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This research examines:

- how teachers deal with the design process in different ways
- how emphasis on 'making' can lead to the neglect of the design process and problem solving skills in technological education.

Abstract

Technological activity is defined by its concern to create products that are part of our material world. But there are two ways of looking at the importance of these products in the educational context. One is to consider that they are the way we test the significance and feasibility of ideas, particularly design ideas. However, teachers of technology in schools in most countries in the world (where it exists in the curriculum) have a craft tradition, and hence a strong concern for 'making' and for the products that result. For both of these reasons, namely the centrality of the creation of products to the domain of technology, and the motivational role such products have in classrooms, we cannot avoid the creation of products. Along with this creation comes a form of tyranny, which we will illustrate from our research in technology classrooms. By considering the impact of a concern for products on pupils, through case studies of three classrooms, we are able to show that product outcomes undermine some of the design process and problem-solving activity that the teachers are concerned to foster.

The importance of product outcomes

Technological activity is defined by its concern to create products that are part of our material world. Unlike science, which is about the creation of knowledge and understanding of the material world, technology intervenes in it, particularly by responding to people's needs and desires. This view of technology is evident in technology education proposals on both sides of the Atlantic: the conceptual framework developed for the International Technology Education Association (ITEA) talks of technology responding to "human needs and wants" and involving "actions to extend human potential" (Savage and Sterry, 1990, p. 11); an early statement from

England defined technology as "the practical method which has enabled us to ... create ... our habitats, our food supply, our comfort and our means of health, travel and communication" (Black and Harrison, 1985, p. 3). This focus on creation and intervention in the physical environment is translated into proposals for technology education. Thus in the Netherlands students are expected to "develop technology, acting in a practical way, to deal with a number of technical products" (de Vries, 1992, p. 31); in England the term 'capability' has been coined to encapsulate this, and this is to be manifest "through combining their designing skills and making skills ... with knowledge and understanding ... in order to design and make products." (DFE/WO, 1995, p2). Technology as a domain is therefore defined by the creation of products.

However, in the educational context there are two ways of looking at the importance of these products. First, they are the way that the significance and feasibility of ideas, particularly design ideas, can be tested. This is encapsulated in the model of the interaction of mind and hand developed by the team of the Assessment of Performance in Design and Technology project (Figure 1), where "pupils' thoughts and intentions were as important ... as were the products that resulted from them." (APU, 1991, p. 20). Second, in schools in most countries in the world (where it exists in the curriculum) teachers of technology have a craft tradition, and hence a strong concern for 'making' and for the products that result (McCormick, 1992). This is often reinforced by those in industry who are concerned with the economic importance of developing technological capability, giving a focus on making and the associated skills. For example, the Engineering Council in the UK supported a 'Technology Enhancement Programme', with the aim of laying the foundation to improve the performance of industry. Some have gone further and argued for a return to the emphasis on the making skills encouraged by a craft approach.

These different, and at times conflicting, conceptions of the purpose and essence of technology education are manifest in the classroom in the way teachers differently

interpret and give meaning to their view of technology. In addition to these philosophical differences and the different traditions that teachers come from, there are those connected with teaching and learning. Most teachers who have a craft background are very aware of the motivational importance of making a product, especially one that can be finished and taken home. It is evident that many students see this as a favourable characteristic of this area of the curriculum, and contrast it with the other areas that are dominated by writing. Teachers are therefore anxious that, despite the emphasis on the intellectual basis of, for example, design activity, they maintain the interest of the students and hence are concerned that they end up with a finished product.

For both of these reasons, namely the centrality of the creation of products to the domain of technology, and the motivational role such products have in classrooms, we cannot, and should not, avoid the creation of products. Along with this creation comes a form of tyranny, which we will illustrate from our research in technology classrooms. However, before we do this, it is important to explore how technological processes are differently conceived both in models of technology and in the minds of teachers. The link between products and processes is at the heart of views about technological activity in the classroom, as the quote from the Assessment of Performance Unit above illustrates. If the process is as important as the product, then it is crucial that technology educators agree about the nature of that process.

Views of designing and problem solving

In England and Wales the process of design is a central part of technology education. This has remained so even though now there has been a resurgence of the importance of the 'making' skills in the most recent version of the National Curriculum. For example, one of the main assessment components is still 'design skills' (DFE/WO, 1995); previously assessment was defined entirely in terms of designing (DES/WO, 1990). In the USA and indeed Scotland, *problem solving* is seen as more central; the ITEA framework takes problem solving as a the main part of 'technological method'

(Savage and Sterry, 1990). Such problem solving is seen as having a number of steps or stages:

defining the problem
developing alternative solutions
selecting the solution
implementing and evaluating the solution
(Savage and Sterry, 1990, p. 14).

These resemble the way the design process is depicted:

identifying a need or opportunity
generating a design
planning and making
evaluating
(DES/WO, 1990).

