The role of modelling in Design and Technology

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I have suggested elsewhere[1] that design activity can be construed as a kind of 'modelling' process, where the aim is to produce a set of written, or graphical, or other (eg, computer programme) specifications detailing the construction, function, and performance of an artefact or system

What I would like to do here is to examine in more detail some aspects of those modelling activities which can be considered to constitute a part of the 'design process'.

Modelling in the national curriculum
The National Curriculum Working Party for design and technology[2] has emphasised modelling activities., it states that pupils should be able to use models for imaginative and creative work; models should be used to represent ideas; to develop them; to help make aesthetic decisions; to explore ideas further; to explore alternative solutions; and to specify intentions. Pupils should also be able to consider details using mock-ups, prototypes, or working models; should be able to use anthropometric and mathematical models to produce and develop design proposals; should be able to use modelling techniques to model systems; to resolve conflicting requirements; and they should be helped to develop specialist modelling techniques and use a range of modelling media to assist them in all of these requirements. The Working Party expressly states that pupils should:

> *"... develop the ability ... to model what is required in the mind, symbolically, graphically and in 3-dimensional forms ..."*[3]

The notion of 'model' offered here is clearly a very broad one, and — certainly at the more advanced attainment levels — quite a sophisticated one involving work in a variety of media in both 2 and 3-dimensions, covering a range of applications.[1]

However, these specifications are not very precise, which is understandable, given that the terms of reference for the Working Party were such that they:

> *"... should leave scope for teachers to use their professional talents and skills to develop their own schemes of work within a set framework which is known to all. It is the task of the Working Group on Design and Technology to advise on that framework ..."*[4]

Thus, it is for teachers, and others concerned with the implementation of these proposals, to set out more precisely what they may mean in terms of the role and function of modelling activities as they fall within CDT.

Modelling in GCSE contexts
How do teachers presently view the uses of models and modelling techniques? One way of finding out is to take a look at the ways in which this is approached in some of the more current publications aimed at CDT for the GCSE examinations. As one might expect, the advice and guidance is practical and down to earth, and the rationale assumed for the usefulness of modelling is similarly plain: Models are *"... used to get a clear idea of what a finished design will look like"*[5]; they are *"... a key stage, to see how (the design) works, or how it can be improved"*. They can *"... be most helpful in developing and refining a proposal"*[6]; models are *"... useful to give a sense of proportion ... They are also useful in showing up faults in your designs before you have put too much work into them"*.[7] Again, modelling is *"... also a useful means by which prototypes for products and devices can be designed"*.[8] They can help *"... test design ideas in 3-dimensions"*.[9] Not surprisingly perhaps, advice and guidance aimed at pupils tends to focus on materials from which models can be made (such as balsa wood, clay, wire, plastics, card etc) together with discussions of the ways these materials can be manipulated using standard tools and equipment. 'Purpose-mades' such as Lego and Meccano are popular, together with small electrical and electronic components. Writers recommend their use since, for example, *"They are quick to use, and give realistic versions of design ideas ..."*[10]

Texts directed more specifically at teachers are fewer; one popular example which focuses on the use of models in CDT from a 'product modelling' viewpoint, states that here, the aim is to *"... examine in detail a range of product modelling techniques ... which lead to the creation of prototypes whose appearance corresponds closely to the intended commercial product"*. For this reason,

Left: Pupils can use models to clarify and develop ideas.

"... particular consideration will be given to models whose outward appearance is exact and which are constructed to function — especially where this depends on electronics".[11]

On the basis even of this brief survey, it is possible to see the considerable store of practical experience and wisdom thus revealed. The emphasis is mainly on the use of models as an aid to 'visualising' an artefact (or some part of it) either in its appearance, or in terms of its function (for example, a simple mechanism, structure, or circuit). There is plenty of practical advice on the materials and processes involved in the construction of such models.

Models as information carriers

Models thus tend to be seen in the main, as *carriers of information* which is either already 'there' in some less developed form (for example, as 'thoughts', sketches, or drawings) and which the model can help represent, develop, or refine in some way; or which the model can present in some *alternative form* so as to render that information more accessible or intelligible.

