An examination of a mode of curriculum delivery in which science is integrated with design and technology in the primary school

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Abstract
This paper describes a curriculum development project in which formal science lessons are located within a short design and technology project. The objective is to examine one model of curriculum delivery in which science is integrated with design and technology in order to enhance learning in both subjects. The approach is illustrated by describing the results of a project in which units of work from the National Exemplar Schemes of Work for science and design and technology (QCA, 1998) are used.

Some conclusions are drawn as to how pupils might be helped to gain the appropriate science knowledge they need for designing and making by adapting the nature of the science activities.

Keywords: primary, case studies, cross-curricular, science

Introduction

Many cross-curricular approaches in the primary school tend to revolve around a central topic such as The Weather, Homes or The Vikings. While the separate subjects are linked by this central theme it is often not clear how one subject is related to another or how the learning in one will be of benefit to learning in another. We might imagine the subjects on the rim of a wheel, linked to the central theme by the spokes but not necessarily linked in any meaningful way to each other.

An alternative model for curriculum delivery which will be examined in this paper involves the integration of science and design and technology so that learning in each subject enhances the other. It is proposed that this might be achieved by enabling the skills and knowledge gained in science to be *used* in pursuing the goals of design and technology.

> "...design and technology is concerned with more than just understanding the world; it is concerned with making use of knowledge and skill to enable us to *intervene creatively* so as to improve the made world in response to our needs"
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> (Kimbell et al, 1996 p. 112)

The nature of design and technology, then, is such that it is an ideal vehicle for harnessing ideas gained in other subjects. The design and make task can become the central theme at the hub of the wheel. Science (and possibly other subjects) can be linked directly to the task in a meaningful and useful way. It is the nature of the scientific knowledge and understanding and the way in which it might be combined with designing and making skills that is the main focus of this study.

Different kinds of knowledge

McCormick (1999) describes the different kinds of knowledge that a pupil might acquire in order to gain capability in design and technology. Procedural Knowledge and the higher order Strategic Procedural Knowledge are concerned with how to go about solving problems, whereas Factual and Conceptual Knowledge describes the ideas and information that might be required to complete the task successfully. He points out that this conceptual knowledge will often be presented in one form in a science lesson and yet be required in another form in design and technology. Furthermore when the "device knowledge" is required in design and technology it is often of a qualitative nature whereas it may have been learnt in a more quantitative way in science. He refers, however, to examples in secondary schools where lessons in science and design and technology are given by different teachers and may have reached a more abstract level. In the primary school science is often learnt in a more qualitative manner and is presented by the same teacher who can more readily point out the links with other subjects.

Methodology

The methods used to trial this particular mode of curriculum delivery followed the same pattern in each of four trial schools. Each project took between 10 and 15 hours to complete over a five week period. The trials took place in two phases, working in two schools at a time. Lessons learnt in the first phase were applied subsequently in the second phase. The four projects are described in more detail in Appendix 1. They are:

	Trial year group
Phase 1	
Pushes and pulls with Moving pictures	Year 1
Changing sounds with Musical instruments	Year 5
Phase 2	
Circuits and conductors with Torches	Year 3
Friction with Moving toys	Year 5

In each case the concept of pupils' design-related research was used as a mechanism for combining science ideas with the processes of designing. This concept is described in a number of publications (Johnsey, R 1997a; Johnsey, R 1997b; DATA 1999) and essentially describes how children gain information through teacher-led activities that will help them with their design and make task. Focused practical tasks (FPTs), investigative and evaluative activities (IDEAs) as well as other strategies might be used to gather this information. Design-related research is seen as one part of what it means to design something.

In each school the project was begun by defining and discussing the design and make task. The children were asked to make a list of the things they would need to find out in order to complete the task. This was followed by a series of science activities which were designed to both achieve science learning objectives and provide information and skills that would be needed in the designing and making. The children were repeatedly reminded of the products they were going to make and thus understood why they were carrying out the science activities. In many instance the activities addressed the ideas listed by the children when they planned their research agenda.

