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### **A case study of the inter-relationship between Science and Technology: England 1984-2004**

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# A case study of the inter-relationship between Science and Technology: England 1984-2004

## **Abstract**

This paper takes the case of England over the twenty years 1984 to 2004 and explores the relationships between the two linked, but separate, school subjects of science and technology. Using a framework of analysis, we consider three inter-related strands: the curriculum rationale (focusing on the specified curriculum); teacher knowledge (focusing on the enacted curriculum); and pupil learning (focusing on the experienced curriculum). We consider the strands as they apply to each subject separately and also in relation to each other and, for each strand, attempt to draw lessons that can be learned and applied to other national contexts.

Key Words: Science and Technology; Teacher Knowledge; Pupil Learning; Curriculum Development.

## **Introduction**

Politicians often refer to Science and Technology as an epistemological unit. In the early 1980s, the UK Thatcher Government generously financed a Technical and Vocational Education Initiative (TVEI) which tried to explicitly bring together the two curriculum areas of Science and Technology.<sup>1</sup> Indeed, despite the school politics that has surrounded the teaching of the two subject areas, which stresses the differences, there are some clear similarities. Both subjects opened up the group of pupils who would take the subject (science moved from being a specialist subject just for those going on to do it at higher levels, Technology had to appeal to the academically 'able' as well as the traditional group of 'non-academic' pupils), both make much of 'hands-on' learning; both claim to promote problem solving and other 'processes'; both try to explicitly link school tasks to useful learning for every day life and the needs of the work-place.

Our framework of analysis is illustrated graphically (Figure 1).<sup>2</sup> We consider both science and technology developments in England over the last twenty years, both separately and together through their common features, by considering three strands:

- Curriculum rationale (the *specified curriculum* as found in national curriculum documents, which, in England, has statutory significance);
- teacher knowledge (focusing on the *enacted curriculum*, i.e. what they bring to bear to plan and implement their teaching);

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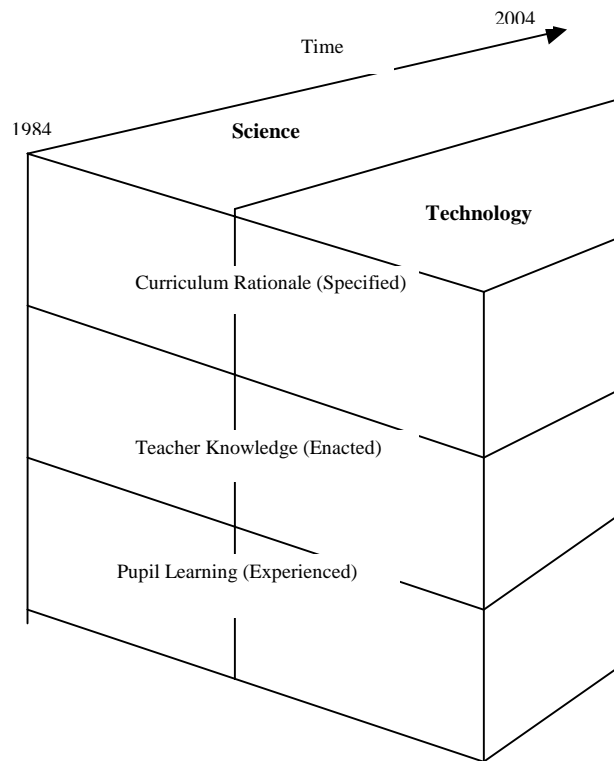
<sup>1</sup> There have of course been a number of moves to link these two, most notoriously the failed attempts at applied science (see McCormick, 1990; McCulloch, Jenkins & Layton, 1985).

<sup>2</sup> This framework was developed for an Open University course E836 *Learning, Curriculum and Assessment*.

- pupil learning (focusing on the *experienced curriculum*, i.e. how both of the above are interpreted and made sense of by pupils).

Through our research at the Open University in both science and technology school lessons, we explore common issues and consider what each subject can learn from the other.<sup>3</sup> We hope that the case of England will highlight issues for consideration in other countries.

Figure 1. Analysis Framework




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<sup>3</sup> We would like to acknowledge our debt to the teachers and colleagues who have been involved in the research upon which we draw, and whose contributions have helped form our views.

## ***The Specified Curriculum***

The following statements are from the current National Curriculum in England published in 1999:

### **The importance of science**

Science stimulates and excites pupils' curiosity about phenomena and events in the world around them. It also satisfies this curiosity with knowledge. Because science links direct practical experience with ideas, it can engage learners at many levels. Scientific method is about developing and evaluating explanations through experimental evidence and modelling. This is a spur to critical and creative thought. Through science, pupils understand how major scientific ideas contribute to technological change — impacting on industry, business and medicine and improving quality of life. Pupils recognise the cultural significance of science and trace its worldwide development. They learn to question and discuss science-based issues that may affect their own lives, the direction of society and the future of the world.

### **The importance of design and technology**

Design and technology prepares pupils to participate in tomorrow's rapidly changing technologies. They learn to think and intervene creatively to improve quality of life. The subject calls for pupils to become autonomous and creative problem solvers, as individuals and members of a team. They must look for needs, wants and opportunities and respond to them by developing a range of ideas and making products and systems. They combine practical skills with an understanding of aesthetics, social and environmental issues, function and industrial practices. As they do so, they reflect on and evaluate present and past design and technology, its uses and effects. Through design and technology, all pupils can become discriminating and informed users of products, and become innovators. (DfES/QCA, 1999)

These two statements lay out what has been the culmination of a change process in the school curricula of science and technology (in England 'Design and Technology') over the last twenty years, namely the rationale for the designation of the two subjects as required areas of study during the years of compulsory schooling, 5-16. In 2005 the requirement for all pupils to study technology is restricted, and Design and Technology (D&T) is now only an obligatory subject between the ages of 5-14 years. Science, however, is still a requirement for all pupils up to 16 years of age. Over the last twenty years, what lessons can be drawn about making the two subjects compulsory for all pupils? What decisions were taken about what all should be able to 'know, understand and do' as a result of studying science and technology in the school curriculum and what was communicated to teachers, pupils and their parents?

Science led the way. Building on the curriculum initiatives of the 1960s following the 'Sputnik panic', by the 1980s most secondary schools required all pupils to learn science and, as most schools were becoming 'comprehensive' (non selective), there was a desire to widen the science curriculum to all pupils including those less academically gifted. For example, Nuffield Secondary Science became popular, as did Science at Work in the 1970s as curricula specifically designed for such students. Science in England was being accepted as a core area of study for all pupils on a similar footing to mathematics and (mother-tongue) English. Also in the early 1980s the nature of a science curriculum for all pupils – a science for citizenship or 'scientific literacy' was being debated. In particular, the importance of learning 'facts' in science was questioned and a case was made that the processes of the scientific method were much more important for all pupils. The government policy document Science 5-16 (DES, 1985), that pre-dated the national

curriculum, did not merely define what should be taught in terms of content such as ‘electricity’ or ‘plants’, but instead emphasised the importance of a process approach. Indeed, science curriculum innovation in the middle 1980s saw a large number of new courses such as ‘Warwick Process Science’ and ‘Science in Process’ for secondary schools. These focused, not on science concepts, but rather on processes such as observation, interpretation and classification — aspects critical to ‘the scientific method’.