This 'information carrying' function is taken generally to be unprobematical, at least as far as its pedagogic role is concerned, and attention thus focuses on various methods of constructing models from a (frequently ingeniously and inventively chosen) range of materials.

Now I would suggest that we might call this a *craft-centred approach* to the role and function of modelling activity; modelling is seen primarily as a '—make' issue, and the challenge to the teacher is one of helping pupils to develop the practical skills they need in order to render their design ideas (ie, the information they already have 'there' is some form) with greater clarity.

However, the growing emphasis on *design and technology*, with greater stress on the richly creative pedagogic possibilities opened up, both from a consideration of the 'design process' itself, and also from a consideration of the more specifically technological concepts thus introduced, should give us cause to at least re-assess the role and function of models in the light of these changes.

I think there at least two main questions worth airing here; Firstly, do models as typically presented in current literature on CDT exercise their function as 'information carriers' in ways that are *pedagogically effective*? 'Secondly, can modelling activities in the CDT context, have pedagogic roles which are distinct from that of information carrying?

Firstly then, the kind of modelling activities we have been looking at usually presuppose that (for example) there is prior possession on the part of the observer (ie, the user of the model), of the concepts appropriate to its application. For instance, it is generally assumed that the observer can make a ready distinction between the model, and the domain (the artefact or system) being modelled; or that the observer possesses concepts such as that of scale, or a ready appreciation of what different elements of the model are taken to symbolise, and so on.

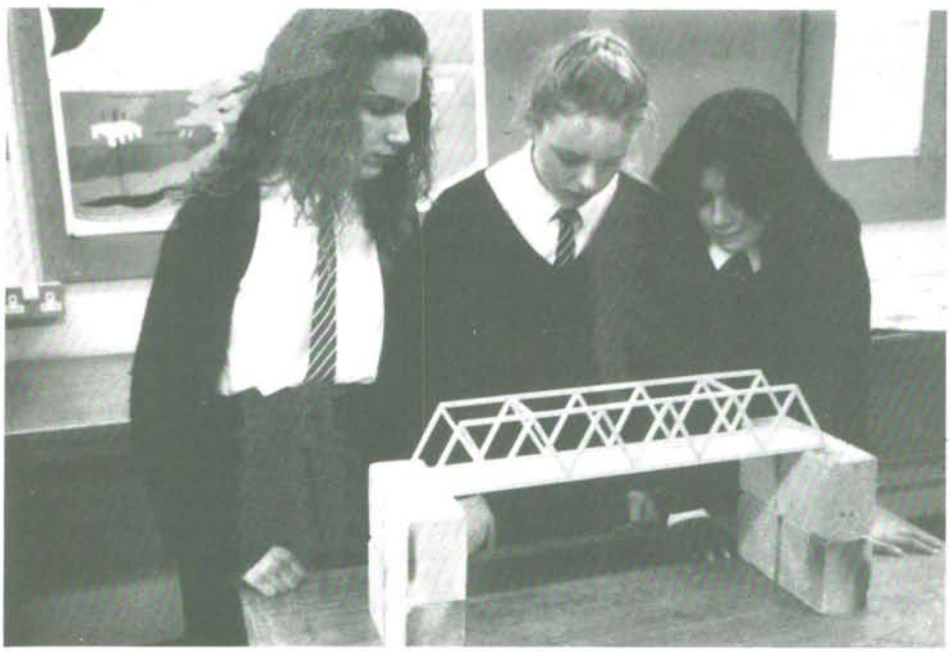
As a simple example, consider a map: this is in effect a 2-dimensional model, to scale. The successful user of a map needs in possession of several concepts fundamental to map usage — the notion of a distinction between map and domain being mapped — the notion of 'scale' — and some notion of the ways in which the various symbols on the map can function so as to represent elements in the 'real' world. In short, a map is really only usable by those who are *already in possession* of quite a sophisticated conceptual scheme. But although we might (in our role as teachers) use maps as examples of *scaling*, or as examples of the *use of symbols*, we would surely not rely on the *simpliciter* for the teaching of these concepts; we would have to bring in other kinds of material to help bring about *an understanding of these concepts.*

