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Using models in design & technology education: some conceptual and pedagogic issues

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Abstract
Models in design and technology education are generally perceived as information carriers; educators at least tacitly regard them as carrying, clarifying, and enlarging on information of one kind or another which is relevant to design activity.

However, the information carrying role of models is often confused with another pedagogically important one; models in design and technology education can also have a function with regard to the explication and teaching of concepts [an issue frequently confronting science teachers] and this can be distinguished from their function as carriers of information.

In this paper I will attempt to clarify and distinguish these roles. Following upon this, I will suggest ways in which design and technology educators can make their use of models and models in the domain of design & technology education as information carriers and this information carrying role is generally taken to be unproblematic. There is also a tendency to assume that observers or users of the model will have ready access to the information it carries.

However, if models are to serve as effective information carriers, then the users of the model must be able access that information. It must be intelligible to the user; the conventions, form of notation, concepts etc. employed in the model must be understood.

Factors such as mode of representation, schema, context, vocabulary, style etc. play a vital role in determining how the model functions, relates to the situation that it is intended to represent, as well as how that information is perceived and understood.

The issues I want to address in this paper concern the roles that modelling activity of various kinds can play in design and technology education. I will attempt to clarify and distinguish these roles, and then go on to suggest ways in which we might make our uses of models in design and technology education more effective.

Reviewing some of the recent literature on design and technology education indicates that models are commonly used to:

- Obtain ideas about the finished appearance of a design
- See how the design might be improved
- Develop or refine the design
- Show possible faults in the design
- Study possible prototypes
- Test mechanisms, circuits, or other parts
- Represent features such as scale, proportion etc.
- Check features such as weight, feel etc.

The list here is not exhaustive, but we can see that the emphasis tends towards the use of models as 'visual aids' for rendering such things as appearance, function, construction, feel etc. as clearly and vividly as possible. Models are assumed to serve the purpose of taking information which may exist in some less 'developed' form [e.g. notes, sketches, or even 'ideas in the head'] in order to develop or refine this information in various ways, presenting it so as to render it more accessible or intelligible. Information may then be 'fed back' into the design activity so as to advance the process.

This indicates that there is a tendency to construe models in design & technology education as information carriers and this information carrying role is generally taken to be unproblematic. There is also a tendency to assume that observers or users of the model will have ready access to the information it carries.

However, if models are to serve as effective information carriers, then the users of the model must be able access that information. It must be intelligible to the user; the conventions, form of notation, concepts etc. employed in the model must be understood.

Factors such as mode of representation, schema, context, vocabulary, style etc. play a vital role in determining how the model functions, relates to the situation that it is intended to represent, as well as how that information is perceived and understood.
As an example, consider Fig. 1. I might look at this and see it as representing a duck. Now supposing someone points out that it might also be seen as a rabbit. After this I realise that the figure can be 'seen' as either a duck or a rabbit. What this indicates [among other things] is the important role that assumptions, expectations, prior learning etc. play in determining what kinds of information observers might obtain from various kinds of representations, including of course, models.

Figure 2: Flying boat

Even where the basic interpretation is correct, many other kinds of ambiguity lurk in models commonly used in everyday teaching contexts. Fig. 2 masks the possibility that the wire hooks might bend, that the propeller might jam against the bead and spacer, that the balsa wood fuselage might slip out of place, that the energy stored in the band might be insufficient, that the band might release its energy too quickly, and so on. All this might be taken in by the practised observer, and suitable modifications made to the model in order to get it to work. It is however, doubtful whether the learner would notice many of these difficulties from mere inspection of the model. The expert tends to assume that the model is more transparent to the learner than it actually is. This transparency factor is important if the model is to serve its purpose as an effective communicator of information.