The projects were completed by enabling the children to design and make their products. They set out specifications for their products and planned and modelled their ideas in a variety of ways. In many cases the final construction took only 3 or 4 hours. Each product was then evaluated against the specifications set out earlier.

Once the project was finished a small sample of children were interviewed from each class and, in some instances, a short written test was given. The objective of the interviews and tests was to examine to what extent the children had learnt science ideas related to the project and to discover how much these ideas had played a part in the designing and making.

The children's agenda for design-related research.

One would not expect pupils who are learning about design and technology to know what they, as yet, do not know, and yet the children's response to being asked to list "What they would like to find out" was of interest.

The responses fell into a number of categories. There were requests for information regarding scientific principles such as "How to make different sounds from one string." and "I need to know how to make a switch." A series of similar requests involved what might be termed technical principles. "How to make an up and down movement" and "I would like to know how to make a switch button." Inevitably many pupils wanted to know more about construction techniques. Typical requests were "How can I make the slots.", "What about the fluff?", "How do you fix it together?" and "How to make a wooden frame."

In some instances the children betrayed a lack of confidence in their ability to make design decisions. Requests such as "What colour would it be? and "How big is the frame" suggests they were expecting these decisions to be made by their teachers. Some requests were, in fact, a description of how the information was to be found - "You should look inside the torch if you are going to make your own". Because the teacher had specifically mentioned safety aspects in the electricity project a number of children had listed this as part of their "need to know" programme.

These responses, especially from the children at Key Stage 2, show that children possess a surprisingly astute awareness of the things they need to know about a project which has only just been introduced to them. The children had predicted many of the activities which had been planned for them during the research phase of the project. Just as carrying out design-related research is part of the larger picture of designing products, this evidence indicates that children could equally be involved in planning an agenda for this research.

Linking science with design and technology

Class teachers felt that the closeness in time between the science activities and designing and producing a product was of benefit to the children. A number of teachers described the increased motivation they had noticed as a result of their children knowing they were about to design and make a useful product. In all cases, science activities were followed within two or three weeks by designing and making and it became an easy task to remind the children of what they had already learnt.

One of the conclusions drawn at the end of the first phase of the project was the need to plan science activities that were more relevant to the design and make task and yet still achieve the science learning objectives. For instance, in the evaluation of the project on making musical instruments it was noted that

...In the sound topic the investigation on pitch could have involved more examples of the kind of instrument the children were to make. For instance use of fishing line to make a harp-like instrument, or wooden rods to make a xylophone with sound box. In the amplification investigation it should have been arranged that the children learnt about other aspects of the sound box such as the need for it to be rigid and of a suitable size.

An attempt was made in the second phase to devise science activities that would be of greater use. For instance, children made and tested three different kinds of switch as a preliminary to designing and making torches. The switches, which were made of aluminium foil, plastic and card, were such that they could be easily adapted for use in the torch. The science activities in which friction was investigated took a radical departure from the conventional text book science. Rather than pulling objects along with force meters to measure the friction between object and table top, the children carried out an alternative activity. This required the children to measure the friction between a wooden wheel on an axle turned by falling masses. The apparatus used, more closely resembled the mechanism for the toy that the children would make and thereby added to their accumulating knowledge.

A second activity which investigated how friction could be increased for useful purposes involved another mechanism and, more importantly, a qualitative set of results. This was in contrast to the quantitative results gained in the first exercise. It was interesting to note that when interviewed after the project, some children said that the second activity had helped them more with the design and make task. Could it be that they were able to gain a greater degree of "device knowledge" in this way? It was certainly good primary school science, involving observation and written recording but perhaps arranged in such a way that could be more readily applied later on. Much of the science work in the other three projects was also of a qualitative nature providing children with experiences which lead to a more intuitive understanding of how materials would behave.

