Improving children's performance in the procedures of design and technology

Abstract

Teaching pupils how to design and make in better and better ways should be one of the major aims of the design and technology teacher. Part of becoming a better designer is to do with an understanding of how to proceed in more effective ways within a design and make assignment. This paper focuses on the separate behavioural skills that have been identified in a recent research project which examined how primary aged pupils design and make. It goes on to suggest a model for how these skills might be employed in a variety of tasks and how this image can help teachers organise learning programmes and establish a firm direction to their teaching.

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RESEARCH

Introduction

The development of design and technology as a curriculum subject has been impressive since its formal introduction as part of the National Curriculum in March 1990. Much groundwork was achieved well before this date and it has not been easy to reach where we are today. There have been misunderstandings and blind alleys together with fierce debates concerning the direction in which the subject is evolving. But we are on our way. We are approaching a point in the development of the subject at which we can be much clearer about what teachers should teach and pupils should learn.

An overview of the subject

If one steps back for a moment, it becomes possible to identify three broad, inter-linking areas within design and technology about which pupils should learn. These are:

1. The procedures of design and technology

A knowledge of the procedures of design and technology involved an understanding of how best to go about designing and making. This means pupils will learn how to take a number of broad procedural skills such as identifying needs, modelling or evaluating and use these at appropriate times within a design and make task.

2. Knowledge and understanding in design and technology

This involves areas of knowledge and conceptual understanding which are unique to design and technology (such as an understanding of mechanisms or products and applications) as well as knowledge from other subjects. The knowledge and understanding provides an essential support for the central aim of achieving capability in design and technology.

3. Practical capability

This involves an understanding of how to handle materials, tools and the related processes. It also involves an ability to solve the many practical problems that occur as designing and making proceed. This ability often comes with prolonged involvement with practical tasks such as those associated with many hobbies, DIY or careers involving practical work. This kind of practical capability represents an aspect which is unique to design and technology.

Pupils' procedural understanding

This paper focuses on the procedures children use when designing and making and how these can be enhanced in the primary classroom. In the past it has been tempting to define a single process of design which might be applied in a variety of situations. Models for the design process have been drawn up and often used to structure pupils' projects in this subject. This simplistic view has been largely discredited by recent research and curriculum development (Kimbell, 1991; Mayo, 1993; Henessey and McCormick, 1994; Johnsey, 1995a; Roden, 1995; McCormick et al, 1996) and so a new perspective is required. The following discussion sets out an alternative model which incorporates the imaginative, creative and flexible aspects of the subject while providing a basis upon which teachers can organise the teaching of procedural skills.

Identifying the procedural skills for design and technology

While belief in a fixed process of design – transferable to a wide variety of situations – is to be discouraged, it is possible to identify the separate procedural skills exhibited by those successfully involved in designing and making. These may be observed in the activities of engineers, professional designers, the DIY enthusiast, pre-school children at "play" or school pupils in design and technology lessons. The identification and clear definition of these skills is an essential step in understanding the subject.

Two of the ways in which the procedural skills of school pupils can be identified for design and technology are by surveying the literature which describes the procedures of designing and making or observing pupils directly as they design and make and classifying the behaviours exhibited.

The author has published the results of a literature survey in which 17 publications were examined for their version of the process of design (Johnsey 1995b). Furthermore research was carried out by the author in which video recordings were made of children designing and making in a classroom setting. These recordings were subsequently analysed to provide a picture of the whole design process (Johnsey 1995a).

Both exercises gave rise to a list of procedural skills used by pupils from Nursery to Key Stage 2 as they design and make. These are:

Investigating and exploring the design context.
Identifying needs, opportunities and potential for design and make tasks.
Clarifying the implications of the design and make task.
Specifying criteria for judging the outcome of the design and make task.
Carrying out research into the problem and its solution.
Generating ideas for a product which will provide a solution.
Modelling ideas as a preparation for making.
Planning and organising the making of a product.
Making the product.
Evaluating various aspects of the process and the product as work proceeds.
Evaluating the final product and processes used against original criteria.

