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# Learning about structures: a pilot study comparing physical and IT - based models

Terry Liddament and Dominic Clare

Department of Design Studies, Goldsmiths University of London

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## Abstract

*The identification and presentation of conceptual structures and relations can be an important task when considering the pedagogic roles models can perform. With this in mind the authors are setting up a pilot study to develop some modelling materials aimed at investigating some of these issues. The chosen focus is learning about structures, and it was decided to use both a 3-dimensional physical model, and a comparable IT-based model presented on a computer programme. The aim with both types of model is to identify key concepts and conceptual structures, and present these perspicuously through the models, then go on to trial their use with selected groups of pupils.*

*The pilot study is aimed not only at developing pedagogically effective modelling materials, but also at making some comparison of the effectiveness of differing model types through a comparison of the physical, with the IT-based model.*

*The authors discuss the development of the modelling materials used, together with the empirical and other research strategies devised to test their effectiveness. Some of the results obtained from their work using the modelling materials with pupils are presented and an assessment is made of possible ways in which the research programme might undergo further development and refinement.*

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## Introduction

It has been argued elsewhere<sup>1 2 3</sup> that models as used in design & technology education may be seen not only as information carriers, but also as capable of modelling conceptual structures, and conceptual relations. When models are carefully produced to carry out the latter function perspicuously, they can fulfil a teaching role which is quite distinct from their role as information carriers. However, our researches, both into much of the current literature dealing with the uses of models in teaching and learning, and into the everyday uses of modelling activities in the classroom, indicate that models and modelling activities are often not as pedagogically effective as they might be.

One of the main difficulties highlighted in earlier discussions is that designers of models and modelling materials, particularly those used in pedagogic contexts, tend to assume that these models are more transparent to the learner than they actually are. This transparency factor as we may describe it, is an important consideration if models are to serve not only as effective carriers and communicators of information, but also as pedagogic devices for the teaching of key concepts in design & technology education.

## Background

The notion of a transparency factor can be refined and developed a little further; to begin with, it is

important to note the distinction being made here between what are in a sense really quite separate functions; between, that is, the model conceived of as an information carrier; and the model conceived of as having a pedagogic function, by which we mean, the specific role a model may have in a teaching/learning situation, in conveying ideas or concepts new to the learner.

These two functions are epistemologically distinct; the former focuses on the conveying of information, while the latter attempts to usher the learner into a new domain, conceptually speaking. The two are often confused, for the quite understandable reason that a given model can [and frequently does] serve both functions. The effective communication of information does indeed require the model to be transparent [or as transparent as possible]; this alludes to the mode of communication, and models may do this more or less effectively depending on their design. A well designed model will be maximally transparent in the sense that it will communicate with maximal efficiency. It exploits, or presupposes at least, a shared system of communication within a domain that is shared both by the constructors, and the users of the model, and which is encapsulated in the conventions utilised by the model. We will refer to this particular notion of transparency as informational transparency.

Now, informational transparency still does not capture the notion of transparency with respect to

a model's pedagogic role; this requires us to take account not only of efficient communication, but also the structuring of the model so as to teach concepts new to the learner. We will refer to this notion of transparency as epistemic transparency, as an indicator of its distinct role in considering the function of models with respect to the development of new areas of understanding on the part of the learner. This notion of epistemic transparency enables us to focus more explicitly on what is often a neglected consideration in the design of modelling materials to be used for teaching purposes, namely, that the model needs to differentiate clearly between the information the learner is already presumed to be in possession of, and the 'new' material it is intended that the learner will absorb. This material will thus be new not merely in the sense that it is new information, but also in the sense that it entails the grasp of new concepts on the part of the learner. In developing the concept of epistemic transparency more precisely, we should be able not only to separate it usefully from informational transparency, but, just as importantly, sharpen up the objectives, epistemically speaking, of the modelling materials.

