Managing Problem Solving in the Context of Design and Make Activities: Reflections on Classroom Practice

Jim Newcomb

Lecturer, University of Wales College, Newport

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Abstract

This article describes a half-term project undertaken at the request of a local school as a means of assisting them to introduce a wider range of design and technology activities to top junior children. The intention was to help both staff and pupils to develop a better understanding of both the design and make process and how practical problem solving might be managed to secure effective results. The work was carried out with children who required additional experience of designing and making generally and the use of resistant materials specifically.

Introduction

Defining 'problem solving' is problematic and this paper does not intend to belabour this issue. Rather, along with the suggestion of Fisher (1987) below, I would like to focus upon what it usually involves, in the context of design and technological activity, and how teachers can best support the development of pupils' associated knowledge, understanding and skills. In broad terms then:

> "What problem solving involves is thinking and doing, or acting for some purpose. It is a way through which we can learn, practise and demonstrate essential thinking skills and knowledge."

These thinking skills include, for Fisher, creative aspects (seen to be associated with areas of performance such as: the consideration of a range of possibilities, being prepared to look at a situation in different ways etc.); critical or analytical aspects (for example, a willingness to reflect on experience, to explore the consequences of preferences, to value time etc.) and strategies such as observing, designing, decision making and team working.

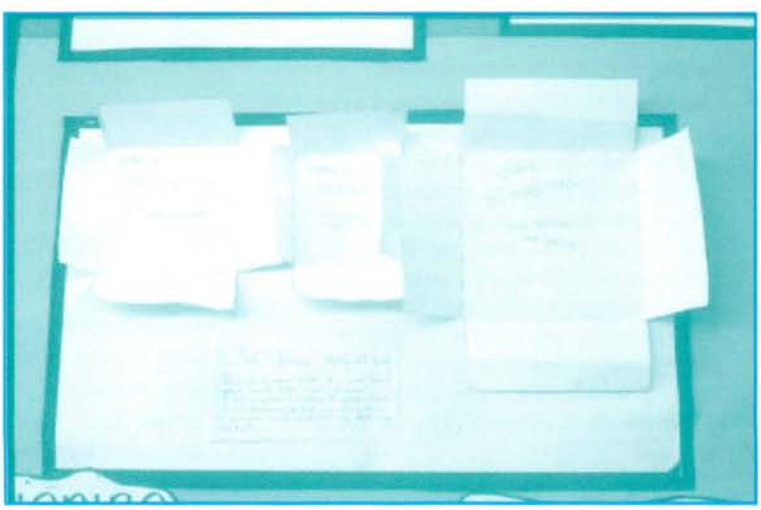

Figure 1: Example of early modelling for coal cart containers.

However, whilst aspects of performance and associated benefits may both be identifiable and appreciated they need to be considered in the context of understanding the need for both general and subject specific problem solving strategies to be effectively taught. As Bransford and Stein (1993) suggest, our ability to solve problems is not simply equivalent to a set of general problem-solving skills but often depends upon specialised knowledge in a discipline. Indeed, effective problem solvers utilise a great deal of specialist knowledge and skills that allows them to understand why, how and when to apply specific strategies.

In this case study, for example, it was hoped that the use of three-dimensional modelling, judged to be an effective strategy for initially exploring the first task that the children were set (see below), would help to signpost both 'how' to go about such a task (procedural knowledge) and 'when and why' the strategy was appropriate (conditional knowledge).

A number of authors, Meadows (1993), Hennessy and McCormick (1994), Stephenson (1997), have stressed the importance of supporting the development of children's procedural abilities which can be seen as a means of aiding them as 'novices' toward more 'expert' forms of practice. Indeed, reference to the analysis of problems into a sequence of appropriate sub problems (tasks) and the need to teach such problem solving strategies in contexts where they are useful are seen as critical to the development of 'capability'. As Henessy and McCormick stress:

> "Design and make activities that always include an holistic process, with little or no focus on particular sub processes (such as generating design ideas) are likely to make it difficult for pupils to build up their understanding and skills at using such processes."

What knowledge and skills, then, are important? Though there is no intention here to undervalue the important interplay that exists between different forms of knowledge and skill, the focus for this paper will be on procedural knowledge and skills. The 'knowing how' rather than the 'knowing that'; developing children's understanding of the ways and means by which they can, for example, explore problems, generate and communicate ideas through a range of modelling strategies and plan effectively etc. In short, the thinking behind the doing!