This mood was picked up in the developing primary science curriculum at that time. Although not totally accepted by some (for example, Jenkins, 1987), many in the teaching profession generally welcomed a move away from what was often considered as merely the memorising of poorly understood facts. In contrast, there emerged a generally common consensus that science might be more accessible to all pupils if it emphasised skills applicable to other areas of life both inside and outside school. The attention to ‘doing’ science — raising questions that could be answered by an investigation — became the corner-stone of the developing primary science and in 2005 is a core principle in new courses which pick up on perceived failures of the national curriculum (see below). For example, the question ‘What is the best carrier bag?’ would be turned into an investigation question such as ‘Which carrier bag carries the greatest weight?’ in what was considered a problem-solving approach. To answer such a question, so-called ‘dependent and independent’ variables were identified. Thus the importance of the procedural knowledge of science was developed. At this time (1980s), primary teachers (normally untrained in science) were concerned about the introduction of science into their day to day work. The rhetoric from those advocating that science should indeed be part of the primary curriculum was that the teachers could ‘learn with the pupils’; it was argued that only the process was important, not the science facts or concepts that the teacher did or did not know.

At this time there was concern more generally in schools in England about what was needed as a preparation for adult life. Education for competency in the work-place and the need to be able to ‘problem solve’ was seen as essential. Those advocating a core place for both science and technology in the curriculum of all pupils used the fact that problem-solving lay at the heart of the subjects as a key part of the argument.<sup>4</sup> This gave a different slant to the procedural knowledge, with the implication that general problem-solving processes could be identified. As we shall argue later, however, this latter assumption was erroneous. Also, we shall see that problem-solving in science is different to that in technology. However, despite the push to introduce primary science in the 1970s (e.g. Science 5-13) little had been achieved and, in most schools, Primary science is a relatively recent development. Just twenty years ago, Harlen could write a book entitled *Primary Science: Taking the Plunge* (Harlen, 1985) reflecting the fact that little science was then being taught in primary schools.

There was something of a backlash to the ‘process is all that is important’ line and the debate became heated (see Millar & Driver, 1987; Millar, 1988; Screen, 1988; Wellington, 1988 & 1989; Woolnough, 1988). Some argued that, for example, ‘observation’ in isolation for the sake of it was pointless - one had to apply the process to

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<sup>4</sup> See Murphy *et al.* (1995) for the tracing of this for technology and Garrett (1987) for science.

the understanding of science concepts.<sup>5</sup> This was also accompanied by research-led initiatives emphasising constructivist learning ideas, resulting in a concern for pupil conceptual development and the associated pedagogy. The purpose of the science curriculum as the acquisition of ‘facts’ was, however, very deep-rooted. The National Curriculum for Science was first published in 1988 and, although it had an area devoted to process issues, was largely a re-emphasis on teaching ‘content’ or conceptual knowledge. The balance had shifted again away from procedural knowledge, reinforced at all levels by national testing which, despite the rhetoric of a concern for understanding concepts, emphasised memory and did not include a practical element. In the rapid revisions of the science curriculum over the last 15 years, the push has been to cut back on the extent of content in the curriculum but the premier position of scientific method in the curriculum would never be repeated. Throughout the period we have the shift in concern and balance of procedural and conceptual knowledge, a theme which is reflected in different ways in technology as a curriculum subject.

Technology is a relative newcomer to the curriculum for all pupils from 5 to 16 years. The compulsory National Curriculum was introduced in 1990 and focused on Technology as a process concerning design. It had four attainment targets:

- Attainment target 1 – Identifying needs and opportunities
- Attainment target 2 – Generating a design
- Attainment target 3 – Planning and making
- Attainment target 4 – Evaluating

This process-based curriculum was difficult to implement for both secondary and primary schools. Primary teachers were unused to considering designing, although craft activities had long been a feature of primary school life. It was also suggested that a wide range of teachers become involved at secondary level to cover material areas such as food and textiles, and aspects of business studies as well as the more traditional materials of wood, metal and plastics. Few secondary teachers could bring practical experience of design in the way they did for skills and craft work.

After only two years, The Engineering Council produced a damning report by Smithers and Robinson which declared that ‘Technology in the National Curriculum is a mess’ (Smithers & Robinson, 1992, p 1). Their main criticism was that by defining technology solely through a process approach meant that almost all problem-solving activity could be considered as ‘technology’

Defined on problem-solving alone, most activities become technology - writing this report, conducting a scientific experiment, finding one's way to a railway station. What is needed is some statement of technology's domain. (Smithers & Robinson, 1992, p 3).

The report made recommendations as to what should be considered the subject domain of technology and what should not, and for a better balance between process and content. It

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<sup>5</sup> The concern for more refined views of ‘scientific method’ led to a number of projects: The Exploration of Science Project (Foulds, Gott & Mashiter, 1990), the Children’s Learning in Science Project (CLISP) Driver, and Oldham (1986) and the primary focused SPACE project (Liverpool University, 1994).

also tried to untangle the ‘vocational’ and ‘basic skills’ labels that some had attached to the new compulsory subject, and it advocated a consideration of the ‘literature’ of technology; looking at and learning from the products and artifacts that already exist which can inform designing and making. Subsequent developments tried to address these concerns. In 1995 a new version of the curriculum for England and Wales gave a clearer steer to what D&T was, and the main activities that should be employed:

Pupils should be given opportunities to develop their design & technology capability through:

Assignments in which they design and make products, focussing on different contexts and materials and making use of:

Resistant materials;

Compliant materials and/or food (DMAs- Design and Make Assignments).

Focused practical tasks (FPTs) in which they develop and practise particular skills and knowledge;

Activities in which they Investigate, Disassemble and Evaluate familiar products and Applications. (IDEAS) (DFE/WO, 1995, p. 6)

This methodology strongly reflected the pedagogic model promoted by Nuffield Design and Technology (Barlex *et al* 1994). There was a reduction to two attainment targets that had looked for progress in each part of a process, Designing and Making and, eventually, considering even this separation as unhelpful to, now, just one attainment target Design and Making. Although there is a better balance of knowledge, skills and elements of the design process, the current Attainment Target is still based around the design process, with pupils being expected to achieve the following at the penultimate level:

Pupils use a wide range of appropriate sources of information to develop ideas. They investigate form, function and production processes before communicating ideas, using a variety of media. They recognise the different needs of a range of users and develop fully realistic designs. They produce plans that predict the time needed to carry out the main stages of making products. They work with a range of tools, materials, equipment, components and processes, taking full account of their characteristics. They adapt their methods of manufacture to changing circumstances, providing a sound explanation for any change from the design proposal. They select appropriate techniques to evaluate how their products would perform when used and modify their products in the light of the evaluation to improve their performance.

(QCA <http://www.nc.uk.net/>)

Unlike science, D&T has tended not to use concepts to organise content, and in areas where conceptual knowledge is important, for example, control and electronics, this can be a problem as we shall show later (McCormick, 1997 & 2004; Murphy *et al*, 2004).