It would of course be a mistake to suppose that any given model will exhibit either of these modes of transparency to the exclusion of the other; both will always be to some extent present in however a distorted or attenuated form. We might characterise the nature of the relationship between them as being like that of the relationship between the syntax [grammatical structure] and the semantics [the 'meanings of terms'] in a natural language; just as semantics always presupposes some syntactical structure, so epistemic transparency presupposes some level or degree of informational transparency. Another way of putting this would be to say that syntax and semantics stand in an internal relation to one another; they are necessarily connected; likewise, informational and epistemic transparency also stand in an internal relation.

It is also worth bearing in mind that informational and epistemic transparency are not only related to one another, but in addition, are related, both to the intentions and objectives of the constructors of the modelling materials, and to the cognitive level or state, of the observer, or learner. Now, although the former relationship should, as indicated above, be considered a necessary one, the latter set of relationships - between constructor and model and observer - are rather peculiar. For it is an empirical matter as to whether the model actually appears to be informationally or epistemically transparent to the observer or learner; and [perhaps rather more surprisingly] it is, equally an empirical matter as to whether the model actually models the

constructor's intentions in either informational, or epistemic terms. Both constructor and observer stand in a contingent relation to the model, as far as informational and epistemic transparency is concerned.<sup>4</sup> Yet - and this is the peculiarity - notions such as 'observer', 'learner', 'communicator', or 'teacher', are notions which presuppose a shared form of communication, a language. They are notions, which, like informational and epistemic transparency, stand in an internal relationship to one another and to language; they too are necessarily connected. Although there is no space here to develop this point in detail, some study of the nature and working of natural language seems necessary if we are to deepen our understanding of the way in which models function as communicators.

However, it is worth the effort to get clear about the distinctions being made here between necessary and contingent features; models, considered as communicatory and epistemic tools, are themselves a part of our wider language, and will perforce exhibit both sets of features. Our intuitive belief that the model, like any other part of language, must communicate something, is supported by an explication of those aspects which, as we have indicated here, exhibit necessary connections; the intuition seems to be: if there is 'language' at all, then it has to work. Unfortunately this can get translated into an often unwarranted assumption that the model is an effective communicator *per se*. It is, rather, a matter of contingency as to whether particular models actually work in the way intended, or with particular observers. Our intuitions blur the distinction between necessary and contingent features and also tempt us to slide without noticing, from one to the other. The result is that we are then in danger, both of failing to understand how language works as a form of communication, and also what it is about those features of the wider language that models share, that can make modelling such a pedagogically effective activity.

Just as difficult to dislodge, is the tendency to blur the distinction between informational and epistemic transparency, or simply not to notice the distinction at all. As a result, both the teacher and the learner can become confused and disoriented; the teacher, as constructor of the model has expectations on the part of the learner which [probably] won't be fulfilled; and the model may well be quite opaque to the learner.

### A Research Programme

The above considerations indicate a research programme having a number of possible elements: there is scope for developing and refining theoretical

constructs such as informational transparency and epistemic transparency; and there is much useful ground to be covered in relating a more general epistemology of language to modelling activities considered as a specific form of communication- as a sub-species of language.

In addition to this type of theoretical and conceptual exploration, we can formulate empirical investigations to include an identification of these features in commonly used modelling materials; we can attempt to develop modelling materials which aim at exhibiting these constructs and features; we can test some of the theoretical constructs we are attempting to develop and refine by introducing modelling materials incorporating those constructs in teaching and learning situations; and we can also test the efficacy of the modelling materials themselves, by introducing them into suitable learning environments.

One such environment of particular interest here is the one offered by a computer system. Ihde<sup>5</sup>, among others, has explored the relationship between a user and a machine, such as a computer, in terms of functional transparency. The use of computers in this way, as tools for communicating, handling and investigating information, is the focus of information technology in the National Curriculum and the potential of computers performing these functions is well documented. In this paper the role of a computer system in mediating learning, as described by Young<sup>6</sup>, is more pertinent. Young has developed the notion of a conceptual model held by a computer system (that is the hardware and software environment) which is interacting with a learner. Such a model would be determined by the capabilities and constraints of the software and hardware as much as by the author(s) of programs designed to support learning. The transparency of a computer system itself as an information carrier and a pedagogic device will be related to the intentions of the author and the effectiveness of a computer system in supporting learning will depend on the clarity of the informational and epistemic objectives. A microworld developed by an author in this way, using the capabilities of a computer system appropriately, might even support learners in their use of physical models designed to develop particular concepts and communicate some information. In such a limited but controlled, predictable and repeatable way the distinction between informational and epistemic transparency can be clearly maintained and disorientation and confusion avoided, particularly where the learner is dealing with new concepts and information.