Other kinds of ambiguity lurk in models typically used in design and technology education. Fig. 3 shows a typical diagram of the principle of orthographic projection; it is intended to carry that information and communicate it effectively to the learner. It is, however, an illustration which, moreover, can only really be appreciated by those already in possession of the requisite concepts pertaining to orthographic projection. It tacitly presupposes the possession of the very schema it attempts to explicate. In fact the model requires a good deal more than this from the observer; it is interesting to note that this schema is itself encapsulated in a mode of projection [axonometric] which, to some learners at least, would itself stand in need of explication. What is being assumed is that by enmeshing the orthographic schema in the axonometric schema, the principles of orthographic projection will somehow become clear. The transparency of many such everyday illustrations and models tends to be assumed, when in fact, classroom observation of learners in such contexts often indicates that they may be [to the learner at least] quite opaque.

Models such as these contain information, but this is, as it were, locked up in the model, only accessible to those already in possession of the requisite concepts. But the concepts, ideas, and information etc. are precisely what the model is supposed to be offering the learner or observer. Models that are designed to carry information generally tend to do just that; but they also generally presuppose an often quite sophisticated understanding as a necessary precondition to accessing this information. Educators using such material need to be careful to avoid the tacit presupposition of the very ideas etc. they seek to teach through their use, and I'm afraid that surveys of educational material used in this domain will find this problem cropping up quite frequently.

I will return to this point again in a moment; but first, there is another area of ambiguity I would like to explore briefly. Models can be used in design and technology to teach underlying concepts; for example, a model might be used to model the behaviour of a material or structure. Thus, plasticine might be used to model the behaviour of metals when being extruded, or subjected to various kinds
of loading; again, a material such as foam rubber might be used to model the behaviour of a steel beam subjected to a uniformly distributed load or a point load etc. In these examples, the plasticine or foam rubber etc. is being used as an analogue for a resistant material [such as steel].

Now, I think analogies can be a wonderfully fertile means of teaching, of conveying and extending ideas. But I think two main problems can arise here. Firstly, it is easy to over-estimate the transparency of this kind of analogy. The practised observer [the expert, the teacher et. al.] can ‘see’ the important points of analogy the model makes with the ‘real world’ artefact; but the learner may not gain any clear idea of the crucial relationships that the model is alluding to via the analogies it is attempting to set up. The danger is, that the model may tacitly presuppose the possession of the very concepts required to ‘read’ the analogical relationships between the model and the artefact or system etc. being modelled. As with our earlier information carrying examples, some prior grasp of the conceptual structure may be required in order for the learner to grasp the points being made by the model. But of course, this conceptual structure is often the very thing the model is supposedly aimed at teaching!

The second problem relates to this; the properties of materials commonly used in models of this kind often make rather poor analogues for the properties of the materials being modelled. Foam rubber, plasticine, card and paper etc. are very tractable materials to model in, but they don’t perform structurally in ways very similar to commonly used resistant materials such as those used in engineering, building etc. particularly with respect to key properties such as rigidity, elasticity, malleability and ductility. Again, I think it is tempting for the expert to tacitly weed out these points of disanalogy as it were, and assume the model has a greater transparency for the learner than it really has.

The above considerations highlight the fact that although models as used in design and technology education tend to be conceived of as information carriers, this information carrying role doesn’t necessarily translate very adequately into that of a teaching role, particularly where we are attempting to teach the learner new concepts and develop new areas of understanding. Indeed, these two roles are really quite distinct. It is interesting to note that this kind of difficulty also crops up in the neighbouring area of science education where, for example, one is seeking to explicate the nature and behaviour of electricity in a circuit, of light in optical instruments, or of the action of gravity on physical bodies. The problem is usually to find models and analogies which are useful and illuminating without either presupposing a prior grasp of the concepts one is aiming to explicate, or misleading the learner as to the ways in which the analogy is supposed to function.