D&T, although a required subject for all pupils under the 1990 national curriculum, was always under attack from those who could not see the justification for that position. The reasons for the animosity range from those who would put science and technology together as one curriculum domain (especially at primary school level) to those who, more prosaically, just considered the subject too expensive to deliver in terms of tools, equipment and materials. The response from the D&T lobby was to argue that the subject was important as it prepared ‘pupils to participate in tomorrow’s rapidly changing technologies’ and so much was done to introduce new technologies such as CAD/CAM mainly at secondary level as a tool for the designing and making processes.

So, in both Science and technology, there has been debate over the last twenty years as to the balance that should exist in the specified curriculum in both subjects between procedural knowledge and conceptual knowledge. However, these debates have largely been within each subject community, independent of each other, and tend to emphasise the inevitable differences between the goals of each subject rather than the common ground between the subjects. What can be learned generally, and what can the two subjects learn from each other?

A key lesson to be learned by the rapid revisions of the specified curriculum of both science and technology in England over the last twenty years is that it is very difficult to impose a curriculum onto teachers. As will become evident, a top-down method of seeking to describe the curriculum in close detail without working with teachers, and those involved in pre-service and in-service teacher education, to develop a common understanding of purpose, leads to a mismatch between a teacher's 'personal subject construct' and what is prescribed to be taught. Teachers have a view about what their subject is about and, although they wish their pupils to do well in externally set examinations, when the specified curriculum moves independently of these held views teachers feel obliged to 'teach to the tests'. It is therefore imperative that the tests accurately reflect the intentions of the curriculum designers.<sup>6</sup>

As evidence of the state of science, in 2002, the Westminster Parliament Science and Technology Committee reported on *Science education from 14 to 19* and said the following as part of the document summary:

Science has been a core part of the education of all students up to age of 16 since the introduction of the National Curriculum in 1989. Most students take double science GCSE [the national examination syllabus] from 14 to 16. This course aims to provide a general science education for all and, at the same time, to inspire and prepare some for science post-16. It does neither of these well. It may not be possible for a single course to fulfil both these needs. Government is supporting a pilot that may be resolve these tensions, which is welcome but not enough. Existing GCSE courses should be changed and a wider range of options in science offered to students. [...]

Current GCSE courses are overloaded with factual content, contain little contemporary science and have stultifying assessment arrangements. Coursework is boring and pointless. Teachers and students are frustrated by the lack of flexibility. Students lose any enthusiasm that they once had for science. Those that choose to continue with science post-16 often do so in spite of their experiences of GCSE rather than because of them. Primary responsibility should lie with the awarding bodies; the approach to assessment at GCSE discourages good science from being taught in schools. (House of Commons, 2002, p. 5)

The national assessment for D&T also has its critics:

teachers provide coaching which allows pupils to pass through the assessment hoops for D&T GCSE coursework at the expense of following the wider rationale of D&T learning objectives (OfSTED, 2000, p3)

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<sup>6</sup> Kimbell (1997) gives an account of the failure of the government to produce tests in D&T that reflected what he and his colleagues thought were assessing what the curriculum was aiming for.

...public examinations in D&T have, on the one hand, enabled many pupils to achieve success in terms of performance, whilst on the other hand, they have wasted valuable education opportunities for the development of high order thinking skills at a crucial stage in a pupil's education. (Atkinson, 2000, p277)

In response to these criticisms the science community has attempted to introduce courses which exploit the relevance of science to contemporary life. Courses being piloted in 2005 include 'Science for the 21<sup>st</sup> Century', which attempts to 'square the circle' of providing science literacy for all and a grounding in science basics for those who wish to study the subject further. D&T has for a long time taken refuge in the links to 'real life' and has tried to provide pupils with authentic tasks. However, as the quotations indicate, to make the real world manageable to pupils within the constraints of time and resources that schools impose on the participants sometime leads to an algorithmic approach to the processes – going through the motions in a mechanistic way -and merely showing a 'vener of achievement' (McCormick *et al*, 1994)

The last twenty years has seen extremes in both science and technology education. Tasks in technology, such as building and testing various model bridges to destruction, at the one extreme, to lock-step production of a textile bag (to take home) where the only design decisions concern the decoration, at the other. In science, tasks have ranged from making twenty observations on a burning candle to open-ended investigations on conditions for plant growth to memorizing the names of the parts of a flower.

So the government's attempts to control what pupils learn by specifying in detail the curriculum has had limited success according to those charged with monitoring its impact. We turn now to consider wider lessons to be learned from how the curriculum is enacted by teachers.

### ***The Enacted Curriculum***

To explore the nature of the 'enacted' curriculum, we draw on classroom research we have conducted in both science and technology lessons. We highlight two aspects of our research which gives some insight into the problems teachers in England have faced in trying to enact the specified curriculum. The first considers the teaching of problem solving in science and technology, the second centers on teacher professional knowledge and in particular its implications for the teacher training curriculum. Both examples, however, highlight that the way that teachers enact the specified curriculum depends on their own professional knowledge.

### ***Teacher professional Knowledge***

In our observation of teaching it is evident that success or failure of lessons organised by teachers was often linked, not only to their college-based subject knowledge and their choice of pedagogic strategies, but also to their appreciation of how their subject is transformed into a school subject. In D&T, in particular, an appreciation of the way the subject in schools had been created by an amalgam of the requirements of a national curriculum, the personal history of the teachers who currently teach this 'new' subject and the contextual constraints of accommodation, materials and equipment conspire together to create a particular area of teacher knowledge. We call this 'school

knowledge'. Working with colleagues in Finland, Canada, New Zealand and other areas of the UK we have seen that the key areas of teacher knowledge: Subject knowledge, Pedagogic knowledge and School knowledge can provide a framework for us to consider teacher expertise in a number of different national contexts (see Banks *et al*, 2004). However, as indicated above there is more to consider than what is required by the state and the teaching capability of the teacher. Lying at the heart of the dynamic process between the different aspects of teacher knowledge are the 'personal subject constructs' of the teacher, a complex amalgam of past knowledge, experiences of learning, a personal view of what constitutes 'good' teaching and how pupils learn, and belief in the purposes of the subject. This all underpins a teacher's professional knowledge and is as relevant for highly experienced teacher as it is for the novice. A student teacher needs to question his or her personal beliefs about their subject as they work out a rationale for their classroom practice. But so must those teachers who, although more expert, have experienced profound changes of what contributes 'school knowledge' during their career (as has happened with the introduction of the national curriculum in England), particularly when that knowledge is open to external scrutiny by Her Majesty's Inspectors of Schools.

### **Example: science tasks and technological contexts**

This example of the enacted curriculum draws on our work on the implementation of science tasks in the classroom (See McCormick *et al*, 1996; Murphy & McCormick 1997). Models of science investigation are depicted as problem-solving processes (e.g. Gott and Murphy, 1987). Although such models are not simplistic step-like processes, they are interpreted as such; just as design processes are in technology education. Primary teachers of science now often use planning sheets and indeed are advised to use them to support children's procedural decision making. These sheets identify stages in children's decision making and ask them to focus on specific features e.g. what shall I do to make it fair, what shall I measure, how shall I measure? This produces in the child's mind a notion that these questions and procedures are appropriate and useful across *all* problems.