It is interesting to note that in the teaching of geography, where this problem is actually encountered, investigation of this learning situation suggests that although:

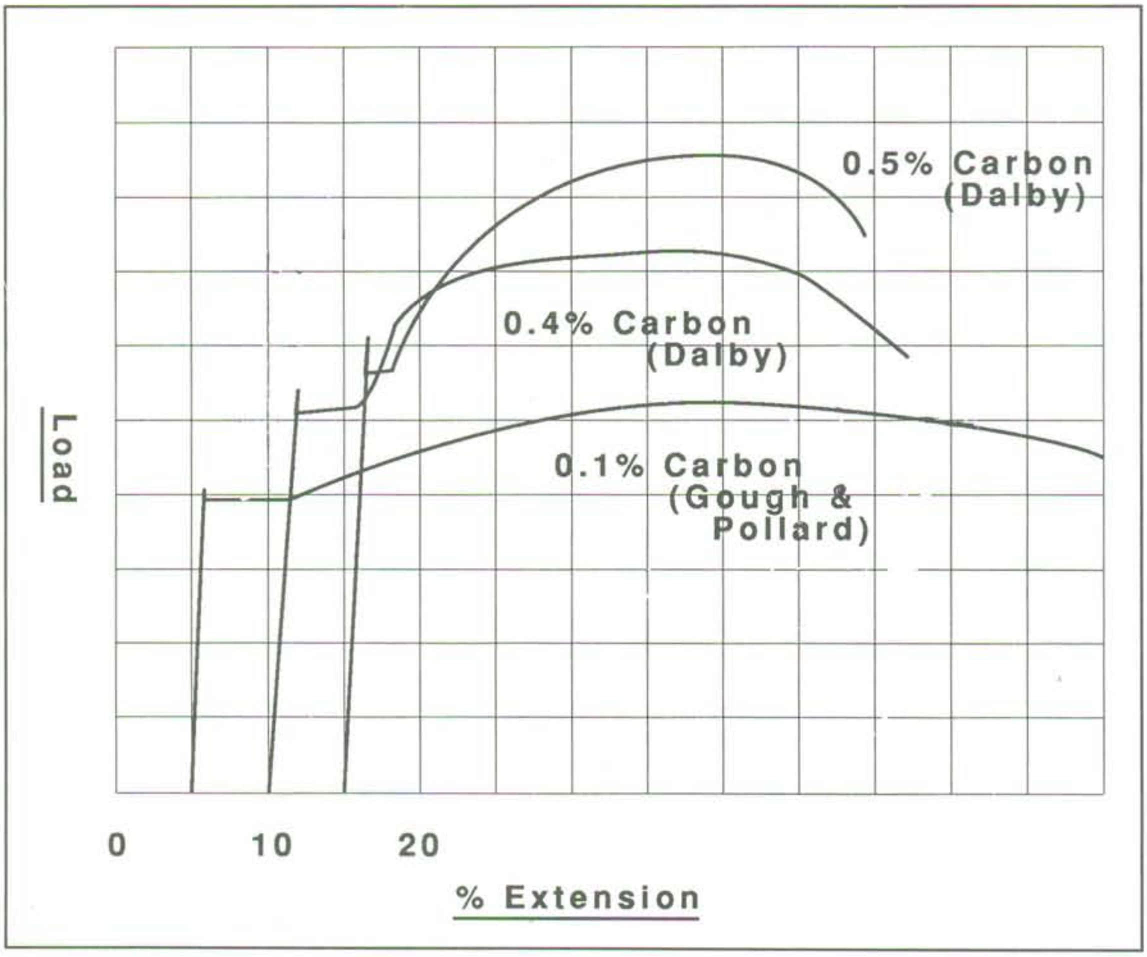
> *"... Children ... may well be able to learn to differentiate among different maps, and to learn that this shape is Britain ... this achievement may have nothing geographical about it, and is often merely the ability to discriminate among shapes ... True understanding of maps needs considerable grounding in practical activity so that the abstractions and conventions ... are genuinely related to those aspects of the real world which they symbolise".*[12]

