (now ICT) that might be involved in design and technology. As can be seen, ICT can be used to assist modelling and manufacture, it can be part of the product, and it can be used in the form of computer assisted learning (CAL) to assist learning in design and technology. At the conference, three areas were identified that teachers most needed support for introducing ICT into design and technology. These were manufacturing, control and modelling. It was the group's experience that most teachers found the third area the more difficult to initially see a role for IT in it. There was a tendency for some teachers to be unaware that the term modelling included more than 3D modelling. Two resource packs were published by National Centre for Educational Technology (NCET) (now BECTA). The latter 'IT in D&T – The Modelling Pack' published in 1996 still has aspects in it that would be of interest to design and technology teachers today even though more modern IT facilities are now likely to be available.

Introducing computer aided design/computer aided manufacture (CAD/CAM) into schools over the last 10 years has been difficult. This has been for a number of reasons of which the key ones have been the cost of the hardware and software to provide sufficient access for a class of pupils, the hardware was often not adequate, there has been a long learning curve for most of the software and it was difficult for teachers to obtain sufficient training and sufficient time to become reasonably proficient. Some of the best early work was produced by pupils in the areas of textiles and using 2D computer controlled vinyl cutters or embroiderer machines.

In the last few years the opportunity to use computers for modelling in schools has developed apace as the speed and power of computers has increased and the costs have come down. Software for the modelling of electronic systems and the modelling of printed circuit board designs by pupils at a reasonable cost and with sufficient capability for schools are now available. Software for the modelling of mechanical systems is available at both a simple and high level.

Figure 5b: Pupil's 3-D sketch model RCA Design in General Education Primary.

There have been a number of CAD/CAM initiatives to introduce it into schools such as Manufacturing by Design supported by the CBI and the latest initiative using a software package called Pro/DESKTOP, which is supported by PTC, DATA, DfEE, Delcam, CBI, and the Warwick Manufacturing Group. Training is required before the teachers are given the licence to use the software with pupils. Over 1,700 licences were given out in the first 12 months. It will be interesting to see what the impact of this modelling and manufacturing software has as it becomes more readily available to pupils.

One of the key problems in using CAD is the learning curve even though software is becoming easier to use. One way round this, pioneered by amongst others Tony Hodgson (1995, 1998) at Loughborough University, is to provide support learning materials on a CD-ROM which can be used while actually using the CAD software. This method of learning has the advantages of pupils being able to work at their own rate, they can put in more time and they can go beyond the teachers' current capability.

Once a solid model has been obtained in the computer (Figure 6), a wide range of further modelling opportunities become available. Putting the model into virtual reality will be covered later but one can also put the object into an animation package to model how it might operate or be assembled. Having produced CNC code from the CAD model, the parts can be manufactured using CNC machines. If quick models are required, foam or wooden moulds can be produced using a CNC router. Plastic forms can then be produced by vacuum forming using the wooden moulds or by producing injection mould tooling, again using CNC code from the CAD model of the mould tool.

Rapid prototyping is now a common, although relatively expensive, method in industry of producing models of parts that have been drawn in CAD. A fairly recent relatively low cost and relatively fast system takes the CNC code and uses a 3D 'printer' which puts down layers of starch and deposits a binder solution where a build up of material is required as shown in Figures 7 and 8. The binder holds the powder together layer by layer to build up the 3D object. By the year 2005, the company in the USA that produces the 3D printer expects it to be down to desktop size, cost $2000 and be used by 11 year olds. Further information is available from the Innovative Manufacturing Centre Nottingham.

Figure 6: 3-D CAD model using Pro/DESKTOP by teacher Kevin Jones on INSET course with Tony Hodgson at Loughborough University.