The advantages of integrating the science with design and technology

In a number of instances the children continued to develop and reinforce their understanding of science ideas as they designed and made products. This was especially true of the group making torches since connecting circuits and avoiding short circuits and poor connections became part of the designing and making process. The children who made instruments were able to talk about changing the pitch and volume of sounds in their evaluations. This additional experience in developing science ideas through design and technology was often of a practical nature which was well suited to the children's learning needs in science.

Besides the chance to re-learn ideas already encountered, many children were able to adapt what they had learnt to a new context and thus to expand their learning. Some children who had made an electrical switch in their science activity were able to make a new more appropriate one for their torch. Those who had investigated using a hollow box to amplify sounds in a science experiment used this knowledge in making some of the musical instruments. Year 1 children who learnt about how pushes and pulls create different kinds of movement as part of their research were able to adapt this knowledge to make a head or tail move on their puppet.

One of the most apparent advantages of such an approach to teaching both science and design and technology was the teacher's ability to use the products made as an assessment tool for science. As children described their products it became very apparent how much science had been learnt. The child who covered her bulb holder in silver foil as a decorative device had not appreciated the problems with short circuiting. The child who glued smooth plastic to her cam was able to describe in detail how this reduced friction. Another who was asked to show where friction was occurring on her model merely pointed to the axle and clearly had not understood the concept in this particular context, despite detailed questioning by the teacher.

Matching science ideas to designing and making

One of the major difficulties in conducting this project was to do with finding science ideas that were actually going to be useful in the designing and making task. On paper there would seem to be no problem with this. Children who make a musical instrument would benefit from knowing about changing the pitch of a sound. Those who make a cam driven toy would benefit from knowing how to reduce the friction between the cam and the follower.

In practice, however, it became apparent that only small parts of the science programmes of study were of direct benefit in the design and make task. There was a much greater need for the children to learn about construction skills and to develop their designing skills. They also showed a greater need to learn knowledge which is found in the design and technology programmes of study such as an understanding of the way mechanisms work and how to build products which are structurally strong.

When the Year 1 children made moving puppets a knowledge of forces was of relatively little advantage. What they really needed was experience in constructing levers and control rods to work their puppets. The Year 5 children who made cam driven toys needed much more experience with axles, wheels and strong frameworks than a knowledge of how to overcome friction.

This problem might have been alleviated if the self-imposed constraint of using units of work from the Exemplar Schemes of Work had not been adopted. With some thought it should be possible to find design and make tasks which employ a wider range of science principles more readily.

Conclusions

The idea that there are strong links between science and design and technology has been an assumption made by educators working within both subjects for a long time now. The assumption that science ideas, once learnt, can be automatically adapted by children to use in new contexts needs to be challenged. There is evidence to suggest there is considerable educational advantages to linking subjects such as science with design and technology in the way described in this paper. However, the nature and form of the knowledge which is used in designing and making must be examined more closely. McCormick's concept of "device knowledge" as something which is more readily of use to pupils in their designing and making, may require teachers to consider alternative ways of teaching science which, when appropriate, might then be more relevant to the real world.

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Appendix 1

Case Study Descriptions

Project: Sound and Musical instruments

This trial was carried out with a year 5 class of mixed-ability children. Previously they had not studied Sound in science at Key Stage 2 nor made musical instruments although they had regular music lessons supported by a well equipped music room and music trolley. The teacher worked for a one hour and then a one and a half hour session each week for four weeks and a single one and half hour session in the final week.

The teacher began with a mystery sounds quiz in which the children tried to describe and identify some unusual sounds. In their evaluations many children said that this was one of the most interesting lessons. The point of the lesson was that the children began to listen to sounds and build a vocabulary for describing them. In this lesson the children were introduced to their design and make task - to make a musical instrument within a group that would be used to accompany a theme such as a TV commercial. At this point the children were asked to identify the information they needed to find out in order to complete the design task.

The children were asked to describe in a diagram how a person could hear the sound from a musical instrument of their choice. There followed a series of fairly formal science lessons in which the children explored sound with the purpose of preparing themselves for making instruments. These included work on vibrations, sound travelling in different mediums, the ear and investigating pitch. The children also designed and carried out an investigation in which they explored how to make sounds louder by using sound boxes.