Procedural skills in the National Curriculum

The procedural skills identified above are similar to those outlined in the National Curriculum for design and technology (DES/WO, 1995) under Designing skills and Making skills. This can be demonstrated by providing a brief synopsis of these skills.

Pupils should be taught to:

Designing Skills:
a) ... generate ideas (and use information sources to help in designing (Key Stage 2))
b) ... clarify ideas (and develop criteria for their designs Key Stage 2)
c) ... develop ideas
d) ... model ideas
e) ... suggest how to proceed
f) ... identify strengths and weaknesses (in their design ideas)
g) ... indicate ways of improving their ideas (Key Stage 2 only)

Making skills:
a) ... select materials, tools and techniques
b) ... measure mark out, cut and shape a range of materials
c) ... assemble, join, and combine materials
d) ... apply finishing techniques
e) ... suggest how to proceed
f) ... evaluate products
g) ... implement improvements ... (Key Stage 2 only)

This list provides a helpful analysis of the procedural skills but may perpetuate a number of misconceptions regarding the realities of designing and making in the classroom.

One of the key procedural skills – *researching* – is not represented on this list. At Key Stage 1 children are expected to "draw on their own experience to help generate ideas" and at Key Stage 2 pupils should be taught to "use information sources to help in their designing". The definition of design related research provided in this paper expands on this idea considerably.

Another procedural skill – *specifying criteria* – is absent at Key Stage 1. It has been argued that specifying criteria for the success of a product is an essential precursor to effective evaluating in design and technology (Johnsey 1995d). Evaluating can only be carried out effectively if it is done against a clear idea of the purpose (or more accurately, purposes) for the designed product. Children at Key Stage 1 can articulate their ideas on this subject and thus provide a more profound evaluation of their work.

A further problem in the way the procedural skills are represented in the National Curriculum is the way in which Designing skills are listed separately from Making skills. Observations of pupils designing and making (Johnsey, 1995a), together with common sense, suggest that there should be no divide between these two sets of procedural skills. In any activity pupils will naturally intermix skills from these two lists. For instance children can be expected to model their ideas while they are involved in making a product and all designers continue to generate ideas and add specifications once making has begun. There is evidence to show that the making skills stimulate the designing skills, especially in young children who learn through practical experiences (Johnsey 1995c).

The toolbox model

The question remains, however, "How do pupils proceed effectively in their designing and making and how can teachers encourage them to become better and better at it?"

Observations of pupils who have been given a design and make task which they carry out in their own way suggest that the procedural skills are employed in a fairly random way. There are similarities to the way a mechanic or chef might use implements from a "toolbox". Each tool is chosen and used when appropriate and the order in which these are employed varies with each task. There are certain patterns which might emerge such as, in the case of the chef, the use of a range of sharp knives early on for preparing ingredients for a meal and spoons for stirring and serving later in the task, but essentially all the tools are available to be used when appropriate.

We can imagine the design and technology procedural skills arranged in a toolbox which the pupil learns to use in a variety of ways. (*See Figure 1*)

The toolbox is divided into a number of sections each of which contains a set of tools or strategies. For instance, the strategies found in the 'evaluating' section might be