Children's first task, when presented with a practical problem to solve, will be to understand the problem, to clarify intended

goals and to recognise how best to get started and to develop their proposed solution(s). Teachers have a responsibility to assist pupils in this endeavour, and this will require them to:

- help pupils to recognise how a global problem might be broken down into more manageable steps
- help them focus on aspects that are significant, but may not always be obvious
- help them to develop a wide range of communication and modelling strategies from which, in time, they can choose efficiently.

Bearing these points in mind, the intention of the approach taken in this case study was one of attempting to provide these essential 'clues' by, on this occasion:

- guiding the children through a number of related sub tasks rather than leaving them, as novices, to tackle a global problem – the design and manufacture of a coal cart – by themselves
- introducing them to a range of communication and modelling techniques, to increase the range with which they were familiar
- offering focused practical tasks to develop related, subject specific, knowledge and skills.

As Rogoff (1989) suggests, by structuring learning activities in this way children can be helped to focus on 'manageable' aspects of a task through which they can extend current knowledge and skills to a higher level. Indeed, if the development of knowledge and skill is seen to involve the discovery of what is best paid attention to, borne in mind and acted upon, in an appropriate goal achieving sequence, then the suggestion here is that teachers must take responsibility for developing in children appropriate strategies for doing just that.

The focus here was to help the pupils toward being able to operate more as 'experts' might. In line with Kimbell *et al* (1996) the project was seen to be assisting the pupils in the skills of 'self-management' by their learning to take greater responsibility for the efficient progress of a project. However, I also recognise that, over time, the degree of guidance must be gradually reduced to facilitate the children's growing confidence in the decisions and actions they make and take. At this stage, the aim was not to simplify the tasks to be undertaken by the pupils but to simplify their roles. That is, to 'scaffold' their involvement by structuring a series of steps toward their eventual goal, whilst encouraging and extending their current levels of knowledge and skills in tasks which continued to offer appropriate levels of challenge.

Summary

The interim conclusions, which can be drawn from the discussion so far, are:

- it is vitally important for teachers to consider that practical problems, inherent to design and make activities, may need to be appropriately broken down into manageable sub tasks to aid effective teaching and learning
- that in so doing, teachers and children can come to better understand how best to use elements of task associated conceptual and, in particular, procedural knowledge and skills. For example, developing the ability to choose the most efficient means of communicating and generating ideas.
- that over time, children can be moved toward more expert levels of performance requiring greater responsibility for the decisions and actions they make and take.

Description of project

The project, stemming from work in history, required pupils, working eventually in teams of three, to design and make a coal cart. Here, the global problem was broken down into three inter-related areas:

- the design and manufacture of the cart's **container**
- the design and manufacture of an associated **chassis**
- the design and manufacture of a suitable **wheel and axle assembly.**

In structuring the project in this way it was felt that the pupils would be signposted to the essential features of each task and helped to recognise that the means of communication

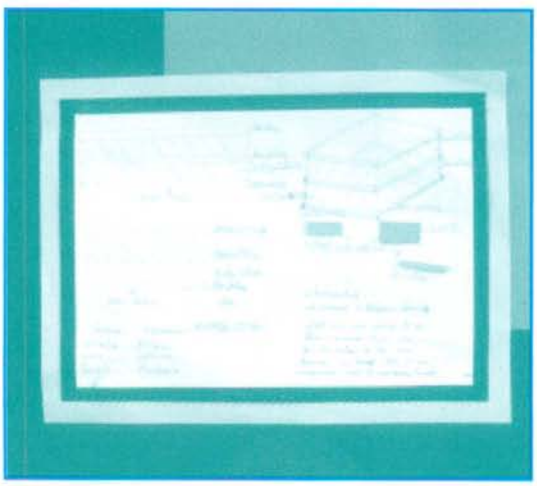

Figure 2: Simple orthographic and isometric drawings of coal cart container.

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and modelling ideas can be varied to suit the task on hand.

Introduction

The class (30 Year 6 pupils) was initially divided into five teams of six mixed gender pupils reflecting the normal ability groupings for the class. As such, they were used to working together. It was stressed that the progress of their work, and a successful conclusion to the project, depended much upon them being able to organise themselves effectively and to be willing to take as much responsibility for their decisions and actions as possible.