So, for some, designing is problem solving. If a person with arthritic hands has a problem with opening a jar (a 'problem', 'need' or 'opportunity'), then a 'design' for an opening device would be the 'solution' to the problem. In our interviews with teachers of technology we have examples of this view:

"take a problem, research it, define it and actually be able to tackle that particular problem in an intelligent way and work their way through the processes that would lead to a solution." (Case Study 1)

There are those, however, who do not see design and problem-solving as being the same thing. The fact that there may be no evident problem does not prevent design from taking place. The design of the compact disc was not a response to the 'problem' of the poor quality of sound reproduction at the time, but an idea that originated in quite a different context and was eventually seen as a way of exploiting a consumer electronics market (Guterl, 1992). For such people design would be seen as a set of skills, such as being able to 'generate design ideas' or 'evaluate' ideas. In particular they would not want design to be seen as a series of steps. There are some difficulties with this conception, but putting them aside, we have not found teachers who have this view of the design process.

The idea of design as a series of steps is, however, very frequently followed in our experience, even by those who see it as synonymous with problem solving. This is because they treat it as an algorithm, just as problem solving is treated in this way. For other teachers it is treated as steps because they see it, not as an intellectual enterprise, but because it is a sensible logic to follow when carrying out a project:

although I'd like them to understand and use the design process and I think it's quite a nice framework for them to fit things on to, I don't think there's a great need to be dogmatic about it and say you must learn it....the nature of projects leads them through the design process despite the teacher's bit, going through it with them in front of the class...

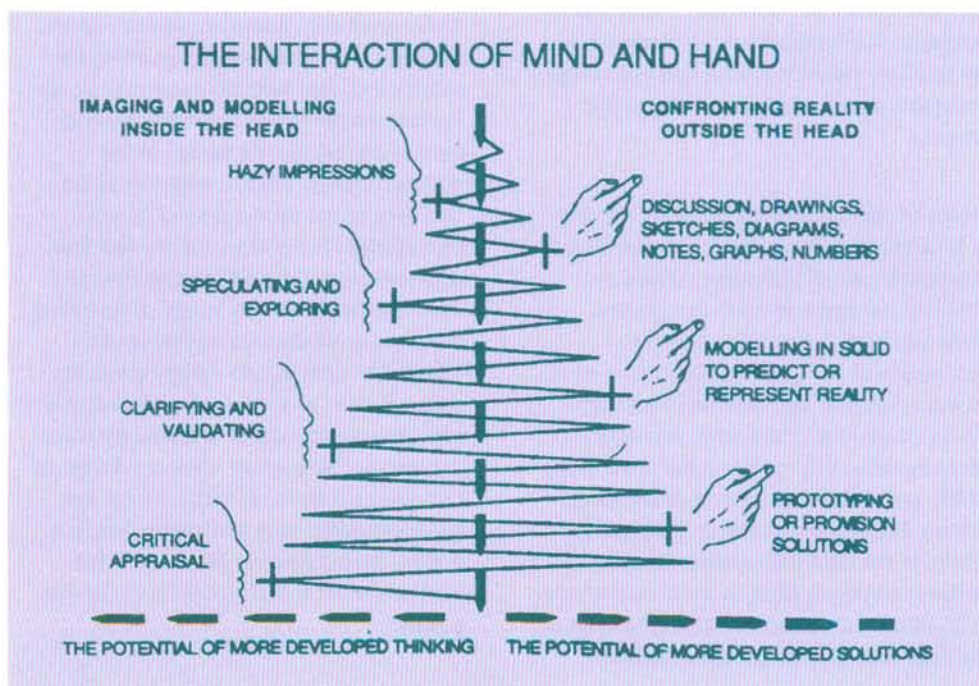
This makes the design process seem like 'a way of working' more akin to planning. These three different views of design and its relation to problem solving (design as problem solving, design as a repertoire of intellectual skills, design as planning), result in different practice in classrooms (even within the same school) and hence different experience of technological activity for students. What then of problem solving and the views of those who do not see it as synonymous with the design process?

Interestingly there is very little analysis of the kinds of problems that students will encounter when they undertake technological activity (for example Waetjen (1989), in his review of the field does not discuss the nature of problems).

Our experience of observing classrooms indicates that most of the problems are what we would call *transient problems* and connected to the making of the product. For example, a student who was designing and making a mobile for her bedroom, which consists of stars made from thin wire orbiting a planet, has to work out how to solder the ends of the wire (to form the complete star) when the ends do not quite meet. Once she has sorted this out (in this case by trial and error), she moves on to the problem of how to cut a curved moon shape out of aluminium sheet. So it goes on, with technological problem solving being a series of such transient and small-scale problems.