In Secondary school science there is ritual that has grown out of what constitutes a 'tradition' of procedure in practical science. For example, it was common practice, and often remains so, to structure reports of experimental activity around *title, method, results* and *conclusion*. Shifts in this have been to include *hypothesis* as opposed to *title*, and 'What I did to make it fair' prior to the method section or directly following it in the report. In observations in classrooms, selected because of 'good' practice in science, pupils were found to be including a whole range of disparate procedures under 'fairness'. These included the setting up of the test of the independent variable as fairness was translated to mean 'sameness' hence 'I tested X then Y then Z', 'I did the same thing', was an aspect of fairness in the pupil's mind. The 'assessed practical' is an example of ritual in science being supported by the concern of teachers for pupils to do well in the external examination regime in England. Hooke's Law, the observation that within the elastic limit, extension of a stretched spring being proportional to the load applied, is a common practical investigation easily carried out and understood by 11 year old pupils. However, as this is a phenomenon which many 15 year old pupils can offer an hypothesis which

can be investigated, for which results can be quickly and easily gathered and data graphically displayed, it is often repeated for assessment purposes. This is an example of the dead-hand of assessment criticized as 'boring and pointless' by the parliamentary committee in the quotation earlier.

The authenticity of science tasks can also be thwarted even when teachers attempt to introduce 'contexts' to make science learning meaningful and purposeful for pupils. A typical approach to this is to use an everyday scene to contextualise a science investigation. For example, an investigation was set up to find out how temperature affected the time taken for sugar to dissolve (Murphy *et al*, 1996). 'Dissolving' was the science concept that the teacher wanted to teach and made relevant through the context of a family scene drinking tea.

The reactions of a girl and boy were characteristically different. The girl integrated the context in formulating her response to the task. The boy ignored the context. He went straight to the task 'Find out how the time taken for sugar to dissolve depends on the temperature of the liquid' and wanted to test a range of temperatures including room temperature. The girl could see no point in testing cold water. As she commented "nobody drinks cold tea." Neither the boy who was working as her partner in the practical task nor the class teacher could understand the girl's perspective. She would not 'play the game' as would the boy and as the teacher intended. She saw no point in investigating anything that was outside the real-world English context of drinking hot tea! This 'ritual of science in the classroom', although for a different purpose, we have called 'school knowledge' in the novice teacher example above as this is the approach to science investigations implicit in what is set by examination boards. The girl's main problem was that her solution had to be applied in the context of tea drinking. Another pupil acting as a mediator tried to help Rennie keep her concern with the authenticity of the context but also to play the science game. "Say Martians came down Rennie, they might not know about drinking cold tea. They might *like* cold tea!" The girl felt supported by this but basically accepted defeat and carried out the (in her view) artificial task required by the teacher, at some considerable cost in her view of herself in relation to science and to the teacher.

This concern with the reality suggested by context can be also be confirmed by a further example which also illustrates the way that boys often react differently to girls (Murphy, 1988). For an investigation of the thermal properties of different textiles such as nylon, felt, cotton wool and a range of other similar materials, pupils were given a copper can, hot water, thermometers and a stop clock. The pupils were asked to find out which of the materials was the best insulator to make a jacket for a mountaineer. In a similar way to the sugar and tea example, the boys at once saw that what the game to be played was all about. They set about wrapping the various materials around the can full of hot water and plotted a range of comparative cooling curves. The girls' reaction to the context was different. Some wanted to make a small jacket to do a 'proper test' on it and spent a lot of time making such a model. Some other girls rejected at the outset cotton wool (the best insulator amongst the samples offered) as 'No one would make a mountaineer's jacket out of cotton wool!'

## **Example: novice teachers in training**

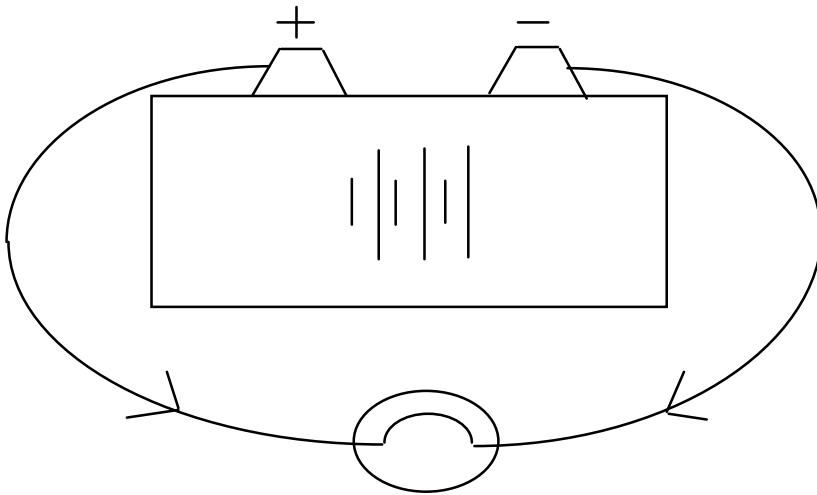
This example illustrates the difficulty teachers have in bringing together the different types of professional knowledge when organising lessons. The theoretical framework underpinning this work was developed by one of the authors and colleagues in the Centre for Research and Development in Teacher Education at the Open University (see Moon and Banks 1996, Banks 1997) and has been explored with many technology teachers (see Banks & Barlex, 1999, Banks *et al.* 2004). Although the teachers in this example are both very new and still on a pre-service course this example illustrates rather starkly the dilemmas which still face more experienced teachers (as shown above). The example has implications not only for how we should conceptualise the teacher training curriculum and but also lessons to be learnt for better links across school science and technology. As we will see, despite very obvious overlaps in curriculum content, here there was little collaboration between the teachers of science and those of technology.

Although they are at the *beginning teaching* phase of their course to become D&T teachers, Alun and Geoff have already planned and begun to pair-teach a series of lessons for their placement school. The department was concerned that the existing school scheme of work offered to 11 year-olds did not yet include aspects of simple electronics. Although some discussions took place with members of the Science department, the student teachers were largely left to themselves to carry out this work. Using their own ideas and curriculum materials such as text books and electronic kits already in the school, the students decided to organise their teaching around the development of a face mask with flashing eyes. They found this a very difficult exercise, and as we will see, the face mask product was rather pushed out by other considerations. A particular lesson concerned the pupils investigating which materials were conductors and which insulators. To do this the student teachers employed a standard kit called *Locktronics*, but talked first about the circuit by drawing diagrams on the chalkboard.

### **Subject knowledge**

The teachers' own understanding of simple electricity was sufficient, but lacked the flexible and sophisticated features to ensure that it was conveyed clearly (McDiarmid *et al.*, 1989). They understood electricity themselves, but were unsure of the depth and nature of the topic pertinent to this design and make task. For example: a description they gave of current flow also involved a confusing discussion of electron flow; a picture of a battery was combined (incorrectly) with a diagram of the electrical symbols. The rather unsatisfactory chalk-board illustration shown in Figure 2 was the result, which inadvertently corresponded to a classic 'clashing current' misconception of pupils (Shipstone, 1985).