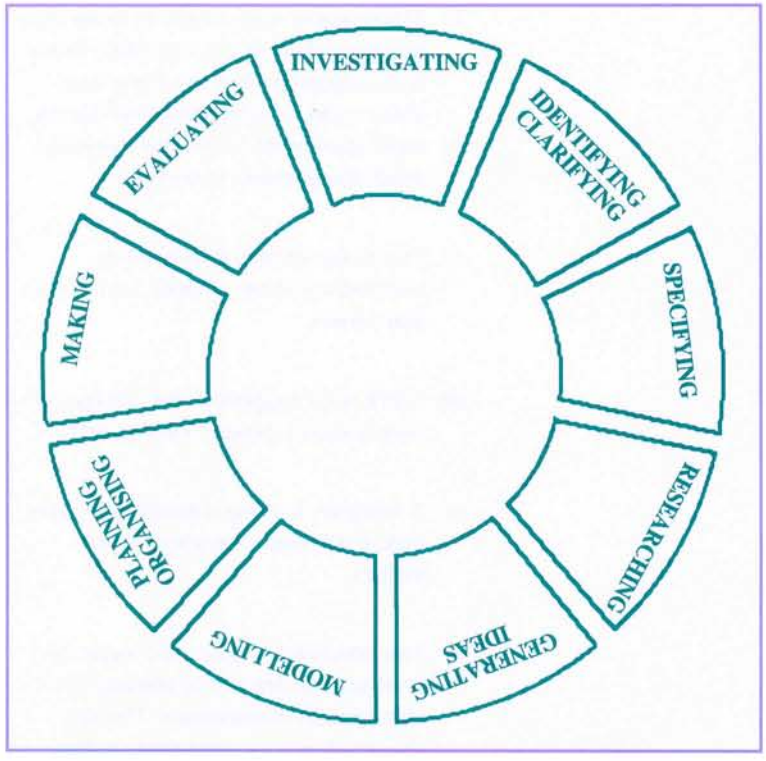

Figure 1: Tool box model for designing and making procedural skills

- ability to make judgements against specific criteria
- ability to conduct an opinion survey
- ability to test the strength of a product scientifically, etc.

Each pupil will develop a personal set of strategies for each section of the toolbox and learn to use these in different ways. The teacher's job will be to enable the pupil to develop:

(i) a wide range of these "tools" for each compartment of the box

(ii) a range of appropriate ways in which to combine these tools depending on the context and circumstances of each design task.

Describing the procedures for the whole task

The curved lines joining the compartments might represent an imaginary path taken by the pupil in completing the design and make task. The lines are arranged to show the following points which are based on conclusions drawn during the research project (Johnsey, 1995a):

i) The designer may choose to move from one procedural skill to any other. There is no suggestion that there is a fixed linear route. The path taken will be the most appropriate for the context within which the designer is working.

ii) The same procedural skill will be revisited a number of times, some more than others.

iii) There is no suggestion that "designing" skills should precede "making" skills.

iv) A designer, tackling a design and make task, might begin anywhere in the toolbox.

v) The effective designer will choose the most appropriate tool or strategy while visiting each compartment. The tool chosen should be appropriate to the context of the design task.

vi) The importance of making for the primary aged pupil is shown by more lines going to and coming from this compartment.

vii) The research findings highlighted a strong relationship between making and evaluating. This is illustrated by a predominance of connecting lines between these procedural skills (see Johnsey 1995c).

Advantages of the toolbox model

The toolbox model has a number of advantages for the teacher of design and technology.

- It avoids the view that there is a single, transferable process for designing and making which can be taught to all pupils. The route that a pupil takes from one section to another, selecting the best tool for the job, will vary from pupil to pupil and within different design contexts.

- It does provide the basis for a set of identifiable skills which might be taught and assessed by teachers. More research and development is needed to expand these sets of strategies and how these might best be fostered in the classroom.

- The model will enable teachers to focus on a small number of procedural skills in any one design and make assignment. If schools ensure that each procedural skill is emphasised at some time during the primary years then teaching procedural skills becomes more manageable.

- The model allows for and, indeed, encourages the notion that design and technology requires creativity and imagination. The route that a pupil takes through the design and make assignment will be a reflection of his or her personality, experience and intuitive judgements. It allows us to escape from the notion that there is one correct way to design and make but at the same time provides clear guidance to what might be taught and used by the pupil.

- The model is consistent with the requirements of the National Curriculum for design and technology but takes teachers' understanding of the procedural skills within the subject one step further.

- By paying attention to one procedural skill at a time, it becomes possible to sketch out a progression within each one. For example pupils' modelling skills might begin with an ability to use the materials of construction, held in temporary arrangements, as a way of deciding how the final product should look. They might progress by learning how to make sketches and doodles to "try things out" before making and as they gain more experience, pupils may be able to make mock-ups of simple mechanisms with card before constructing these in more resistant materials.

With some thought, it would be possible to devise a progressive learning programme in each of the other procedural skills identified in this paper.