Because such problems are associated with the making, they are largely unpredicted by the teacher (and the student), and are unrelated to the design activity. How is a teacher to plan and support problem solving if the nature and timing are entirely open to chance? Some problems are, however, not so transient, but are nevertheless unplanned by the teacher. Elsewhere we have reported

Figure 1: The Assessment of Performance Unit model of interaction between mind and hand. Source: APU (1991, p. 20)



a problem of a student who designed a face for an electronic badge with light-emitting diodes (LEDs) for the eyes, where his eye spacing did not match that required by the circuit that was underneath the face (McCormick, Murphy and Davidson, 1994). This problem persisted for several lessons and the student tried a variety of ways of getting the light from where the LEDs would come through the face to the points where he wanted the eye pupils to be.

Unfortunately he failed, although he arguably experienced some very important problem solving or at least attempts at it. The problem arose because of the order in which the teacher disclosed the construction of the product and, although he did this consciously, it was entirely fortuitous (or not, depending upon your point of view) that this resulted in a problem for this particular student. (We will return to this case later in the paper.)

The argument and evidence

Our main contention is that, whatever view is taken of the design process and problem solving, the fact that students and teachers place a great emphasis upon making a product results in both types of process being neglected or unsupported. This argument will be illustrated by considering three case studies of design and technology classrooms in England, each of which shows the work of teachers with different views of design and problem solving.

These case studies of projects try to capture the range of activity for selected 'target' students, as well as collecting evidence of their perceptions, and those of the teacher, concerning what they think they are doing. All the students were in Years 7-9 (Key Stage 3). Each study involved semi-structured interviews with the head of department, the class teacher under observation and up to four others, one from each different subject area involved in the teaching of design and technology, plus all members of the target groups of students. Interviews took place before, during and after completion of the project and were audio-taped and transcribed. All timetabled sessions for each project were observed; one target group of students was video-recorded, and audio-recorded by way of

back-up. The folders of drawn and written work were copied, and the final products photographed.

The three case studies will be used to show how the design process was dealt with in different ways, reflecting the different views of the teachers, and the ways in which product outcomes affected the responses of students.

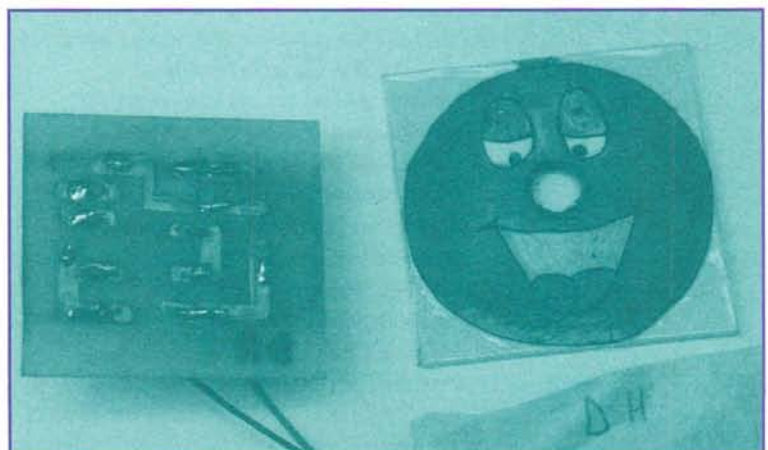
Case study 1: process as ritual

This study is of the electronic badge project mentioned earlier, namely where students had to design and make a badge that would advertise the opening of a theme park, with the face on the badge to be one of the cartoon characters from the park.¹ We followed three boys, referred to as B, D and T, as they designed the face for the badge and constructed the acrylic backing for the face and the transistor circuit that was triggered by a light-dependent resistor (LDR) to switch on two LEDs (see Figure 2).

The teacher started off with the 'Situation' being presented: a theme park opening that requires a lapel badge to advertise the event. This is set within the general title of 'Festivals', however, at no point in the whole project was reference made to festivals or to its link to the 'Situation'. The teacher goes through 'Situation', 'Design brief' and 'Considerations' (specification), tasks which all the students seem to be familiar with. He does not, however, elaborate on the 'Situation' or the 'Design brief', nor invite students to discuss them in the context of the planned project. The three target students' design briefs include some

1. See McCormick, Murphy and Hennessy (1994) for a fuller account of this project.

Figure 2: Case Study 1: Electronic badge – showing the acrylic backing, transistor and badge face.



interesting differences that illustrate how the 'Situation' is being interpreted by them. The teacher's definition of the 'Situation' (written on the board) contains the words:

"To make these badges more interesting, a basic electronic circuit will make something happen on the badge."

B & T interpret this as meaning that a "button is pressed to light up the eyes", whereas D makes no such inference, but says "to design and make a clock badge". The implication of these differing interpretations, and the lack of discussion of potential outcomes, is that the students have no strong ownership of the project within the context as set up. Furthermore, their initial ideas of what their personal "briefs" are lingers and influences future tasks. For example, D continues to talk about a "clock face" for several lessons and abandons the idea only when he realises that the electronics will not be like that of a watch. He also imagines that the battery will be like that in a watch and is almost incredulous when the teacher shows a comparatively large conventional dry battery that he (rightly) considers too heavy for a lapel badge.