A key requirement, or restraint, in the design of successful products is ergonomics. Whether it is making an item easy to use or comfortable in use, the application of ergonomics can help. A simple, but often overlooked aspect of ergonomics, is that two people may be the same height but one has a short neck, long back and average leg length while another might have long legs, short back and average neck length. A 3D ergonomic CAD modelling package developed at Loughborough and Nottingham Universities from 1986 called SAMMIE CAD enables models of different sized people to test out the ergonomic aspects of products and systems.

A typical example would be a car interior, a Brussels tram or the cab for the new Hong Kong Airport train. It can save thousands of pounds compared with building physical models, but once a design works using SAMMIE, a full size model can be produced which can be tested by humans.

One example of the use of SAMMIE has been in the designing of car park layouts for the disabled. It identified the space required to

Figure 7: Rapid Prototyping using 3-D printer.

enable a driver to take out her/his wheelchair once parked. As can be seen in Figures 9 and 10, 3D analysis is essential when people are involved in complex tasks.

Currently this package is not available for schools. At present, the learning and programming time required to use it is far too long. However, it is clearly one type of package that will one day be available to pupils in schools to help them in their design modelling.

Not all modelling using ICT has to use specialist software. Mathematical and graphical modelling, for instance, can be achieved using generic software such as a spreadsheet including Microsoft Excel. Such software can be used by pupils for modelling.

Little research has been undertaken in the area of using and learning with IT in design and technology. Questions certainly are arising that need to be answered quickly if progress is not to be stifled. Typical examples of questions are:

Figure 8: Rapid Prototyping using 3-D printer.

- how should CAD work be assessed compared with manual and other machined work?
- how can the work of pupils from two schools be compared when one has CAD/CAM facilities and the other does not?
- how can the design development undertaken using a computer be recorded and assessed?
- is it acceptable for pupils to be ahead of the teachers when using CAD/CAM?
- should CAD replace drawing by hand? If not totally, what should be the time spent on each?

Virtual reality

One of the latest forms of the use of IT in modelling is using virtual reality (VR). The UK VR Forum (2000) defines VR as follows: 'Virtual reality refers to a suite of technologies which permit human intuitive interaction with real-time, three-dimensional representations of information held in computer databases.'

After an initial wave of publicity in the 1980s with people wearing immersive headsets and pilots using the successful, but very expensive, flight simulators, VR has been slower to come into everyday use than had been perhaps anticipated. Two areas of recent growth of VR applications have been in the computer games market and in 'walk through' architectural models. In the last two years the hardware necessary has come down in price and the software is becoming easier to program. Already VR is available in schools as aids to learning about manufacturing with Denford's VR Robot and VR CIM. A CD-ROM is available for enabling to learn about food manufacturing using VR. Probably, before too long, pupils will be able to place their models of products in a VR environment. IBM and TEP (2000) have created a virtual reality library of over 60 animations illustrating mechanical, electrical and manufacturing key concepts.

A recent development made possible by IT is virtual reality haptic modelling. Such modelling is based around a special joystick which provides physical feedback while interfacing with a virtual environment. One such system is the PHANTOM haptic interface by Sensable Technologies. This system enables designers to use their sense of touch while modelling on the computer. It is intuitive to use and is somewhat similar to working using physical modelling with clay or foam, yet with the advantages of using a completely digital tool i.e. the resulting code