Now before we rush to congratulate ourselves on being masters of a 'practical activity' anyway and therefore not prone to such errors, we should remind ourselves that although modelling activities are indeed (in the sense we have perceived here) 'practical', their role (as we have also perceived so far at any rate) tends to be that of a sophisticated 'information carrier' and if we *do* conceive that role as being unproblematical, it is because we tend (at least tacitly) to assume that the requisite concepts are 'in place' as it were, by the time pupils come to use models in a CDT context. But this may be a mistaken assumption, for although some concepts (such as the ones just referred to in the 'map usage' context) may be possessed — at least to some extent — by the majority of pupils by this stage, others just as essential for the successful use of models may not be.

As a typical instance, take, say, a balsa wood model of a bridge of the type



Left: Accessing the information in this kind of model requires a prior grasp of the concepts involved.



Left: Load-extension graphs for a range of medium carbon steels. The graph clearly exhibits the relationships between load elasticity and ductility, and thus helps to clarify the relations between these concepts

popularly used to demonstrate structures. Here, the *effective use* of the model presupposes some understanding of its salient features. But what appears as salient will depend to a great extent on the experience and conceptual sophistication of the observer; considerably more is demanded here than notions of scale or modes of symbolisation presupposed by the previous 'map usage' example. The observer needs to have some grasp of what 'strength' of a material means in this kind of context, and of how choice of materials is related to methods of construction and strength of structure. Such relations are complex and can only be properly understood via rather sophisticated quantitatively based concepts. Although this model does indeed carry information, it does not carry *this kind* of information as such; rather, it presupposes this kind of conceptual background as a necessary precondition to accessing the information it *does* carry. And, as in the 'map usage' example, where the information carried is of the details of the terrain being mapped, so in this example, the information carried is of the constructional detail of the type of bridge being modelled. As with map users, this kind of information can be extremely useful — but only to those who have already grasped the conceptual 'lingo'![13]

Generally, models constructed as information carriers tend not to work very effectively as pedagogic instruments since, as we've noted in the above examples, they (tacitly at least) presuppose prior acquisition of the very concepts the information they carry is premised upon and thus cannot be used to *teach those concepts.*

Yet pupils who quite happily employ balsa wood, craft knives and glue guns in the construction of model bridges are not necessarily wasting their time, since of course, much can be learned (from materials manipulation, to at least a qualitative sense of the relationship between weight, material, strength, and structure). But it is doubtful whether this kind of activity is — by itself at least — a very effective route to the grasp of underlying conceptual structure.

'Modelling' conceptual structure

The issue of conceptual structure takes us to the second point I wanted to raise; can modelling activities in a CDT context have pedagogic roles which are distinct from that of information carrying? Well, to begin with, I think that the discussion thus far makes it clear that we need to distinguish between models as *information carriers*, and those which might be used to perform a *teaching function* since these are by no means necessarily congruent. Teachers, and other professionals in the field of design education will be quite used to the information carrying function of models, and will be very familiar with the concepts which render that information accessible, but it may sometimes be this very familiarity which can lead the expert to fail to see the opacity of elements in a particular model when viewed by a learner.

I would suggest then, that the identification and elaboration of the underlying *conceptual structure* of a model may often be an important task for the teacher. Other experts (designers, engineers, architects etc) *use* modelling techniques, but do not (normally at least) undertake this additional pedagogic task, which is specifically one for the teacher.

It is evident that models, particularly when used in the teaching of technology, often aim at teaching pupils about underlying concepts; a popular example is the use of one material to model the

behaviour of some other material (eg, the behaviour of a material such as steel) under conditions of loading. Thus plasticine might be used to model the behaviour of steel under conditions of shear loading, or foam rubber might be used to model the behaviour of a steel beam subjected to a load.

In such examples, the plasticine or foam rubber is used as an *analogue* with the aim of giving pupils some grasp of flow under shear, or elastic deformation under load, of a material such as steel. A difficulty with this kind of model, is that the properties of materials such as plasticine or foam rubber make rather poor analogues for the structural properties of steel, particularly in terms of key properties like elasticity, rigidity, ductility and so on, which help to make steel such a useful material for structural work.