I think that it is worth noting that, with one or two exceptions, the children worked extremely well together and approached the various tasks in a very sensible manner. They seemed to enjoy the responsibilities given to them and on many occasions worked for long spells with very minimal intervention.

Most of the work was carried out within the classroom, with all the children working at the same time. A small number of children, at any one time, also used a workspace in the adjacent corridor, where glue guns were based.

In the main, children used square section timber, doweling, MDF wheels, card, paper, and assorted found materials together with a limited range of associated hand tools and equipment.

An on-going display of all elements of the children's work was regularly updated by the class teacher; vital to the children recognising the value of both the process and the product.

A brief description of the work is provided below:

Week 1

- The project began with a whole class discussion about the general nature of child labour during the Victorian era, building upon previous experiences undertaken during topic work.

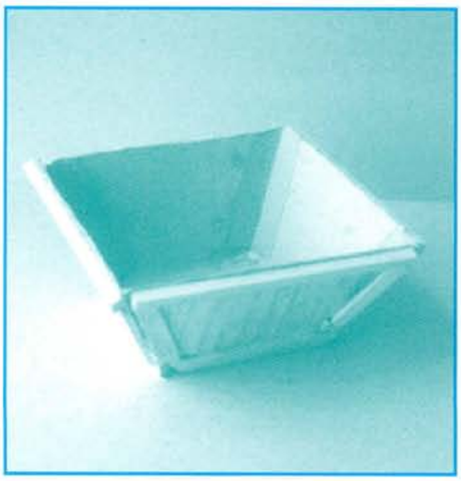

Figure 3: Partially constructed container using square section timber and lollipop sticks.

- Three, A3 photocopies of mining trucks were then used to stimulate discussion about the way in which the vehicles were hauled, the materials from which they had been manufactured and the difficulties associated with pulling them through the darkness of the mine.
- At this point, the children were introduced to the materials from which their own trucks were to be made and asked to think about which they might prefer to use and why.
- The children were then given their first problem solving task, the design and manufacture of a suitable container for the coal truck. This centred on three-dimensional modelling in card. In order to constrain the overall size of these models the pupils had to produce a container that would hold a set amount of dried peas (used to represent a quantity of coal) displayed in 250g coffee jars.
- The pupils, seated in their groups of six, began by working individually to produce paper nets (building on prior work in Mathematics) based on their estimation of the required shape and size of a suitable container. Completed models were temporarily sellotaped to allow them to be tested by emptying the contents of the coffee jar into them. This encouraged all pupils to modify initial ideas and to work towards an 'optimum' solution in a meaningful way.
- They were also encouraged to add brief notes to ideas which did or did not meet the criteria, thereby suggesting a reason for a solution's rejection or selection.

Week 2

- At this stage the groups were divided to allow teams of three to continue with the project.
- Their first task was to select one of their individual models to act as a template for the next stage of the work. They were then asked to carefully un-stick the paper model and transfer the design onto grey card to produce as accurate a model as possible.
- They were then asked as individuals to produce a sketch of this model in both two and three dimensions. This work followed a short blackboard introduction to rudimentary elements of orthographic projection (front and side elevations) and

isometric drawing using an underlay and the classroom windows as a 'light box'.

- Each individual had then to decide how to enhance these drawings by adding suitable surface details in order to develop the design into a more lifelike representation of a coal cart.
- On the plan and end views pupils were free to draw around actual pieces of material, for example, square section timber or lollipop sticks to achieve an accurate result. Samples of the materials chosen were also stuck onto their design sheets as a simple form of 'planning'.
- The three dimensional view of their design was similarly enhanced.
- Each trio was then asked to make a further choice by selecting what they believed to be the most appropriate design within their group. Having done this, the teams began to measure, mark, cut and fix their resistant materials to the card model in order to complete the coal cart container.

