Creating Change? A Review of the Impact of Design and Technology in Schools in England

Valerie Wilson and Marlene Harris

Introduction and Background

The role of Design and Technology in schools in England is changing. These changes were heralded by the Government Green Paper *14–19: Extending Opportunities, Raising Standards* (Department for Education and Skills [DfES], 2002), which proposed that education and training of 14–19-year-olds should be delivered by a more flexible curriculum with a broad range of options. Beginning in September 2002, Design and Technology (D&T) is no longer a compulsory school subject from age 14: the age which marks the end of Key Stage 3 in the broadly-based National Curriculum in England. Students will have a statutory entitlement to opt to study D&T subjects, but also more freedom within what was recognized as a very crowded curriculum to select other subjects of their choice. It is anticipated that these changes will impact considerably on D&T provision in schools. But what exactly is D&T? How has it been taught in elementary and secondary schools to date and what impact has it had on pupils? These are some of the questions that researchers from the Scottish Council for Research in Education (SCRE Centre) addressed in a literature review commissioned by the Department for Education and Skills (DfES) in England. This article is based upon that review (Harris & Wilson, 2003). In the following sections, we present the research evidence mainly from the UK regarding the origins of the concept of D&T, its unique educational components, and the impact it has had on the curriculum in England. These findings are summarized at the end of each section.

The main aim of the review was to search for evidence of the impact of Design and Technology (D&T) on schools in England. Literature was identified that highlighted issues relating to:

- The concept of D&T
- The effect of including D&T as part of the National Curriculum in English schools
- Gaps in the research evidence.

Valerie Wilson (valerie.wilson@scre.ac.ukis) is Director, SCRE Centre, Glasgow University and Marlene Harris is a Chartered Psychologist, Edinburgh H C I Co Ltd, Software Consultants, Scotland.

Key words applicable to this review process were used to search literature from four educational databases: the British Educational Research Index (BEI) for research published in British educational journals; Educational Resources Information Center (ERIC) encompasses international literature, as does PsychInfo, which concentrates on articles published in psychology journals; and Current Educational Research in the UK (CERUK) for recent studies in the UK. The number of references found is displayed in Table 1.

As in previous SCRE reviews (e.g., Harlen & Malcolm, 1999), we utilized the concept of "best evidence synthesis," which Slavin (1990) applied to reviewing educational research. It requires the reviewer to identify criteria for determining good quality research and to place more emphasis on those studies that match the criteria than those which have identifiable shortcomings. Four criteria for inclusion of studies in our review were established:

- Papers published during the past twelve years.
- Studies relating to primary and secondary mainstream schooling.
- Papers published in peer-reviewed journals and government policy documents. Where these were not sufficient, relevant conference papers may have been included.
- Studies of well-designed experimental interventions in D&T education.

The first three criteria were used in this study. However, unfortunately it proved impossible to adhere strictly to the fourth because of the dearth of published evaluations of well-designed experimental interventions in D&T.

Origin and Concept of Design and Technology

"Design and technology" was introduced into the National Curriculum in England and Wales as a distinct academic subject in 1990 (under the *Technology in the National Curriculum* Statutory Order, DES and We1sh Office, 1990). Some suggest that this was a response to government recognition of the importance of technology to the British economy (Layton, 1995). However, most agree that little research evidence existed before the introduction of D&T into the curriculum on which to base decisions (Department of Education and Science/Welsh Office [DES/WO],1988, Section 1.15; Kimbell, Stables, & Green, 1996; Penfold, 1988; Shield, 1996). Nevertheless, its associated distinctive model of teaching and learning had been evolving over a few decades (Kimbell et al.; Kimbell & Perry, 2001; Penfold). It is claimed that England and Wales were the first countries in the world to make technology education compulsory for all children between the ages of 5 and 16 (Education Act, DES/WO, 1988; Kimbell & Perry). This has been described as a pivotal moment in history. However, since its introduction, it is clear that a range of meanings and usages of the term D&T have developed. In her letter to the Secretary of State accompanying the Interim Report, the chairman of the National Curriculum D&T Working Group (DES/W/O, 1988), Lady Parkes, explained that:

> Our *[the Working Group's]* aim has been to develop an approach to design and technology which will enable pupils to achieve competence by engaging in a broad range of activities which are currently undertaken in a number of different school subjects. (Letter accompanying Working Group)

It is, therefore, not surprising that D&T has come to be acknowledged as a multidisciplinary subject with potential for cross-curricular activity. The Programmes of Study (PoS), which describe what will be taught in each curricular subject, stated that pupils in D&T should be given opportunities to: "apply skills, knowledge and understanding from the Programmes of Study of other subjects, where appropriate, including art, mathematics and science" (DfE/WO, 1995, p. 6). But this assumes that conceptual knowledge learned in one area of curriculum can be applied to another area, and that it is the same knowledge. Yet in 1995, as Levinson, Murphy, and McCormick (1997) note, there were no cross-references with the science curriculum. However, more recent PoS, including the current National Curriculum, link D&T with a range of other subjects including science, mathematics, art & design, and ICT. Others (Kimbell & Perry, 2001) suggest that D&T is deliberately interdisciplinary: "It is a creative, restive, itinerant, non-discipline" (p.19). The Working Group (DES/WO, 1988) also stressed that the new subject should encompass more than just technology:

> Our use of design and technology as a unitary concept … is intended to emphasize the intimate connection between the two activities as well as to imply a concept which is broader than either design or technology individually and the whole of which we believe is educationally important. (DES/WO 1988, para. 1.6)

From the documentation it is clear that one of the central features of D&T is its focus on designing and making activities, and developing technological capability for all pupils. Curriculum guidelines stress that:

- Pupils are able to use existing artefacts and systems effectively.
- Pupils are able to make critical appraisals of the personal, social, economic, and environmental implications of artefacts and systems.
- Pupils are able to improve and extend the uses of existing artefacts and systems.
- Pupils are able to design, make, and appraise new artefacts and systems.
- Pupils are able to diagnose and rectify faults in artefacts and systems. (DES/WO, 1988, paras. 1.42-1.43)

Table 1
Search Strategy

		No. of References Identified			
No.	**Searched Phrase or Term**	**British Educ Index**	**ERIC**	***Psych-Info***	**CERUK**
1	"technology education"	909	1092	22	8
2	Design (and OR &) technology	388	3	13	6
3	1 OR 2	654	1094	34	12
4	3 AND (age* OR stage*)	32	84	6	<12
5	3 AND ("national curriculum")	139	26	2	<12
6	3 AND (gender OR sex)	24	61	10	<12
7	3 AND (disab* OR (special WITH needs))	12	29	3	<12
8	3 AND (ethnic* OR race OR racial)	2	13	0	<12
9	3 AND ((social (inclusion OR exclusion)) OR (economic* disadvantage*) OR poverty)	0	5	0	<12
10	3 AND (attainment OR achievement OR outcome* OR result* OR examination*)	31	194	16	<12
11	3 AND (literacy OR numeracy OR ((key OR core) skills) OR "cognitive development")	19	166	2	<12
12	3 AND (truan* OR attend* OR motivat*)	4	52	8	<12
13	3 AND ((cross OR across) WITH curricul*)	11	8	0	<12
14	3 AND (employ* OR work OR business OR industry* OR vocation* OR profession*)	92	376	12	<12
15	3 AND ((out WITH of WITH school) OR (extra WITH curricular))	1	9	0	<12
16	3 AND ((teach* (method* OR approach*)) OR (curriculum WITH delivery) OR pedagog*)	25	121	8	<12
17	3 AND ("continuing professional development" OR "CPD"	13	35	0	<12

Table 1 (continued)

18	3 AND ((new WITH technolog*) OR “CAD” OR “CAM” OR “ICT” OR electronics)	32	117	0	<12
19	3 AND (resource* OR fund* OR financ* OR econom*)	20	241	7	<12
20	3 AND (able OR gifted)	2	7	0	<12

Note: CAD = Computer-aided Design
CAM = Computer-aided modeling
ICT = Information and Communications Technology

Doherty, Huxtable, and Murray (1991) identified three main concepts at the heart of D&T:

- What resources are required for the activity (i.e., human, physical, financial. or technical)?
- How is a D&T activity handled (e.g., processes, techniques and methods employed)?
- How/why are people linked to processes/resources?