## The Pilot Study

This is potentially a large programme which we recognise will take some time to develop fully; the activity discussed here is a pilot study aimed at developing some modelling materials aimed at investigating some of these issues. The chosen focus was learning about structures, and it was decided to use both a 3-dimensional physical model, and a comparable IT-based model presented on a computer programme.

The structure chosen was a bridge which could be configured in a variety of ways; both physical and IT models were designed to be highly interactive so as to engage the learner as fully as possible. The aim with both types of model, was to identify key concepts and conceptual structures, and present these perspicuously through the models, then go on to trial their use with selected groups of pupils. The modelling materials were also designed to differentiate clearly between informational and epistemic transparency, and to register both of these constructs clearly and distinctly in terms of the results obtained from the use of the materials.

## Methodology

1. A 3 dimensional physical model was produced [see Figure 1] to model some of the forces acting in the structure in a maximally perspicuous way. The forces chosen for this were loadings, and the the model was designed to ensure that the relationship between load and deflection was exhibited.
2. The model was designed to be used in various configurations, by the addition of an arch, and trusses, so that load/deflection relationship could be exhibited as a function of the design of the structure.
3. A similar IT based model was developed [see Figure 3]. As with the physical model, the IT based model could be configured in a variety of ways in order to demonstrate both the load/deflection relationship, and to illustrate this relationship as a function of the design of the structure.
4. A set of tasks was devised to test the pupils' ability to:
  - extract relevant information from the models
  - grasp concepts central to the employment of the models
  - extrapolate from the information obtained and the concepts grasped, and formulate responses to specific questions aimed at testing their

**Sample page from pupil activity booklet <sup>7</sup>**

Assemble the parts of the model bridge shown here in FIG. 1. Fit the steel ruler into the slot in the base. Measure the height of the deck with the ruler and record this in the box here.

Now place a 0.5 kg weight on the deck in the centre. Notice that the deck is now sagging slightly. This sag is the amount of deflection. Measure the amount the deck has deflected using the ruler and record this in the table shown in FIG. 2 against the weight in kg. Now adding the weights to the deck in steps of 0.5kg record the deflection of the deck against the weights in the table in FIG.2

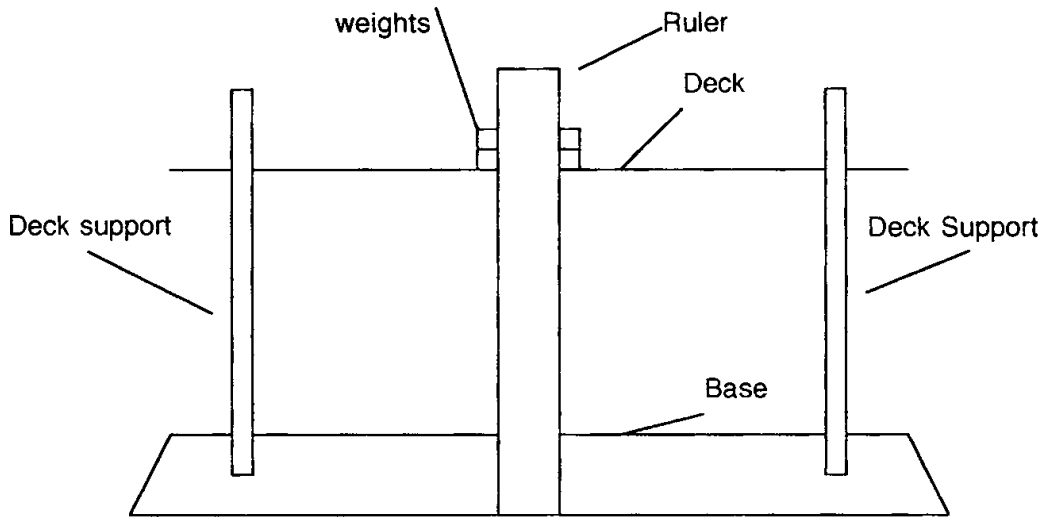


Figure 1

<b>Weight kg.</b>									
<b>Deflection mm.</b>									

Figure 2

- understanding transfer understanding between IT based and physical models

used as an index of the effect which prior experience with the previous model had on pupils' learning.