Models as Pedagogic Instruments

Models can thus serve not only as information carriers, but also as pedagogic devices in the development of the learner’s understanding of new concepts and ideas, and as long as we bear the possible pitfalls in mind, models and modelling activities, can be extremely effective vehicles for teaching and learning. Pupils wrestling, for example, with the problem of creating a design for a mask will readily appreciate how a piece of paper, folded to create an axis of symmetry, will help to solve the problem. The mask shape, drawn from the fold, then cut out can provide not only a solution to the problem, but function also as a model which actually serves as a graphic explication of the concept of symmetry through its actual use. Again, pupils grappling with the problem of constructing a butt-jointed frame will quickly come to an appreciation of how a gusset can help to strengthen the joints; and also how the size, shape, etc. of the gusset is an important determinant of the strength of the joints. Note too, how the concepts of symmetry and strength can be usefully linked here; the effectiveness of the gusset as a means of strengthening the joint is governed to a significant extent by considerations of symmetry. Carefully inter-related modelling activities of this kind will allow the learner to approach key concepts in different ways, from different ‘directions’ as it were; many of the concepts we want learners to grasp can only be understood adequately through a variety of applications.

Maximising the interaction between learner and model thus becomes an important objective, for example, by using the model to obtain a set of results from which a ‘picture’ of the concept, or conceptual relationships being modelled might emerge. The simple model in fig. 4 for example, could be set up in a variety of configurations in order to measure deflections under loads. An objective would be to lead the learner towards a grasp of concepts such as strength, rigidity, elasticity, and of how these relate to mode of structure and so on, through active investigation using the model. The model, properly conceived, thus becomes a means of guiding the learner, by rendering key conceptual relationships with maximum perspicuity. It can do this by discarding poor analogies and
irrelevant details, and focusing explicitly on what we want the learner to learn, bringing this out as clearly as possible.

As a further example, graphical techniques [see fig. 5] can serve as good explicators of many kinds of conceptual relation, and, of course, they provide some good models. They can also provide learners with plenty of opportunities in design and technology, to become actively involved through the development of graphical materials based on their own investigations. Graphs can be used to give an accurate quantitative rendering of such concepts as strength, elasticity and ductility of materials, by plotting relationships between load, area, extension etc. Pupils, in carrying out their own investigations into properties of materials can, by modelling their results in graphical form, begin to achieve a more effective grasp of such key concepts. This becomes possible because graphical techniques are explicitly designed to model relationships between various kinds of data; that, in effect, is what they are designed to do, and in doing so, they can render some kinds of concept with a perspicuousness that would be difficult, if not impossible by other means.

Again, it is interesting to note that although graphs are frequently used in mathematics teaching as straightforward information carriers, they can also be used successfully to explore relationships between, for example, volume and surface area, or to teach sophisticated concepts such those of differentiation or integration. The graph serves as a vital link in the development of such key mathematical concepts. As in science, design and technology, mathematics educators are continually faced with the challenge of developing models which are effective pedagogic instruments.

Conclusion

I have put forward a view which indicates that models in design and technology education are commonly perceived as information carriers; they are regarded chiefly as carrying, clarifying, and enlarging upon information of one kind or another which is used in design activity. Although this is usually considered to be unproblematical, I have tried to make it plain that ambiguities of one kind or another are frequently present in models, and that care needs to be taken in ensuring that such ambiguities do not mislead or confuse the learner. A model used in teaching and learning environments needs to clearly relate to the needs and abilities of the learner, using a shared medium of communication so that it is maximally transparent.

I have also argued that this information carrying function, useful though it is, is not necessarily the only role a model may have; it can also serve as a pedagogic instrument for the teaching of ideas, concepts, and conceptual relationships which are important in design and technology education. We need to carefully distinguish between these different roles, and in particular, we need to exploit this pedagogic function effectively. It is vital to ensure that the model does not tacitly presuppose the prior possession of the very ideas and concepts it is supposed to be explicating.
I have argued too, that provided we take some care to select and use them appropriately, models can be very effective as pedagogic devices; pupils undoubtedly enjoy both using and making models, and they can learn much from this kind of activity. The use of models also extends across a range of teaching and learning contexts closely related to design and technology. As design and technology educators, there is much we can share with colleagues in other curriculum areas, particularly in science, mathematics and art, that might help to promote the more effective use of models as aids to teaching and learning.

References