Figure 2: Chalkboard diagram



### School knowledge

The purpose of the project was unclear in the minds of the beginning teachers. When describing the task they would sometimes see it as means to teach designing and making (a practical ‘Design and Make Assignment’), however the functional aspects of wearing the mask were not thought through (e.g. the weight of the battery, its location, or how it would be supported). They also considered practical skills such as soldering as being central, but had not allowed enough time to develop such skills. In practice, the face mask became a means of ‘selling’ the lesson to the pupils – but that became secondary to the desire to teach aspects of conceptual knowledge about electric circuits.<sup>7</sup>

Geoff and Alun thought that an understanding of  $V=IR$  was important, but the science department staff had suggested that the use of such a difficult equation would not be taught and reinforced by them to these 11-year-old pupils. Although a D&T lesson, their desire to teach the *science* subject background, such as (in this lesson) conductors and insulators and the existence of electrons, cut down on the time for any designing and making. They were unclear if the overall purpose of the activity was designing, acquiring specific skills, or a ‘seeing-is-believing’ confirmation of scientific principles. Their prior selection of the subject knowledge they wished to teach was transposed into knowledge for teaching but, as their understanding of school technology was poor, it was without the necessary pedagogic rationale or appropriate teaching strategies.

### Pedagogical knowledge

Only Geoff had used the electronics kits before as a pupil, and both novice teachers were unfamiliar with the way they could be used in the classroom. The pupils had some difficulty in manipulating the components and interpreting the circuits the teachers had constructed on the boards. Making a simple series circuit with battery and bulb was difficult enough with the new kits, and introducing a break to accommodate different

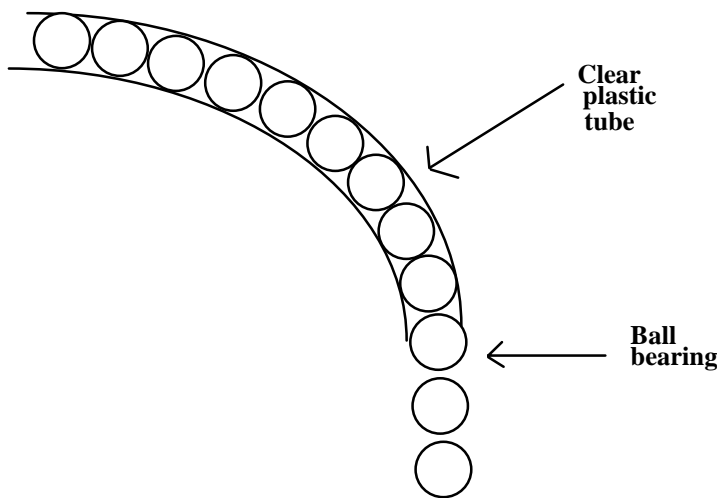
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<sup>7</sup> We have found this kind of problem with experienced teachers, where the context is used to ‘deliver’ some electronics (McCormick & Davidson, 1996).

shaped rods of various materials in an experiment to classify ‘conductors’ and ‘insulators’ defeated almost all pupils.

As these beginning teachers were not able to enlist the experience of their mentor (whose own subject was business studies), they drew on their own embryonic pedagogical knowledge to formulate teaching activities for the project. They naturally used analogies to try to convey ideas about electrical flow.<sup>8</sup> For example, Geoff talked about how it is easier to walk around a hill, rather than walk over it, in an attempt to quickly cover the idea of a short circuit. As they considered a knowledge of electrons an essential pre-requisite to an understanding of conductors and insulators, Alun showed the following real model and then talked about it using this chalk-board diagram (Figure 3).

*Figure 3: Model of electrons in a wire*



The actual tube, shown to the pupils later, represented the wire and the ball bearings were the electrons. It is unclear what the pupils thought about the size of electrons and the need for a conductor for electron flow!

Geoff and Alun wished to scaffold the learning of the pupils and they believed a hands-on approach was appropriate. However, they found it difficult to leave the pupils to experiment with the kits, and continually intervened to move them on because of time shortage. Too much was attempted too quickly and some pupils became confused then bored. The novice teachers did not have the pedagogical knowledge to know which aspects of electricity were difficult to convey.

### **Personal subject constructs**

Both Geoff and Alun have a personal subject construct molded by experience in industry, which strongly influences their direction and orientation to how and why pupils should learn Technology. They both also have views of how pupils learn and what constitutes

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<sup>8</sup> There is good evidence on the difficulty of many analogies (eg Dupin & Joshua,1989)

‘good’ teaching. They both see hands-on as being vital (although they get side-tracked by a view that detailed theoretical science concepts are an inevitable precursor to understanding of school technology) and wish to emphasise a link to marketing the face-mask product (although that aspect is not made explicit to the pupils).

Alun: I’ve a belief that everyone should follow Technology with a business and a legal aspect, i.e. unless you know how much it's gonna cost, it's pointless designing something [...] Can we make it? Far too often we find we design things which do not take into the remit [...] realistic targets. So I'd like to relate Technology to more...creative depth within the curriculum.  
(Interview)

We feel that the personal subject construct of teachers, such as articulated by Alun, has been a crucial factor influencing the way that teachers select the information from the specified curriculum, chose their teaching strategies and thereby affect pupil learning. Banks and Barlex (1999) support this view, arguing that, within the designing and making process there are features that will appeal in different degrees to a teacher according to the specialism and professional history of that teacher. The list below identifies such features and the often-articulated rationale for its significance. (see Table 1).

**Table 1: possible elements of ‘personal subject constructs’**

- |                           |  |
|---------------------------|--|
| • Aesthetics              | The appearance is crucial. It says everything about the product.                               |
| • Communicating skills    | Unless they communicate their ideas nothing will be accomplished.                              |
| • Design procedures       | Without the procedural competence of design nothing can be achieved.                           |
| • Making skills           | But if they can’t make it it’s a complete waste of time.                                       |
| • Technical understanding | If it’s not technically sound it just won’t work.  |
| • Values                  | Without an appreciation of the values implicit in the endeavour the whole exercise lacks worth |

Ideally a balanced design and make assignment will call on each of these features if not in equal measure then certainly to a meaningful extent. But, if a teacher is strong in just one or two aspects, or believes that one is more significant than any of the others, the breadth and balance within the designing and making experience is lost. Many technology teachers were trained initially as craft teachers and their work has been generally criticised by the Office for Standards in Education.

.. in general pupils' attainment in designing lags behind that in making. This is because pupils are either not introduced to a sufficiently wide range of designing strategies [...] or are not taught to use them effectively. Pupils are generally confident where work is closely directed by the teacher, but less so when working independently to their own plans, with little awareness of how their work will develop in the later stages of their projects.  
(OFSTED, 1998)

The above quotation points up one of the lessons to be learnt from the tradition in both science and technology for practical hands-on work. To make the tasks manageable in the classroom, economic on resources and generally successful in terms of teacher-intended outcomes, teachers tend to closely direct the activity of pupils.

We therefore have the situation where both science and technology teachers who adopt a general problem-solving approach to investigation and design run the risk of it being treated as rituals in the classroom. These rituals become associated with the science and technology classrooms and hence students' problem-solving strategies are more to do with this classroom culture, than with problem-solving in the domains of science and technology.

We now turn to consider what pupils are learning in science and technology lessons; how what is specified by government, mediated into tasks by teachers results in 'learning' by pupils.