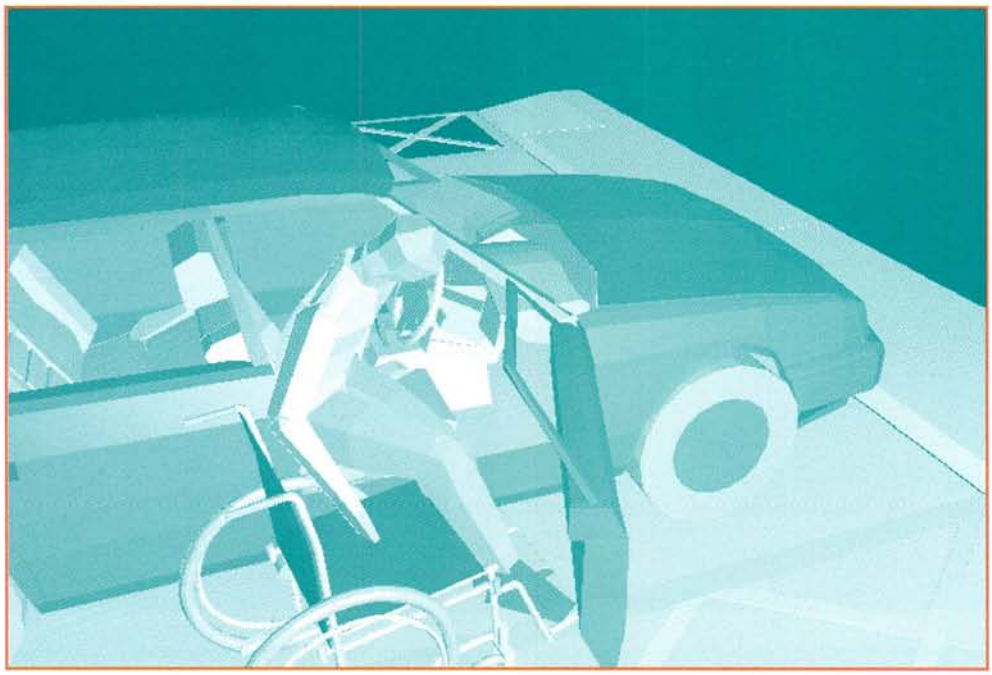

Figure 9 and 10: Modelling space required for person with wheelchair parking using SAMMIE CAD by Mark Porter Loughbourough University.

can be used with a rapid prototype machine to produce the object designed on screen. The three Figures 11, 12 and 13 show stages in development of a broach designed by Mark Evans of Loughborough University using the above system. The central shiny metal part was added after the virtual reality modelled part had been made by rapid prototyping. Evans *et al* (2000) report that while the system trialled currently had shortcomings, it had much to offer in generating 'almost craft effects'.

So far the discussion about modelling has been largely related to older children and adults but we know, from experience and the work of Professor Ken Baynes and others, that children in Key Stages 1 and 2 enjoy modelling in 3D and that they use cognitive modelling to generate ideas. In working with primary teachers and Key Stage 1 and Key Stage 2 pupils, Professor Baynes has developed 'ways of talking' that help children to be aware of their ability to 'see in the mind's eye' and to make use of sketch models for developing ideas.

- 'When you listen to a story do you imagine pictures of the people, places and objects inside your head?'

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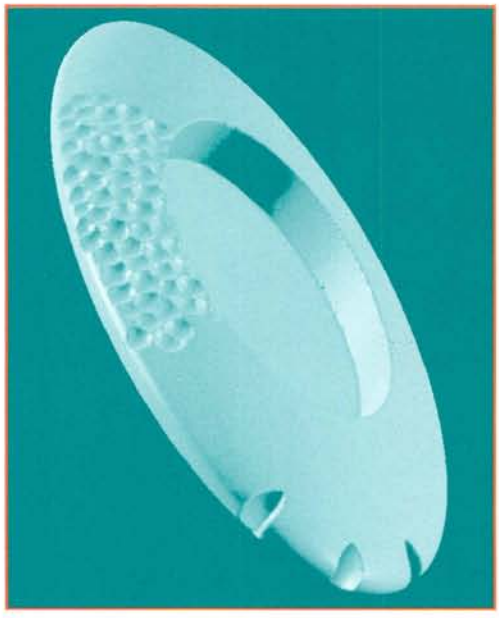