Conclusions – extending the toolbox

The toolbox model provides an image which is consistent with current research into how primary children design and make, and at the same time provides a structure for organising and teaching the subject based upon the requirements of the National Curriculum. It places procedural skills alongside knowledge and understanding and practical capability at the centre of the subject and suggests a way in which these might be organised and monitored.

It is possible to extend the image of a pupil's personal toolbox to one which incorporates the three broad, inter-linking areas of design and technology which were identified at the beginning of this paper. (*See Figure 2*)

Each layer of the toolbox represents the three aspects of design and technology. Each section of each layer of the toolbox is available to be drawn upon at the appropriate moments within a design and make task. The effective pupil designer will be one who has a wide range of tools at his or her disposal, at all levels of the toolbox, and knows which section will be of most help in furthering the design task at any one time.

The procedural skills

The following examples of procedural skills are the result of extensive observations of primary children as they carried out design and make tasks in a classroom setting.

Identifying the potential for a design activity and clarifying the meaning and implications of the design task

Pupils displaying the *identifying* behaviour will be observing and exploring a context in which design tasks might arise. At the same time they will be actively involved in suggesting problems which might be solved, needs which might be met or opportunities for designing and making. They may identify a client or a set of clients as recipients for the designed product(s) and show an awareness of their needs. While displaying this behaviour pupils will not necessarily be suggesting solutions to problems or outcomes for design tasks.

When pupils clarify the design task they will have been introduced to it (by the teacher)

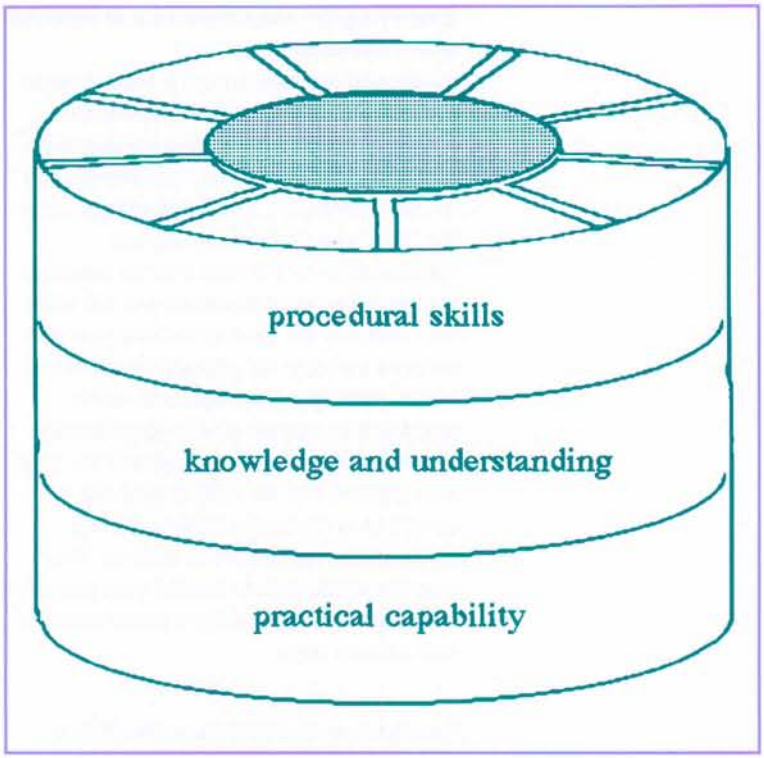

Figure 2: The design and technology toolbox

or will have identified this for themselves. There will be a period when clarification is sought, especially if the task has been given by another person. Clarification will probably precede the generation of solutions to the problem but may well be intermingled with this stage. The following features may need to be clarified regarding the design task:

- What exactly does the problem setter require?
- What is the intended purpose for the outcome?
- Who is the outcome for?
- What is the scale of the outcome?
- What materials are available?
- What time and space are available?
- Should the outcome be a model or the real thing?

Clarification of the task will evolve as the designing and making proceeds and may never be complete, even at the end of the task.