### ***The Experienced Curriculum***

A limited, but important manifestation of how the curriculum is experienced, in terms of the outcomes of pupil learning, are the scores that pupils achieve on tests and examinations. The international tests in science conducted in 1995, 1999 and 2003 (TIMSS 2004) indicate science assessment results for 14 year old pupils in each of the 25 countries which undertook the tests on these occasions. On that measure how do pupils in England perform? In the 2003 'league table' England came 6<sup>th</sup> with an average score of 544 behind (in rank order) Singapore (578), Taipei (571), South Korea (558), Hong Kong (556) and Japan. (552). Leaving aside the technicalities of the testing process, and what features of science it was testing (and the undersized sample for England), this can be seen as good news to the government and to its curriculum advisers. In terms of trends too, the average science score of pupils in England rose from 533 in 1995 and 538 in 1999. There are no similar international comparisons for Technology, and less consensus internationally about what constitutes the common features of school technology (Banks, 1996), however other indicators exist which give clues about the difficulty of science and technology as subjects and pupils satisfaction with their learning experience, as we will shortly show.

A second indication of the experienced curriculum is the amount of participation in the subject, especially where pupils have a choice of what to study. In England the General Certificate in Secondary Education (GCSE), set by government-recognised examination boards, is taken by all pupils around the age of 16 years, and seen by many as the 'school leaving examination'. However, pupils choose (in conjunction with their teachers) what particular subjects to study for and, within specific subjects what course to take, all controlled by the framework of the national curriculum. Those wishing to study in higher education stay at school for two more years to take Advanced Level (A Level) examinations, and here we have an even sharper choice, which is likely to link to a pupil's future career. By considering the data of both science and technology GCSE candidates, and comparing them with A level candidates, one can make some rough conclusions about participation in further study of science and technology, when such study is no longer compulsory. Data exists for the years 1992 to 2001 from the

Qualifications and Curriculum Authority provided by the GCSE awarding bodies in England, Wales and Northern Ireland, and are for candidates of all ages, although the majority were 16 at the time of the examinations. All D&T courses are included and the most common science GCSE ‘Science Double Award’, which includes aspects of all sciences and takes twice as much time to study as technology, counting as two ‘subjects’ (Table 2).

**Table 2: Number of candidates entered for D&T and Science (Double Award GCSE)**

Year	Total Candidates GCSE	Total Candidates D&T (inc. Short courses from 1997)	Total Candidates Science Double Award
1992	5028554	183606	621177
1993	4968634	154720	668272
1994	5029599	150353	810371
1995	5431625	414436	924462
1996	5525620	283974	937304
1997	5455665	269642	929523
1998	5398332	444330	948498
1999	5501193	465252	960870
2000	5514310	467931	980536
2001	5672767	475106	1001610

These data are the Joint Council's final results after any enquiries about the results have been completed.

**Table 3: Number of candidates taking A level D&T and the Separate Science.**

Year	Total A level Candidates	Total A level Candidates D&T (% GCSE in Year-2)	Total A level Candidates Biology (% GCSE in Year-2)	Total A level Candidates Chemistry (% GCSE in Year-2)	Total A level Candidates Physics (% GCSE in Year-2)
1992	731240	9572	48742	42697	41301
1993	734081	10934	47748	40975	38168
1994	732974	11046 (6%)	50851 (8%)	41231 (7%)	36147 (6%)
1995	730415	10659 (7%)	52255 (8%)	42293 (6%)	34802 (5%)
1996	740470	11057 (7%)	52053 (6%)	40418 (5%)	33033 (4%)
1997	777710	11572 (2%)	56706 (6%)	42262 (5%)	33243 (4%)
1998	790035	13220 (5%)	57436 (6%)	41893 (4%)	33769 (4%)
1999	787732	13739 (5%)	55810 (6%)	40920 (4%)	33548 (4%)
2000	774364	14650 (3%)	54650 (6%)	40261 (4%)	31794 (3%)
2001	770995	14909 (3%)	52382 (5%)	38702 (4%)	30802 (3%)

Table 2 illustrates the increasing popularity of Double Award Science over the years compared with the total candidates in the GCSE cohort. Similarly as D&T became established, the number sitting the examination rose steadily and on the face of it, that could be considered good news for curriculum planners. Both boys and girls are now obliged to study aspects of the physical sciences and of control technology for example. However, in both cases at GCSE there was a degree of obligation and that is no guarantee that when pupils have more choice they will later (e.g. at A level) opt to study science and technology in more depth.

Table 3 shows the number of candidates taking D&T and the separate sciences at A level. This is taken by people of around 18 years old who have opted to stay on in education after the compulsory years of schooling. The percentage figure shown in brackets from 1994 onwards is the fraction of the former GCSE subject cohort who passed the subject two years earlier (e.g. 1992), who went on to sit the corresponding examination at A level. Thus 6% of those who in 1992 passed GCSE in D&T went on to do A level in D&T; similarly 8% went on to do Biology at A level. Looking at the total number of A level examination candidates over the years, only D&T is rising in absolute terms. Biology goes up then down and both Chemistry and Physics have a generally downward trend. However, when one considers the fraction of the corresponding GCSE cohort who *could* have studied these subjects further at A level should they have wished to so, the trend since the introduction of compulsory study of science and technology has been that a smaller fraction wish to do so. Naturally looking at this quantitative data does not give a full picture. Not all schools offer D&T at Advanced level and Physics Teachers are often very difficult to recruit, so that even A level (and certainly Double Award Science) is sometimes taught by teachers without a Physics specialism. However, for whatever reason, the decline in the sciences and the reduction in the percentage wishing to study science and engineering in higher education is a concern to the government in England as it is in most of the western world.

The experience of science and technology within compulsory schooling is not increasing participation subsequently. As we have seen, the way that both science and D&T is transformed in schools by the pedagogy used, the need to cater for many pupils' needs at once, and the requirements of the assessment process all have an impact on the pupils' experiences of the two subjects. The final example gives some insights into *how* the learning is experienced.

### **Example: problem solving in the technology classroom**

We noted earlier that problem solving is often treated as a ritual. We and our colleagues have reported a body of empirical evidence that this ritual is the way designing as problem solving can be enacted by teachers, with a limiting experience for pupils (see McCormick & Davidson, 1996; McCormick, Murphy & Hennessy, 1994). This ritual we have already suggested was one of the results of the imposed curriculum. However, it also reflects the state of our knowledge about classroom problem solving that has found its way into teachers' knowledge such that it becomes part of their enactment of the curriculum. An example of this was evident in a case study of a teacher with 12-13 year-old pupils working on an electronic badge project based on a 'face' with LEDs for eyes.

The teacher deliberately did not emphasise the design process; it was not one of his main aims, and he seemed to view designing as a logical approach rather than as a process that involved sub-processes to be taught and learnt:

...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...

(Teacher interview)

He appeared to see the 'logical approach' as a 'way of working', and in that sense the sub-processes were of little significance to him. For him the design process was very much in the background, not just in this project but in general:

I'm relying rather a lot on a subconscious level of going through things. Some of them won't do it, some will.