The teacher does not seriously engage with D as he discusses with the student how a watch battery might be used instead of the large dry battery. As far as the teacher is concerned the students will make a face with an electronic circuit, and his main objective is for them to learn something about such circuits and make a working circuit.

The next step, where groups of students spelt out the 'Considerations', has elements of ritual. The students' choice of 'considerations' are not discussed, no distinctions are made between the range of considerations drawn up by the class, and these considerations are never mentioned again, but new ones are continually added particularly in relation to the making process. These new ones reflect the constraints imposed by the teacher as he works out his plan for the project (e.g. the materials to be used, the dimensions of the face, and the eyes and nose positions to fit

the circuit). The teacher's concern is to control the knowledge input, so students will understand what he wants to teach them about circuits, and to control the progress of the construction of it, to maximise the success of the pupils. So, for example, although he introduces the idea of the Printed Circuit Board (PCB) in an early lesson, it is some time before students actually handle one, drill it to take the components, and solder the components. Each of these activities is taken as a separate task with the teacher instructing pupils at each stage.

This *task control* is part of what the teacher sees as his pedagogy to deal with the making process, as well as being a class control device to ensure all students tackle the project at the same pace. A craft teacher would probably be at ease with this control of the making process, but its use removes the possibility of students making design decisions. Such control by the teacher means that students are unable to foresee what is to come and so they cannot take it into account when working on their initial designs.

We have already mentioned how such control involved a student (D) in some long-term problem solving concerning the spacing of the eyes, but this was not planned or adequately supported by the teacher. The teacher deliberately gives the eye dimensions after the face is designed by students, and expects them to re-design the face to suit. Student D chose not to do this and therefore solved a different problem from that which the teacher expected. There is no doubt a balance to be struck between telling students as much as possible early in a project (or before it is started), and introducing it just when it is needed, and this teacher put the balance towards the latter.

In fact this teacher viewed the design process as a kind of planning process (he is the one whose words we quoted earlier), and considered that the problem that D was faced with was quite legitimate, even if D did not solve it in the way the teacher expected. However, his over-riding objective of ensuring that students would be able to understand the knowledge he was inputting at various stages, and his control of the task

to make sure everyone had a 'working' badge (i.e. where the LEDs lit up when the LDR was covered), dominated the project. This led him, as already explained, to treat the design process as a ritual, to remove from students any significant design decisions, and hence to either confine problems to small incidents related to making or to completely unpredicted problems that he had not planned that students could solve.

The teacher did discuss with D how he might overcome his problem of the light from the LEDs getting to where he wanted them, but he never saw it as important that the student succeeded, and in the end he didn't. The electronic circuit worked in the way the teacher wanted it to, but not in the way the student wanted. This resulted in the student simply pushing the LEDs through the face in a position well away from the eyes (see Figure 2), and in the end not valuing the badge, which he intended to discard when the project was finished. He took home only the circuit, thus in effect ending up with the main thing that the teacher valued.

In this case the tyranny of the product was connected to the knowledge and skills objectives of the teacher (centred around the circuit and its construction), but not the design of a badge for the theme park. The product was simply the working circuit. The context of the badge and theme park were merely an empty shell for the activity.

Case study 2: the hidden curriculum

This study was of a project that involved the design and making of a mobile, for a situation or person chosen by the student. We followed three students, K, A, and V, and their teacher. Students were to design the mobile first by drawing and then by modelling it in card. The teacher was very careful to introduce the meaning and rationale for each stage of designing. Thus he deliberately gets students to "Think about the thing called the design process", going on to get them to say what the start of the process is (the brief). Similarly he discusses the nature of the specification and its purpose:

"These specifications that you set out are important. You're going to incorporate them into your design. When you get to the end of the course [project] I'm going to ask you one question. Did you do as you expected to do in terms of the specification?"

In a later lesson he recaps the meaning and rationale for each of the elements of the design process dealt with so far (brief, specification and design ideas), and then goes on to say why it is necessary to model in three dimensions. This he explains in terms of allowing students the opportunity to think about size and shape, and to be able to do this without risking the final product (and hence, for example, not wasting material). In the next lesson he reinforces these ideas by suggesting that the model is used to gauge the size, proportions and balance. (The latter seems unlikely given that the materials are not the final ones.) At the beginning of most of the early lessons he reviews each of the processes dealt with up to that point and introduces the next one. All this is in contrast to the teacher in Case Study 1, who never dealt explicitly with the processes involved. There is a real concern, on the part of the teacher in this second study, with ensuring that students understand the process elements and in some cases how they relate to each other.