Pupils work on tasks is to be recorded on paper (physical models), on computer (IT models) and on audio cassette with prompts from the researcher as appropriate to elicit the reasons for actions taken.

5. Pupils started worked with either the physical model or the IT model, then after an interval, were set to work with the other model.
6. The IT model automatically traced pupil activity, decisions made and time taken.<sup>8</sup>
7. The results obtained from 5 and 6 were then

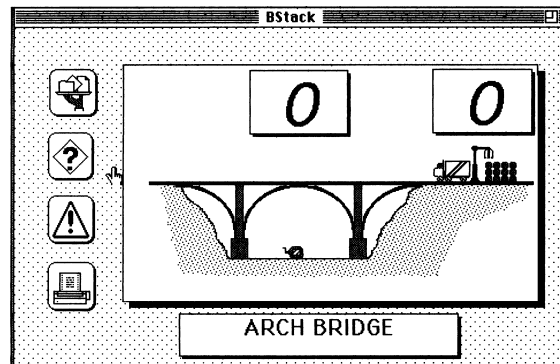


Figure 3

## The IT - based model

A pilot hypermedia system was developed in the form of an interactive Hypercard<sup>9</sup> stack. This provided a graphical interface which pupils may interact with via a mouse or roller ball, with no need for prior keyboard skills. Computer functions were represented by icons or small pictures, giving a minimal dependence on written words. In terms of the learning sequence, hypermedia microworlds have been found to be more effective than either linear or unstructured systems where the focus is on constrained exploration, and also to increase motivation<sup>10</sup>. The hypermedia system might be thought of as a set or stack of card analogues, each giving some information, in this case about the structure of bridges, and providing the opportunity to learn about the behaviour of the structure under load. Pupils choose activities by moving the screen pointer to one of a number of icons and 'clicking' a single switch. The icons can be thought of as buttons which cause some action to take place when 'clicked'. The basic bridge activity card shows:

- the name of the type of bridge under investigation,
- the most recent load used and the corresponding height of the bridge, and
- the number of loads tried.

Icons on the card allow a pupil to:

- reset all values to start a new investigation,
- get some help on how to use the card,
- move to the main menu card, where one of three bridge types can be selected,
- load a 'lorry' with uniform blocks, one at a time,
- drive the lorry over the bridge, and
- see the results taken so far.

The results are held on a separate card with similar icons and showing the loads attempted and corresponding heights measured (Figure 4). One button calculates the deflections and another moves to a third card which graphs the results (Figure 5).