Week 3

- This was a practical session, including relevant FPTs, during which the children, working in their groups of three, concentrated on enhancing their card models to make them look as realistic as possible. The children were encouraged to make regular references to their design drawings and planning work and to discuss any changes that they made along the way, giving reasons for their choices/decisions.
- During the session pupils cut and fixed lengths of square section timber (10mm and 8mm), doweling (5mm) and lollipop sticks. With additional support they also manufactured their own simple cutting jigs.
- During this time a number groups found opportunities to further enhance their ideas by the inclusion of additional detail, often based upon prior experiences. For example, containers were manufactured to allow one of the sides to open and close. This required a simple hinge and locking mechanism to be made that was based upon simple systems employed on, for example, tip up trucks. As such, 'differentiation' was clearly exhibited by outcome.

Week 4

- Having completed their container sections, attention was turned to the design and production of a suitable wheeled chassis to which the container could be fixed. This included the design and manufacture of a simple wheel and axle assembly.
- The pupils were first introduced to the Jink's method of frame construction and asked to think about appropriate dimensions for their own chassis – taking into account the size and shape of their container, and the most appropriate materials for the task.
- Time was also spent, during both whole class and group demonstrations, considering ways in which the children might manufacture realistic wheels for their carts to enable them to run along a short length of track that the groups were to make.
- During this part of the project the pupils designed through discussion and direct manipulation of materials. They did not draw and or model their suggestions in three dimensions.

Week 5

- Pupils concentrated on making a simple length of track way from square section timber. On the surface this seemed to be a very straightforward task. In reality it proved, for the children, to be more difficult than I had expected. Essentially, the children had to decide upon a suitable gauge for the track, working from the dimensions of their own trucks, and construct the necessary sleepers and lengths of rail. Complications set in when the pupils confronted the necessity of keeping the rails parallel to facilitate the efficient running of their carts. A number of modifications were required before all was well.

Week 6

- Whilst the pupils had been evaluating throughout their work they also undertook an end evaluation of both process and product. First as part of a whole class,

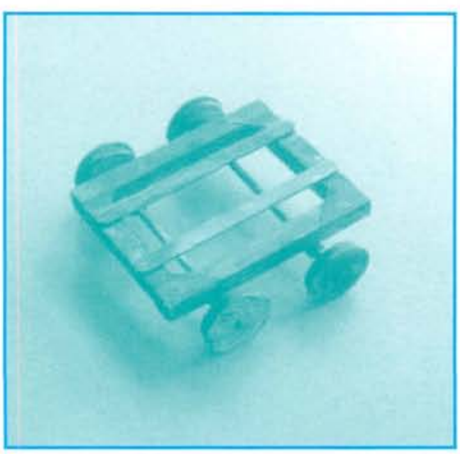

Figure 4: Example of chassis and wheel and axle assembly.

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group based discussion, and then individually. It was clear from the group feedback that, with one or two exceptions, the children had really enjoyed the chance of working as part of a team and that they were very pleased with the results obtained. Generally, they expressed the view that they had relished the opportunities provided for them to take responsibility for their own progress and, within the parameters set, of organising their own actions.

Week 7

- At the end of the project, and under the direction of their class teacher, each group was encouraged to display their work in a life like, three-dimensional dioramic setting. This additional responsibility for displaying the final product helped to maintain the sense of ownership that children had developed for their work.

Conclusion

The development of pupils as capable design and technologists will, in large part, be associated with a willingness on the part of teachers to provide them, in an appropriately progressive manner, with greater opportunities to explore a problem and develop suitable solutions with the minimum of teacher intervention. However, to support this aim it will be necessary, at certain times, to take appropriate control of pupils' oversight of the process by structuring their work into more manageable sub tasks. In this manner, they can be encouraged to work in a methodical way, interacting with and coming to value important sub elements of the process, thereby developing associated conceptual and, most importantly, procedural and conditional knowledge and skills.

This does not mean that work should be overly teacher directed. Rather, each task should provide sufficient challenge to both motivate the children and inculcate the new knowledge and skills that the teacher deems necessary for effective progression to take place.

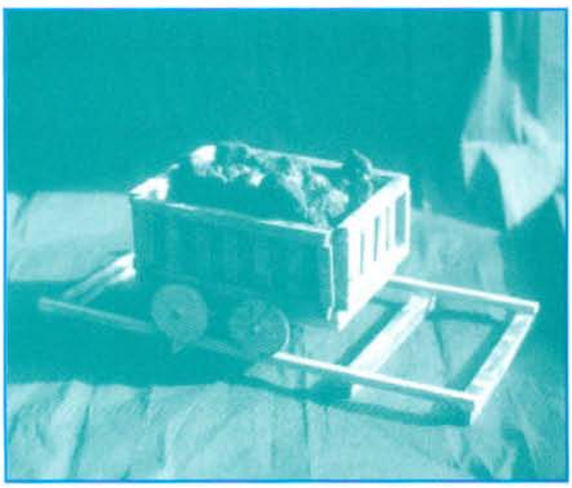

Figure 5: Example of completed model.