However, the teacher has an interest in graphics, which seems to undermine some of the attention to the processes. The first lesson of the project is built around graphics techniques, and the teacher emphasises that the school has a strong graphics tradition. He also sets a number of homework assignments during the project, which are in effect graphics exercises. For example, when he takes them into the workshop for the first time he asks them to construct a poster to warn about safety. Yet he never at any point says explicitly that the graphics is the most important aspect, although in the first session of the project he says: "The quality of people's work [in general] will depend upon how good [their] graphics are." But at various points and through various procedures related to drawing he indicates the importance of graphics. The following are examples of this approach.

Example 1: brief and specification

In the second week of the project the teacher takes them through setting up the 'brief' and 'specification' sheet, insisting on a border, using graphical techniques for the title and including the use of colour in the general presentation of the sheet. When we looked at how V spent her time we discovered she spent almost as much time on the presentation as she did on the content of the brief and specification, as Table 1 indicates.

Later in the lesson they start 'initial ideas' and the teacher talks through the idea of the mobile, and follows this with an instruction to use one of the graphical techniques (annotation). He does discuss the substance of the ideas. At no point does he ever mention the need to colour the sheet, however, students do so.

Example 2: initial ideas

In the third week the teacher reviews 'brief', 'specification' and 'design ideas', mentioning colour as one of the design decisions to be made by students. Again the 'design ideas' sheet is seen as a presentational device, and not one for thinking with. For example, student A resorts to drawing some preliminary ideas on the back of her hand. Although the teacher tells her to use scrap paper, he has not suggested this to other students; K has drawn directly on the formal 'design ideas' sheet. Later in the session, when the teacher looks at K's initial ideas for her mobile, his first words of comment on the ideas are that she needs to think about the presentation and goes on to show her how she could do this. He did also comment on the substance of the activities.

Nevertheless the students pick up the signals about what the teacher values.

Example 3: three-dimensional modelling

Later in the third week the teacher turns to discussing with students what a model is and why it is necessary, and then students start to make their model in card. This is continued in the fourth week where he discusses how one student's model (which she completed at home) gives an indication of size, proportion and balance – the function of the model. K works on her model during this session and has several interactions with the teacher about the nature of the ideas (e.g. the material of some of the objects in the mobile), and at no time does he mention the need to colour the model. Given the purposes of the model there would be no point. Yet K spends considerable time colouring the model, as did many other pupils, to such an extent that again this time exceeds the time on the process of modelling (see Table 2). (There may be some room for interpreting "wandering around the classroom" [12.33] as modelling, because the student may have been thinking but even taking this and one or two other incidents into account, the general balance of time on colouring does not alter radically.

Although the teacher gives no specific instruction regarding colour, nor any explanation of why it is necessary, he nevertheless awards marks to students' models on the basis of the amount of use of colour as he goes round the class. K does not get full marks because she has not used enough colour (see Figure 3)!

Table 1: Case study 2 student's time spent on presentation and on 'brief' and 'specification'

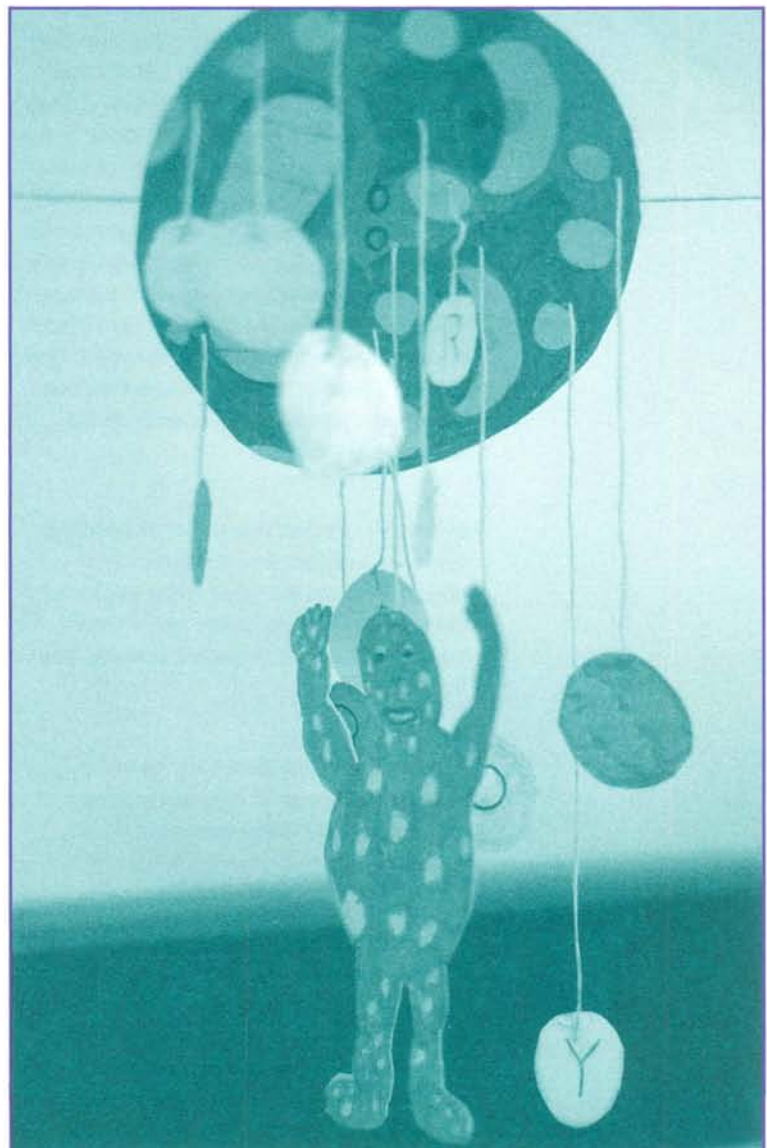
| Time | Thinking/ Writing | Graphics | Pupil activity |
|--------------|-------------------|---------------|--|
| 12:19 | 9 min | | Start writing the brief |
| 12:28 | | 1 min | Colouring border |
| 12:29 | | 2 min | Writing word 'specification' |
| 12:31 | | 5 min | Colouring |
| 12:36 | 4 min | | Brainstorming on items for specification |
| 12:40 | 4 min | | Writing list of specification |
| 14:00 | 11 min | | Writing list |
| 14:11 | | 16 min | Colouring list |
| Total | 28 min | 23 min | |