It resembles, therefore, a planning tool, and we had evidence of this ritual being used in other studies even when there was explicit teaching of the overall process as being made up of sub-process (McCormick & Davidson, 1996).

The particular view a teacher takes of the design process affects the way tasks are structured, the kinds of interventions that are made by the teacher, and the assessment of pupils' work. Not all of these will be consistent either with each other, or with the view espoused by a teacher, but collectively they will have a profound effect on the pupils' perceptions and activities (the experienced curriculum). But, whatever view is taken of designing, there is a tendency to see it as an algorithm to be applied in a variety of situations.

The teacher involved in a *electronic badge project* began it with the 'Situation' being presented:

A theme park has opened in [place] and it wants to advertise itself. It plans to sell cheap lapel badges based on cartoon characters in the park. To make these badges more interesting, a basic electronic circuit will make something happen on the badge.

This was set within the general title of 'Festivals', but the links to the 'Situation' were not discussed, and from then on no further reference was made to festivals. The teacher continued in the session by asking the pupils to define the 'Design brief' and draw up a spider diagram of 'Considerations' (a specification), tasks which all the pupils seemed familiar with. He did not, however, elaborate on the 'Situation' or the 'Design brief', nor invite pupils to discuss them in the context of the planned project.

The three pupils we followed (B, T and D) produced different design briefs that illustrated how the 'Situation' was interpreted by them. B & T interpreted it as a "button is pressed to light up the eyes", whereas D makes no such inference: "to design and make a clock badge". Their initial ideas of their personal 'briefs' lingered and influenced future tasks; for example, D continued to talk about a "clock face" for several lessons and abandoned the idea only when he realised that the electronics would not be like that of a watch. He also imagines that the battery would resemble that in a watch and was almost

incredulous when the teacher showed a comparatively large conventional dry 9-volt battery that he (rightly) considered too heavy for a lapel badge. The teacher's discussion with D about this issue indicated that unlike D, he had not entered into the 'Situation' and 'Design brief' in a meaningful way, but only ritualistically - his ultimate answer to the problem was to "have a strong pin for the badge", a response D felt dissatisfied with.

Next the teacher gave several tasks relating to drawing the faces for the badge, which implicitly reflected the sub-processes of 'generating ideas', 'developing a chosen idea' and 'planning the making'. However, this was again done in a ritualistic way as the following indicates.

At the end of the first session pupils were asked, for homework, to create four cartoon faces as potential designs for the badge. No parameters were given other than that all four should fit into the design sheet and that pupils should be 'creative'. As with the 'Situation', 'Design brief' and 'Considerations', this step of producing four designs appeared to be a standard one and, again, was accepted without question by the pupils. However, in the next session pupils were asked to re-draw the faces so that they touch the sides of a fixed drawn square (70x70 mm). The reason for this was not made clear until a later session. Evidence from the pupils' folders indicates that pupils had to modify their designs in order to fit these new demands. For example, D had originally drawn a thin 'carrot' character, which he had to distort to make it fat enough for it to touch the sides of the square. The fact that the creation of several designs is perceived by pupils to be a ritual, is seen in D's comments to the teacher implying he had in fact already made a final choice while he is still completing the four drawings.

In our research we elaborated some of the strategies that pupils adopted in response to the various ways the teachers viewed and enacted the problem-solving process (Murphy and McCormick, 1997). These strategies certainly do not resemble the "algorithms" of problem solving that are so often taught.

The first strategy is what we characterised as *problem solving as dealing with classroom culture*. This occurs when students try to work out the rules the teacher sets in the classroom, and play to those rules. We saw the teacher setting out rules of the game in our examples of the 'enacted curriculum' above. Examples of pupils seeking this culture out is contrasted in the experience of two girls (Kathy and Alice) producing a mobile. Alice wanted to do something that clinks when the wind blows, and so had an idea of using metal. So, given a restricted choice of material, she chose to cut thick mild steel in the form of disks about two inches diameter. Because she played the rules of the classroom, Alice ended up with very sore hands, and took a long time; her endeavor resulted in a very inappropriate way of creating the effect she wanted. (But she did learn quite a lot about mild steel, as it turned out.)

Kathy had designed a moon and planets going around it, and wanted some kind of glinting material. When presented with the choice of material, Kathy in contrast to Alice, looked elsewhere and saw some aluminium (not available to the class) and asked to use this. The teacher agreed, and she cut this easily with tin snips. Kathy took this approach many times throughout the project. She broke the rules of the classroom, knowing what she could and couldn't get away with. She experienced different kinds of issues and problems from Alice, but she was avoiding many technological problems.

The second strategy is *problem solving as giving and finding a solution*, illustrated in a project involving a moisture sensor. The teacher in this study defined the task in terms of making a box in which to put the electronics (the transistor circuit, the bulb or the little speaker, switch, etc.). This had to be appropriate to the situation of detecting moisture or lack of it. He taught them to cut the material (styrene) in straight lines with a steel ruler and a knife because when he said “box”, he had in mind a rectangular box. He also gave them a jig so that they could put the two edges together at right angles and run the solvent along to stick the two together. But some pupils wanted curved shaped boxes, which gave some of them at least three emergent problems. First they had to cut a curved shape, and pupils asked each other and the teacher how to cut the shape as the steel ruler method wouldn't work (the solution was to cut it slowly). Second, a curved profile on one part of the box required one side to bend to follow the profile, but the styrene they were given was too thick. The pupils asked the teacher who simply gave her a thinner gauge of styrene, without any discussion. Third, the pupil did not know how to support or hold the thinner styrene in place to apply the solvent, and so again asked the teacher. This time the teacher had to think and was obviously solving a problem himself, but again he gave the *results* of his thinking as a ready-made solution to the pupil and did not involve her in his problem solving. All she received was the solution without being involved in the problem solving. This continually being “given solutions” becomes a culture of the classroom at the expense of a ‘problem-solving’ culture.

In contrast, we found a teacher in a primary school, who worked with younger children (10- and 11-year-olds), who was able to create this *problem-solving culture* through interactions with students. When pupils came up with problems, the teacher asked questions about their problem, or posed alternative solutions (because sometimes students cannot cope with the questions or provide solutions). Pupils were given more than one solution, because the teacher was trying to engage students in the problem and the problem-solving process. Such a teacher has to set up a completely different culture in the classroom. It takes longer, and it is harder to do, but it is crucial to foster problem solving.

The final strategy is the *student collaboration model*, and that happens in a variety of ways (see Hennessy & Murphy [1999] for the literature on collaborative activity and Murphy & Hennessy [2001] for an analysis of examples of collaboration in technology). One way is through co-operation. In D&T in England pupils are usually set individual projects, so they may be working alongside each other on a table or a bench, and they can co-operate because they are doing similar things; they are not identical, but similar enough to help each other and share tasks.

The second form of collaboration involved pupils in dividing up the task: “You do this bit, I'll do that bit. You're good at that and I'm good at this.” Some of the learning is lost in this approach. But at least it is a way of collaborating, because they have to put the two bits together at some stage, and that has an element of good collaborative problem solving. The final form of collaboration occurs when pupils have a shared task, and they can talk about it. This means the design of the task must *require* the students to collaborate. Designed correctly tasks should require solutions to a problem to be considered by all students through discussion and decision making.