In all of this it is essential that the children are aware from the outset of the ultimate goal of any particular design and make activity and that they are able to see how sub tasks fit into the overall structure and development of their work. Moreover, it is crucial that teachers are aware of, and plan effectively for, the knowledge and skills that should be developed to help children to progressively extend the repertoire available to them.

In this case study the children were told at the beginning that they would be designing and making a model coal cart and that it would consist of a number of parts that would need to fit accurately together; these being the **container, chassis** and **wheel and axle assembly.** This helped to focus their attention from the outset and provided a clear and single goal for all groups to work towards. Moreover, it provided guidance from which the pupils could begin to perceive a framework or structure for tackling design and make activities in a competent manner.

Here, I was attempting to concentrate on what I believe are two important strands of design and technology 'capability'. First, a recognition, on the part of teachers and pupils, of the advantages to be gained from breaking down a global problem into more manageable sub tasks. And, second, recognition of the importance of being able to choose wisely from a widening repertoire of subject related knowledge and skills. That is, to know not only 'what' strategies to use, but 'when' and 'why' to do so in order to proceed, in an efficient manner, from initial ideas through to an optimum solution – to develop 'procedural and conditional knowledge' to good effect.

These issues will need to be considered carefully in teachers' planning. If pupils are prompted to tackle a problem in its entirety they may be overcome by uncertainty and not know what to attend to first or how to logically sequence the activity to ensure optimal success. Teachers will need, for that reason, to consider the extent to which support is required, bearing in mind the age and experience of the children in question. It may, therefore, be essential, when devising a scheme of work, to begin by establishing how a particular project might be effectively broken down in order to provide a suitable pathway through the activity yet still encourage independence and a challenge within each of the linked sub elements. This will help children to construct local expertise by focusing their attention on relevant and

timely aspects of the task, and by highlighting things they need to take account of. It also breaks tasks down into a sequence of smaller tasks which children can manage to perform, and orchestrate this sequence so that pupils eventually manage to complete the whole activity successfully.

At the same time, pupils' knowledge and skills can be developed, in the context of each sub task, so that they begin to appreciate the means by which such tasks may be efficiently accomplished. The examples in this case study include three-dimensional modelling for initial ideas, simple orthographic sketches for ideas development and discussion and the direct manipulation of materials when developing the wheel and axle assembly. This sort of approach is certainly essential as a means of moving beyond the view that 'designing' is simply synonymous with 'drawing'.

This form of teaching has had the metaphor 'scaffolding' attached to it. Built well, such scaffolds help children to achieve heights that they could not reach alone. In effect the teacher aims to simplify the child's role, rather than the task, by means of offering graduated assistance – this will include structuring the activity into manageable steps, demonstration, drawing attention to previous work or associated concepts, simple encouragement etc. What is important is that assistance should be adjusted as a direct response to children's level of performance and perceived needs.

As Wood (1986) notes:

> "Children, being novices of life in general, are potentially confronted with more uncertainty than the more mature and, hence, their abilities to select, remember and plan are limited in proportion. Without help in organising their attention and activity, children may be overwhelmed by uncertainty. The more knowledgeable can assist them in organising their activities, by reducing uncertainty; breaking down a complex task into more manageable steps or stages. As children learn, their uncertainty is reduced and they are able to pay attention to and learn about more of the task in hand."

The focus of this case study has been the development of children's procedural and conditional knowledge. That is, their ability to both choose and utilise appropriate strategies as a means of efficiently completing design and make activities. It has been shown that this will require teacher support in terms of both breaking problems down into manageable sub tasks and the development of suitably targeted knowledge and skills. The significant issue here is that children, as 'novices', need thoughtfully structured direction as an aid to 'capability'. From this basis children will be able to work toward more 'expert' approaches and exhibit a knowledge of not simply 'what they know', but why, how and when it is best to exploit that which they have at their disposal.

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