Table 2: Case Study 2 time spent by K in colouring her three-dimensional model

| Time | Modelling | Other | Description of the activity |
|--------------|----------------|----------------|------------------------------|
| 12:32 | 1 min | | Drawing Mr. Blobby |
| 12:33 | | 2 mins | Wandering around classroom |
| 12:35 | 6 mins | | Drawing |
| 12:41 | | 1 min | With Teacher |
| 12:42 | 6 mins | | Drawing |
| 12:48 | | | Break |
| 14:01 | | 10 mins | Colouring |
| 14:12 | | 3 mins | Stopped to listen to Teacher |
| 14:15 | | 1 min | Colouring |
| 14:15 | 16 mins | | Cutting out shapes |
| 14:31 | 2 mins | | Drawing |
| 14:33 | 3 mins | | Cutting out shapes |
| 14:36 | | 6 mins | Colouring |
| 14:42 | | 1 min | Teacher marking model |
| 14:43 | | 11 min | Colouring |
| Total | 34 mins | 35 mins | |

In addition to these major examples, there are many small incidents when the teacher praises presentation of drawings etc., and so establishes in students' minds the importance of this aspect of their work. So despite a careful approach to teaching the processes, the students are directed to the presentational aspects of their ideas, and the design sheets and the card model become in themselves 'products' that are valued by the teacher. This is reinforced by the fact that at Key Stage 4 students will undertake GCSE technology projects which are assessed in part on the basis of the design folder that contains the details of the 'brief', 'specification', 'initial ideas', 'final idea' etc. The rationale is that the examiners can only get access to the *process* of designing by looking at these interim *products*. Inevitably students construct (or re-construct and even invent) this process so as to impress the examiners, and of course graphical presentation techniques are crucial to this. The teacher in our second case study is therefore quite right in developing these skills in his students from their early years of Key Stage 3. The effect is, however, that the hidden curriculum of presentation may over-ride the attention given by students to the processes of design, despite the emphasis given by the teacher to them.

Figure 3: Case Study 2: K's Model of the Mr Blobby mobile (with colour added after teacher's marking).



Case study 3: losing sight of the context

This case study was of a moisture sensor project and we followed four students, although here we will only focus upon one, N. The students chose the context and the kind of sensor they produced (e.g. a bath level indicator for granny, who is a bit deaf and needs a visual indicator.) N chose a rain detector for the washing line with a buzzer warning, so her mother would know when to take in the washing. The ideas of control systems were an important part of the technological knowledge objectives of the teachers (the class was taught by two teachers, because of a quirk of the timetable). Students were expected to understand 'input', 'control' (more usually called 'process'), and 'output', in such a way that they could make design decisions about them. For example, that if they made a plant pot moisture detector, a 'break contact' was needed for input, in contrast to the 'make contact' of a water level indicator; also they could choose a buzzer or an LED for the output to match the needs of the user. They were told the necessary modifications to the circuit they were to make for each of these choices. These design decisions were only one part of the design task, the second was the box that contained the electronic circuit, and here they had to decide upon a shape and to ensure that the components would fit and that the battery could be changed. One teacher (Teacher 1) focused upon the box design and the other (Teacher 2) on the electronics.