These four strategies of problem solving in the technology classroom differ from the way problem solving is depicted in the national curriculum, and the way technology educators normally think about it. Without a sensitivity to pupils' experience of problem solving the enacted curriculum will not have the required impact imagined by the teacher.

Problem solving in the science classroom has had no similar exploration, partly because the focus of any problem solving is on the development of conceptual knowledge not procedural knowledge (Murphy & McCormick, 1997). This gives some scope for science teachers to learn from technology teachers, even if it is only to be aware of how they set can up climates that encourage productive problem solving directed at important scientific approaches to problems.

### **Example: knowledge in the classroom**

We indicated in our discussion of the specified curriculum that science education has been concerned with conceptual knowledge to a greater extent than in technology. Science educators, and many science teachers, recognise the learning issues involved in concept development (e.g. as illustrated in CLISP; see Note 3). Despite this concern there is evidence in technology classrooms that the science knowledge is inert, i.e. it cannot be used in the technological context. One technology teachers strategy is to enable this use is to teach knowledge on a 'need to know' basis, i.e. when it is needed within a project. This is problematic, and they under-rate the difficulties for pupils in learning and using knowledge, as we suggested was the case for the novice teachers Geoff and Alun in our first example.

One strategy is to design appropriate 'Focused Tasks' to cover the necessary conceptual knowledge requirements. However, teaching knowledge on a 'need to know' basis is an attractive alternative for a technology teacher in the situation where separate 'theory' lessons would destroy the motivation that the subject is able to engender in pupils. In addition, the knowledge demands are not always predictable, and hence have to be dealt with as required. If we consider the electronic badge project discussed in the problem-solving example above, then it is evident that the teacher would be faced with a variety of kinds of knowledge, much of which would not feature in the science curriculum for that year group, or at the very least contains different assumptions about starting points and progression of conceptual understanding. More to the point, science educators would be aware of the conceptual difficulties that pupils are likely to encounter, and in particular the importance of an awareness of alternative frameworks that pupils bring to the lessons. However, technology teachers are faced with a more complex situation than the carefully controlled science lesson, where the conceptual knowledge may be used to structure the tasks. Instead they will have the complexities of knowledge in action and an agenda of *technological knowledge* in addition to that of the scientific knowledge.

Levinson, Murphy & McCormick (1997) indicate such problems in a detailed study of 12-13 year-old pupils of the same age involved in a moisture sensor project. This revealed that the science knowledge (in terms of what was learned in the science classroom) was not available for the pupils to use in their technology activity. In the science classroom the focus is on *explanations* of phenomena, not on its use. Thus, even though students could give an explanation of current flow in simple 'science circuit', they could not use it

to design something nor to make a circuit work in a particular way.

All of the above knowledge relates to science concepts, but, as noted, to add to the complexity of pupils' understanding they also have to master technological concepts. In electronic circuits, and particularly where there is a design element, control system concepts are used and must be understood by pupils. At this level pupils are introduced to the idea of *input*, *process* and *output*, which in the case of the earlier electronic badge project translates into the light-dependent resistor (LDR) as *input*, the transistor (and associated resistors) as *process* and the LED as *output*. This match of system-level description and component-level (e.g. an LED) is not without its complications and arbitrariness (e.g. is the LED's protective resistor part of the output or the process?), and this became evident in the pupils' discussions we have researched (McCormick & Murphy, 1994). In the third session of the project the teacher asked the pupils to make the match of system descriptors and components having defined *input*, *process* and *output*. Pupils were able to use the circuit diagram, which had arrows into the LDR and out of the LED, giving a clue to the input and output respectively. Nevertheless it took even the most able pupils, some time to work this out, and more typically a pupil would insist, quite understandably, that the battery was the input. Indeed this is a legitimate idea, when *primary* and *secondary inputs* are considered (see McCormick, 2004). The teacher does deal with the idea of the 'transistor as a switch' i.e. as the *process* but not in any detail. In more recent work (Murphy *et al*, 2004), observing older pupils (14-15 year olds), we found pupils still having problems with these basic system concepts, and teachers with different approaches to the underlying control ideas (e.g. no distinction between open- and closed-loop control; some using the concept of 'feedback', some not).

The earlier problems with science concepts are at least well researched, and teaching strategies exist to deal with some of them, but in the realm of technological concepts we have much less understanding. Neither do we have much about the interaction of the different kinds of knowledge required in the technological task. So once again we have an area where we are unable as teachers to be aware of the experience of the curriculum for the pupil, without more understanding.

## **Conclusion**

What lessons can be drawn from a consideration of science and technology education in England over the years 1984 to 2004? We have covered some issues in passing and here attempt to draw together what we consider are the crucial points. Although the framework we have adopted (Figure 1) helps us to focus on specific issues, its dimensions are naturally interlinked. Classrooms are social environments and the specified curriculum leads to what is enacted by teachers and what is experienced by pupils. Yet how pupils react to tasks set and how they learn modifies what teachers do and, particularly in the early years under consideration, leads to modification of what is specified.

### **The Specified Curriculum**

- *It is very difficult to control the intended learning of pupils by an elaborate specification in law of what pupils should know.*

A curriculum specified as a legal document is open to challenge in the court if it is not carried out in schools. If teachers themselves are not part of the discussion on what science and technology in school should be, they will ‘teach to the test’ to cover themselves leading to pedagogies that have, for example, elements of ‘ritual’. There will be a clash between their personal view of their subject and that specified by the state and classroom practice will go through a period of extremes until some commonly shared beliefs of what constitutes ‘good’ teaching emerge. In 2005, this concern to control centrally the work of teachers has not diminished. Following on nation-wide initiatives for numeracy and literacy, all teachers of science and of technology will be trained to improve the learning of 11-14year old – the so called Key Stage 3 Strategy (DfES, 2005). In countries such as Scotland where the curriculum is suggested by guidelines rather than legislation, development of the curriculum has been less hectic (see for example Dakers & Doherty, 2003)

### **The Enacted Curriculum**

- *In an effort to direct the learning outcomes for all pupils and make the tasks manageable in the classroom, teachers tend to closely direct the activity of pupils.*

Through constraints of time and resources, teachers transfer their subject into ‘School Knowledge’ and pupils play the game of discovering what that is. Some pupils never quite understand the rules of the game and the relevance of the subject becomes lost to them; others pick up incidental aspects because teachers have either not made clear what is salient or their classroom culture produces effects at odds with their rhetoric.

### **The Experienced Curriculum**

- *Requiring the study of the physical sciences and of technology does not lead to general satisfaction with the subjects and a desire to study it further.*
- *The way that pupils engage in problem solving in technology and in science depends on the view of designing and of investigating held by the teacher.*
- *Technology teachers have much to teach science teachers on the handling of processes and the science teachers much to teach technology teachers about the problems associated with acquiring conceptual knowledge.*

Our overwhelming conclusion, however, would be that science classrooms and particularly technology classrooms are under-researched. As new equipment such as ICT produces yet more pedagogic challenge and new professional development strategies focusing on its functionality attempted, very little is found out about their impact on the curriculum experienced by pupils. Despite considerable classroom-based work over the years 1984-2004 we feel we have merely scratched the surface.



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