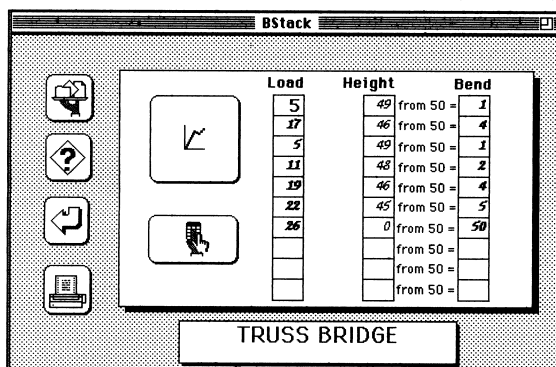


Figure 4

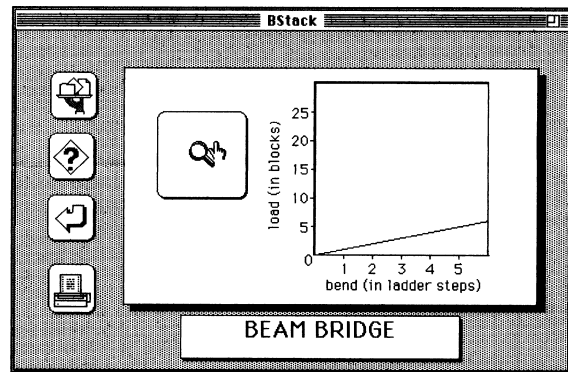


Figure 5

Three such cards exist for each bridge type: beam, arch and truss. When each pupil uses the system s/he is asked for her/his name, this creates a new card for tracing all of her/his activities. Each button 'click' is noted giving the time it takes place, the card and button selected and any values (load and height) changed or choices made. These cards are not available to the pupils (FIG 6). The data gained here will be supplemented with audio recorded informal interviewing of pupils during the activity, intended only to elicit pupils own explanations of their activities.

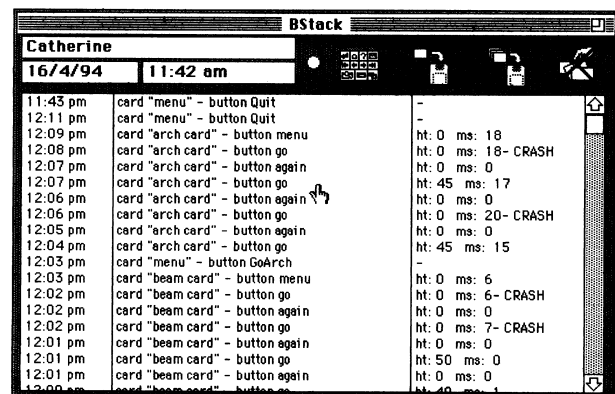


Figure 6

Where pupils are found to unfamiliar with the system, in terms of hardware a tutorial on using the interface including pointing with the mouse, is available. Regarding the hypermedia stack, the way a pupil approaches the activity and finds out how to use the interface will be considered informative, so little help is given other than what can be gained from the screen. This may prove unhelpful in research terms and a hypermedia stack is available to introduce the use of hypermedia to the novice through a simple game.

## Conclusion

We feel the notions of epistemic and informational transparency are useful in looking at materials developed to support design and technology

education. Being able to determine transparency factors and having an awareness of the distinction between the two types will inform those producing such materials whether their objectives have been realised and if appropriate assumptions have been made. This, we hope, will give some significant indication of the effectiveness of learning materials. We have outlined parallel research tools we have developed to exhibit this in teaching about bridge structures, and we expect our research to show the efficacy of the physical and IT-based modelling materials themselves as well as inform us about our theoretical constructs. The pilot study in the field has not been started at the time of writing but initial, informal tests indicate the research tools to be able to effectively return data informatively. We expect to be able to publish the results of these pilot studies in the near future.

### References

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- 2 Liddament T. 'Models concepts & Learners' in *DESTTECH Summer 1992*
- 3 Liddament T. 'Using Models in Design & Technology Education: Some Conceptual and Pedagogic Issues' In *IDATER '93*
- 4 We generally have an intuitive grasp of this point; yet we are often surprised when [as frequently occurs] others fail to 'see' what we see, in a model, or some other communicatory device.
- 5 Ihde, D.A. (1975) 'A phenomenology of man-machine relations' in Feinberg, R. & Rosemont, E. *Work, Technology and Education*, Urbana, Ill: Univ. Illinois Press
- 6 Young, R.M. (1983) 'Surrogates and mappings: two kinds of conceptual models for interactive devices' in Gentner, D. & Stevens, A.L. *Mental Models*, Hillsdale N.J.: Lawrence Erlbaum Associates
- 7 The pupil activity booklets, together with the full results of the pilot are to be published separately
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- 9 Apple Macintosh Hypercard 2
- 10 see, for example, Backer, P.R. (1993) 'Hypermedia: instructional opportunity for technology education' in *Proceedings ED-MEDIA 93 Conference*, June 26, 1993, Orlando, Fla.