Finally the children were asked to design and make an instrument from four basic categories: scrapers, beaters, strings or shakers. They drew the instrument they had chosen and went on to construct these in a single hour and a half lesson. The project culminated in a short rehearsal and performance from each group of children. Individual children evaluated their own instruments in writing against a list of criteria they had devised for themselves earlier in the project.

Project: Pushes and pulls and Moving pictures

The children were in a year 1, mixed ability class and were beginning a topic on the Owl and the Pussy Cat. The teacher worked for a two hour period for five weeks.

The teacher began by reading the poem and talking about different kinds of animals in it and the movements these might make. The children described the parts of the animal that might move and described the kind of movement. They subsequently went on to relate these movements to themselves and their own muscles.

The children were introduced to the puppet task and asked what they would need to find out in order to complete the task. Only a few were able to provide ideas such as "how to make it", about the "fluff" meaning the fur and feathers on the animals. They mentioned ways of making the movement - making "slots", bending the card and holes. One mentioned needing a knowledge of the materials that they would use.

In the second session the children linked their knowledge of movement with the pushes and pulls need to produce this. They made a series of mechanisms involving pushes and pulls and wrote these words on their products. The children went on in the third session to discussing specifications for their puppet. A class list was made including: "It should look fantastic".

The children modelled ideas for their puppets by making scrap paper mock-ups and arranging these on their desks. They then went on to make the real thing using a card oval supplied for the body. Many were able to complete a working puppet, suitably decorated. Some children gave a short puppet show while the poem was read out. The children evaluated their puppets by completing an evaluation sheet with smiley faces on.

Project: Circuits and conductors with Torches

This project was carried out with a year 3 class of mixed ability children who had no previous experiences with electrical circuits at school. The teacher worked for a two hour period for five weeks.

The project was begun with a general discussion about things which used electricity. This was followed by a challenge in which the children were given a battery, length of wire and a bulb which they were asked to make light up.

The children were introduced to their task - to design and make a torch, light or lamp for someone. There was a general discussion about the occasions on which a torch or lamp might be used and by whom. The children listed the kind of things they would need to find out to make their torch then investigated a variety of battery-operated torches and lights.

The children went on to learn how to use battery holders, bulb holders and switches in a circuit. They learned how to make their own switches using aluminium foil, recorded some of their circuits in diagrams and learnt how to strip insulated wire and connect more than one battery.

The children wrote out their specifications for the torch they wanted to make and explored the materials available for construction. They then made drawings of the torch they wanted to make. They were asked to draw the wiring circuit in red flt pen on to their torch drawings. They went on to construct the torches and test them before evaluating the project as a whole class and individually on paper.

Project: Friction with Moving toys

This project was carried out with a large (36 pupils) year

5 class in their classroom. The children began by looking at a variety of toys which moved in different ways. They were then introduced to their task - to make a toy in which one thing bobbed up and down and another turned round. After discussing what the toy might represent the children wrote down the things they would need to find out about.

The second part of the lesson introduced the children to an investigation into friction which would be of help in making the toy. Pairs of children were given a card box lid and a kit of parts which they made into a wheel and axle arrangement. A bar rested on the wheel causing friction to prevent the wheel turning. The children recorded the number of masses which were necessary to overcome the friction and start the wheel turning. They investigated the effect of different surfaces and a lubricant.

A second science investigation involved an offset vertical wheel turning a horizontal wheel using the same box lid as before. This time the children investigated how to increase the friction between both wheels. The children were given some direct instruction as to how friction worked between surfaces.

When it came to the design task the children wrote out their specifications for the toy and began to construct a wood strip frame to hold it. Much of the remaining time was spent on construction matters and getting the mechanisms to work. Eventually the children demonstrated their models to each other and wrote a short evaluation of their products by referring to their specification produced earlier.