Specifying the requirements and purpose of the outcome

Pupils who are specifying the requirements of the task outcome will be creating the criteria by which they or others might judge how well they have done. The specification will be a statement, spoken or otherwise, of the objectives for the task. Various specifications for the task may be added or subtracted as work proceeds and will often only reside in the mind of the designer and perhaps be taken for granted. For instance a pupil making a greetings card for his grandmother may be able to specify that it should have a moving, pop-up part but take it for granted that the card should stand upright on a horizontal surface. During construction, specifications such as 'The card should be safe to handle' may emerge in the light of experiencing a paper fastener with a sharp edge.

Specifying what should be achieved in a design and make task is closely related to the way it is evaluated at all stages during its construction. If a clear purpose is established for a designed product then evaluation involves establishing whether that purpose has been achieved or not.

Often a teacher, in setting a design and make task, will provide a set of specifications for the final product.

Design and make a game which can be played on a table top. Your game should be built in the lid of a card box and involve a marble. Make your game suitable for a friend in your class.

At other times the design task could leave the choice of specifications to the pupil.

Design and make a toy with a moving part.

The specifications for this task which could be developed by the pupil might be:

- The toy should be suitable for a four year old
- It should be made from a durable material such as wood or plastic
- It should be safe to play with
- It should teach the child something about the alphabet.

Carrying out research into the problem and its solution

Researching is a design process skill which has not been fully recognised or examined in the primary school curriculum. It is a skill particularly suited to the primary school pupil because it can both enhance learning as well as provide the basis for a well designed product. Pupils carrying out design-related research will be gathering information and skills which might support the design task. It can take place at any time after a design task has been defined but will most often be carried out in the early stages. Information found while researching will inform the remainder of the design task. There is evidence to show that pupils will generally not choose to carry out their own research, preferring to base their ideas on what they already know (Johnsey 1995a). It is by carrying out suitable research activities, however, that the quality of the pupil's learning as well as the design product can be enhanced.

Illustrative case study – Umbrellas
A group of children who were studying a topic on The Weather became interested in the idea of protection from the rain. Their teacher asked them to invent something for keeping the rain off her own 4 year old daughter Zoe as she walked to nursery school each morning.

After discussion with their teacher the children decided to begin their research by investigating umbrellas. They looked at a wide variety of these, noting the mechanisms used to erect the canopy and the materials used in construction. They even investigated cocktail umbrellas as part of their information gathering.

Their teacher realised that the group might want to use wooden dowel rod as part of their solution so she took the opportunity to teach them how to saw this safely using a bench hook and junior hacksaw.

The children were also interested in looking through the fabrics box in the classroom in search of suitable waterproof materials for their umbrellas.

After trying out some of these materials by watching drops of water soak into them they decided to use polythene from bin liners instead.

Some of the children wanted to make folding mechanisms for their umbrella so their teacher showed them how to make simple hinges using pieces of fabric and glue.

The finished products varied in style and quality and were carefully evaluated both by the pupils themselves and Zoe on the next rainy morning.

This case study illustrates a number of ways in which pupils can carry out design related research. In some instances the research involved evaluating other's design products (umbrellas), while at other times the "finding out" was more to do with learning something from an expert (being taught how to saw dowel rod safely). It was the children themselves who chose to "research" the contents of the fabric box and carry out their own science experiment on the 'waterproofness' of various fabrics.

Modelling ideas

The word 'model' or 'modelling' has a number of meanings and these can lead to some confusion. Some people understand modelling as the making of the designed product. "The children did some modelling with card boxes today". Others use the word to describe the finished product. "The finished model was very effective and eye-catching". Sometimes we talk about modelling materials such as clay or papier mâché. Modelling is in fact a much broader activity used in design and technology to describe part of the preparation for making a part or all of a product.

> 'Modelling is the ability we have to make one thing stand for another.' (Outterside, 1993).

Children will be modelling if they form some representation of the product they might make and can manipulate this so as to explore and develop its potential. This "representation" (which technically is called the "model") can take many forms such as the following:

- hand gestures to show the form of something
- a discussion about what something might be like
- a drawing or painting
- the forming of the raw materials available into temporary arrangements
- a paper or card mock-up, etc.

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