In the first session Teacher 1 talked to the whole class about a washing line rain detector. He drew a grid (as the sensor to detect the rain), and asked how it would work. One student answered correctly and the responded:

"that part of the circuit will be in the garden near or on the washing line.
Wires will go to the box in the house.
When it rains the buzzer will go off."

A few minutes later the teacher states again that the box must be in the house and a sensor on the washing line. Later in the session he hands out an exemplar design sheet that includes a drawing of a rain detector. After this, in the same session, working with N and her friends he talks

again about a washing line device. He says there is considerable scope for designing and making a nice packaging for the electronics, rather than just a square box. He suggests making a box that looks like a piece of clothing (Y-Fronts!), with a T-shirt hanging on the washing line. However, he does not make explicit the fact that the T-shirt shape is not a box, but a carrier for the sensor pad. This may have been the origin of future misunderstandings.

A further source of confusion is the use of the terms 'sensor' and 'probe' by the two teachers. Worksheets given out by Teacher 1 carry the heading 'moisture sensor project', where the sensor is apparently the whole device. However, a sheet with this heading has a statement 'My sensor must be attached to a washing line', and a further sheet has a drawing labelled 'sensor input is put on the line'. The term 'probe' is also found in these sheets variously applied as a label to drawings: for the casing carrying the wires from the box; the wires themselves; the tip of the wires. Teacher 2 refers to the wires leading from the circuit to the input point both as probes and sensors.

However, N does show in discussion with her friend that, despite these sources of confusion, she understands how a bath level indicator would work, with the probes projecting directly from the box into the water.

In Week 3 of the project, in discussion with Teacher 1, it emerges that N thinks that the sock-shaped box, which she has designed for the electronics, will hang on the washing line. The teacher corrects this idea, telling her that the sock must go in the house, and suggests that she could use the same shape to hold the sensor. It is not until the fifth week (five weeks and eight sessions into the project) that N realises that she needs two objects, one for the box of electronics and one for the sensor (the grid to detect rain).

Before the final session of the project (the fourteenth in the seven week project) we interviewed N and when asked if she would finish she was quite clear that she needs two boxes, but this might mean she couldn't finish:

"I've got to make another one though. I've got one for indoor and one for outdoor, so I don't know [if I will finish]."

Teacher 1 in his final interview before the end of the project also indicated that he thought N understood the idea of the location of the box and the detector. When the final session took place, with Teacher 2, N had a lot to do, mainly because she had missed a few lessons, and was in quite a rush to finish. The teacher assumes that she needs rigid 'probes' (his term) of the kind used in the plant pot moisture detector (that protrude directly from the box and can be stuck into the soil of the pot). While they are discussing the final making stages (with half an hour to go), N says her wires for the probe are not long enough and the teacher says she should get longer ones, and a tube [the tube provides the rigidity for the probe wires], and N raises no objection. Fifteen minutes later, when the teacher comes to help N fix on the probe covers (the tubes) he says:

Teacher: "I would suggest you cut these [the probe wires], are they meant to be so long?"

N: "I dunno, no any length."

This of course is not true (they have to in theory reach from the kitchen to the outside washing line), but the teacher and student are both so intent on finishing that they have lost sight of the overall context of the product. Indeed with only ten minutes of the session left, the teacher suggests that he could do the switch for N, because this is left to do. So N ends up with a sock-shaped box with two rigid probes sticking out, which has to hang on the washing line (see Figure 4).

The teacher when interviewed a few days after this indicated that he had only discovered that this was inappropriate after the lesson (the next day), when N told him that her father had questioned the construction. He explained the problem:

"See all I was interested in was getting the thing finished on time, to schedule, so she could go home with an outcome."

As it is she has ended up [with] the wrong thing ... She didn't think about it and I didn't know what her brief was, to tell her which direction to go."

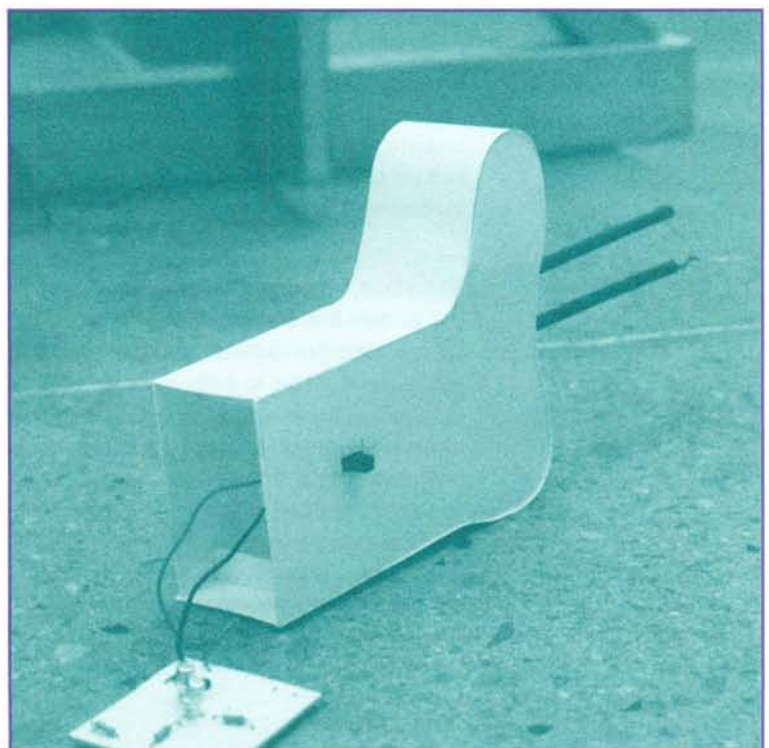
Two things conspired against the teachers. First the unusual split in their teaching, which added to communication problems, and second the fact that students missed lessons and ran out of time. But there is no doubt that for Teacher 2 the making of a working product was extremely important. Earlier in his interview, when commenting upon why students enjoyed the project he said:

"I think they all felt they were achieving something because they were producing outcomes ... we [teachers] weren't having to make the things for them ... they saw something being produced in front of them."

When asked about how he evaluated student work he said:

"We evaluate by outcome ... If they produce the product nicely and the outcome is alright."

Figure 4: Case Study 3: N's sock-shaped box with probes sticking out.



(He also acknowledged the role of developing conceptual knowledge and understanding.)

In this case study we therefore have a situation where the teacher and the student are both driven into a situation that neither particularly wants, because of the desire to create a working product. Although in this case there is no harm done to the pupils' understanding of the design issues, it may be that with students that are less involved or serious about the project that this would not be so. What is affected is the chance for the student to tackle the problems associated with having a detector on the washing line and the electronics in the house. For example, if it is a rotary clothes line, how are tangled wires avoided, should the detector be vertical or horizontal, does it matter how long the leads are, does the detector need to be on the washing line? These are design decisions which are unique to the particular sensor that the student wants to design and make, and they are neglected because of the need to finish.

It has to be said that these issues were not dealt with at an early stage in the project by the teacher for the particular students we followed. One strategy would have been for the teacher to discuss with the student how she was going to answer such questions, rather than invest the time in just finishing. From the comments of the teacher it is evident that he would not have taken this approach because it would have undermined what he saw as a central feature of technological activity and a motivational factor for the students.

The place of product outcomes

It is evident that these outcomes must remain central to technological activity. But it is also evident that, in each of the cases considered, these outcomes undermine some of the design process and problem-solving activity that the teachers are concerned to foster. Each of the teachers has different objectives and different views of the design process and problem solving (and their inter-relationship), yet do not support either in ways that might be expected.

Although the teacher in Case Study 1 does not see the design process as an intellectual process, and hence treats it as a ritual, his support of problem solving is equally neglected. He has limited objectives that relate to the electronic essentials of the product. In Case Study 2 the teacher has great concern for the design process, but this is eclipsed by the focus on creating graphical products. The two teachers in the third case study take different roles and have different views of the design process. Both support the view of design being a problem-solving process, but Teacher 2 thinks that the moisture sensor project did not allow much of a problem to solve. Teacher 1 was also concerned to make the design process explicit. This he did in the first session of the project using an exercise in which groups of students were provided with sets of cards carrying typical names of elements of the process (design brief, modelling, initial ideas, evaluation, research etc.). The groups of students were required to sort these cards and lay them out on the table in a circular pattern to represent the design process. The results were collected and displayed and then through discussion an agreed version was arrived at and recorded by each student on a worksheet. Although recognising the limited brief, and hence design decisions, nevertheless Teacher 2 admitted that his concern to get a finished product effectively ignored the brief. This brief is a central feature of the design process that both teachers subscribed to.

In each case study it is not that the teacher involved had no interest in the design process or problem solving (although they had different views), but that the balance is tipped in favour of some kind of product outcome (but for different reasons). What is missing from each, however, is the view that making is a modelling process, whose prime function is to test out the ideas; the Assessment of Performance in Design and Technology view (Figure 1). All the teachers see the product outcomes and associated skills as important in themselves, and in the end these products take precedence over the processes of design or problem solving. Not only will this affect the students' learning of these processes, but it will prevent students from learning from failure. The desire to ensure success prevents failure to produce outcomes, and reduces the risk in

the process. It is evident in our case studies that teachers can tolerate failure, though this is usually with regard to the making rather than the ideas in the design. Equally we have examples of pupils who have failed to finish, and yet do feel they have learnt something. Perhaps, therefore, teachers have to allow more risk and some degree of failure to produce outcomes. But, in making this suggestion, we are aware of the importance that teachers, students (and their parents) attach to the successful completion of made objects. We would not want to under-rate this importance, nor its effect in the learning situation, however, it may be that the balance needs to be tipped more in favour of the processes of design and problem solving.

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