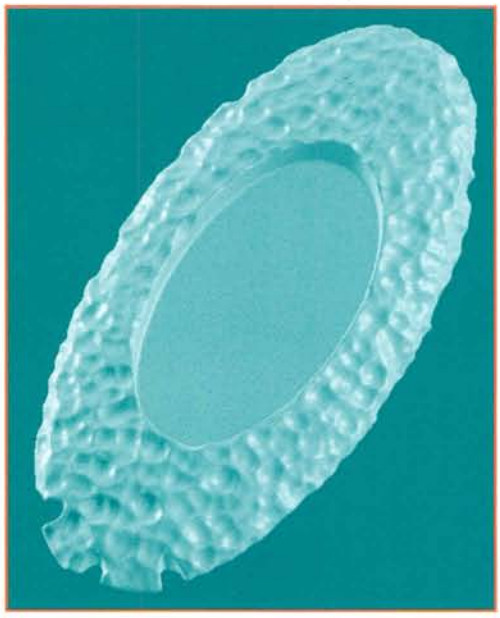

Figures 11, 12 and 13: VR modelling of broach using haptic modelling system by Mark Evans.

- 'Can you do the same when you are thinking about something you want to make?'
- 'How can you share with me what you can see in your head? Talk about it? Do a drawing? Make a quick model?'
- 'What would be the best way to share your ideas? What can a drawing do that talking couldn't? What could a model do that a drawing couldn't?'
- 'Is the model exactly like what we want? Can we improve it by changing it? Does changing it improve the idea in our own head as well?'

At a very basic level such questions encourage children to think about thinking and to be aware of their ability to imagine and visualise, in other words model in the mind, as well as by using 3D models.

If children can model in the mind and have a capability in design and technology which develops through their experience of growing up, the question arises as to what is then left for the teacher to do. Baynes (1992) is quite clear:

> The answer is the same as in every other area of human development. ... Through good teaching the child can become self consciously aware of his or her design capacity and be able to make deliberate use of it. (p. 42)

Teachers can do their best to help children to develop modelling capability based on their knowledge to date but we do not yet know sufficient about how children develop design capability to be sure we are assisting and not stifling such development. Much more research is needed into how children develop design capability not least their cognitive and other modelling skills.

Conclusion

Modelling is central to design and technology and Archer's proposition that modelling is the language of design has so far stood the test of time.

Sketch modelling in 2D is a valuable tool for the development of ideas but it has been argued that, if pupils understood how sketching that left ambiguities enabled new ideas to be generated, they might look on this type of modelling in a new light. Certainly the teaching of drawing for designing would benefit from further research.

One reason for a particular interest in 3D sketch modelling was a reluctance often noticed in undergraduates and pupils to quickly use such 3D models to develop and communicate their ideas. Once they had tried using 3D models, they found them very

valuable for generating further ideas often even as they made them. What is more, if professional designers such as at Dyson use 3D sketch models to help in their designing, how much more likely is it to be helpful to pupils who benefit from thinking with 'concrete' i.e. physical objects.

Information technology is now integrated into much, but not all, professional design work. In schools many successful modelling packages such as for electronic design are readily available, and more advanced CAD/CAM packages are being introduced in some schools. We in education have to consider carefully when to encourage pupils to use ICT and when to encourage use of traditional methods. There is no doubt that IT capability can be taught admirably through design and technology, given the time and the resources, thereby providing pupils with an excellent foundation for life in the future IT based world of work.

It may be that in the future pupils will be able to design and make totally using computer based machines. Whether this will be beneficial is interesting to surmise since, if making is as important as the Crafts Council's report states, then is making with the aid of computers equally important and beneficial?

What is clear is that the development of modelling using ICT should not be held back in schools because of assessment difficulties or a lack of knowledge of the benefits of new approaches. Teachers must be encouraged and supported to take part in action research in the classroom, particularly to help identify successful ways of developing pupils' modelling skills for generating and communicating their new and hopefully innovative ideas.

Modelling is at the heart of design and technology. The more we can encourage pupils to use a range of modelling techniques, including 3D sketch modelling and computer modelling, the more likely we are to generate a population with innovation and IT skills.

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www.sensable.com/apps.htm#design

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SAMMIE CAD
www.lboro.ac.uk/departments/cd

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