Of equal importance here, is the *relationship between* these properties; put simply, it is only because a material such as steel exhibits the particular relationships between these properties that it does, that structures such as bridges can be built using it. 'Modelling' materials such as plasticine and foam rubber have such dissimilar properties from steel that it is far from clear that we can effectively use them to model these relationships.

Of course, to the practised observer, it will be relatively easy to 'weed out' the *points of dis-analogy* and pick up usefully on *points of analogy* between model and artefact in modelling activities of this kind. But it is doubtful whether the learner gains any clear idea of the crucial relationships between material properties that this kind of model attempts to teach because from the learner's viewpoint, such points of analogy and dis-analogy may not be clear. As with our earlier 'information carrying' examples, some prior grasp of the conceptual structure, (ie, the relationships between the properties of a material such as steel) seems to be required in order for the pupil to grasp its significance. But this is the very thing the model is supposed to be teaching![14]

In general, models which aim to teach concepts and/or conceptual relationships, should be *good analogues* of the system being modelled; and they should expressly *avoid presupposition* of those very conceptual relationships they seek to teach. Provided that we are prepared to conceive of modelling activities in fairly broad and flexible terms, these need not be unattainable goals. For instance, the conceptual structure *apropos* the 'bridge' example we have just been considering, might be more effectively modelled using graphical techniques. The use of a graph not only gives an accurate quantitative rendering of concepts such as elasticity, ductility etc, but also avoids the tacit presupposition of the conceptual structure that the graph is modelling. It succeeds in this because it exhibits the relationship between concepts such as elasticity, ductility, and loading factors in explicit quantitative terms; the graph explicates this conceptual structure — that is what it is in effect designed to do.

It is interesting to note that although graphs are frequently used in mathematics teaching as straightforward information carriers, they can also be used very successfully to teach the conceptual relationships involved in mathematical processes such as differentiation and integration. The 'modelling' function here is very similar to the one discussed in the 'bridge' examples; the graph renders explicit the conceptual relationships between, for example, rates of change, and maxima or minima.

What is presupposed of course, is a grasp of the concepts apposite to graphical techniques (eg, of number, scale, co-ordinates etc). But having grasped these, the learner can use this kind of model as an aid to the understanding of other concepts and conceptual relationships.

Reflections on the function of graphical techniques as models of underlying conceptual structure would also suggest that such techniques could well be developed further in, for example, computer based simulation. This relatively new medium could be a fruitful means for the explication of concepts and conceptual relationships, particularly in view of the powerful visual input that new computer graphics techniques affords. The danger here of course, is that these new techniques may be used to simply dress up the old and familiar models without addressing the underlying conceptual problems associated with them. What is needed here, is a research programme which links analysis of the conceptual structures and relationships appropriate to the emergent needs of the learner[15] with some of the imaging techniques available through computer simulation. Such a research programme would be able to generate software capable of extending the role and function of modelling techniques in the design and technology curriculum.[16]

Conclusion

There is nothing wrong with the conventional uses of modelling techniques as devices for the straightforward representation of 'real world' elements; and of course, models can serve a quite irreplaceable role as information carriers. But we should remember that their utility as carriers of information does depend upon users having the appropriate design vocabulary, which means (at least in part) the possession of the requisite concepts.

We also need to develop and refine our approach to modelling techniques as aids to the elucidation of conceptual structures. This has tended to be a rather neglected area of research, but in the context of the contemporary design and technology curriculum, it is an important one.

References

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13. Thus a full understanding of concepts such 'elasticity' or 'rigidity' would require some understanding of their quantitative dimension.
14. For an interesting discussion of the role of models and analogies in the closely related area of science, see M Hesse (1970), 'Models and Analogies in Science' University of Notre Dame Press.
15. This conceptual structure could of course be usefully defined in terms of the Key Stages in the National Curriculum Technology.
16. For a challenging critique of this area of computer research see J Searle (1984), 'Minds Brains and Science' BBC Reith Lectures.