They concluded that “capability” can only be achieved when an inter-relationship occurs between these three concepts and that this delineates ability from capability: “If the separate elements are fostered, ability is developed, however where the concepts are developed in an inter-relational way, then capability is achieved” (Doherty et al., 1991, p.72).

More recent descriptions of capability have embellished and reiterated sentiments set down in the Working Group’s original report. For instance, Kimbell (1997) described capability as “that combination of skills, knowledge and motivation that transcends understanding and enables pupils creatively to intervene in the world and ‘improve’ it” (p. 12). He says that capability provides pupils with a bridge between what is and what might be. Thus pupils are expected to develop the capacity to identify things which need improving or creating in the world, and in response, design and make something that will bring about the desired improvement (Kimbell, 1997; Kimbell et al., 1996). Moreover, the capacity for design should involve the use of cognitive modeling (Layton, 1995; Roberts, 1994). This inter-relationship between modeling ideas in the mind and modeling ideas in reality, described as “thought in action” (Kimbell, Stables, Wheeler, Wosniak, & Kelly, 1991) is seen as fundamental to capability in D&T.

In addition, advocates describe a societal dimension to D&T, one that “entails critical reflection upon and appraisal of the social and economic results of design and technological activities beyond the school” (DES/WO, 1988, para. 1.14). D&T is thought to require a breadth of understanding and social concern and a depth of knowledge and skill, together with a capability to identify shortcomings and take creative action to improve the made world (Kimbell & Perry, 2001).

Kimbell and Perry (2001) note that D&T is about "creating change in the made world; about understanding the processes of change and becoming capable in the exercise of change-making" (p. 3). An explanatory leaflet issued by The Design and Technology Association (DATA) stated that learning in D&T:

> . . . helps to prepare young people for living and working in a technological world. Children learn the technical understanding, design methods and making skills needed to produce practical solutions to real problems. (DATA & DfEE, 1996; see Barlex and Pitt, 2000)

Others (Barlex & Pitt, 2000) argue that "the art of designing" is intrinsic to the concept of technological activity. The Working Group (DES/WO, 1988) cautioned against using the term "design process" (para. 1.27), and cited warnings outlined in an earlier report from the Assessment of Performance Unit/Department for Education and Science against any linear, rule-bound view of what the activity of designing entails.

Finally, although other subjects could be said to involve "process," uniquely within technology education the process is said to define the discipline (DES/WO, 1988; Kimbell, 1997). The contexts in which the "process" is associated are "our made world; our clothes, our food, our means of travel, our shelters, our communication systems" (Kimbell & Perry, 2001, p. 3).

Summary

In sum, D&T:

- Is a deliberately interdisciplinary subject.
- Combines both "design" and "technology" but is broader than both.
- Encourages pupils to develop the capacity and value judgments to operate effectively and creatively in the made world.
- Focuses on designing and making activities, and developing technological capability for all pupils.
- Involves the use of cognitive modeling.
- Combines knowledge and motivation to enable pupils to intervene creatively in the world to improve it.

What are the Unique Educational Components of D&T?

Unsurprisingly, some of the factors which researchers claim make D&T unique are the same as those which relate to the different meanings and usages of the concept of D&T. Paechter (1993) points out that the sudden elevation of what had been a practical subject area for less academic pupils to the core curriculum was unique, especially for secondary schools. In addition, Hendley and Lyle (1995) identified the process-based nature of D&T's curriculum as its most unusual feature. Kimbell (1997) has described this change in pupils' learning as: ". . . a move from receiving 'hand-me-down' outcomes and truths to one in which we generate our own truths. The pupil is transformed from passive recipient into active participant. Not so much studying technology as *being* a technologist" (p. 47).

One of the questions addressed by the Working Group in 1988 was: What is it that pupils can learn from D&T activities which can be learned in no other way? Their reply was:

> . . . in its most general form, the answer to this question is in terms of capability to operate effectively and creatively in the made world. The goal is increased 'competence in the indeterminate zones of practice.' (Interim Report, D&T Working Group, DES/WO, 1988, p. 3)

This unique purpose of D&T remains a distinctive feature after a decade of teaching the subject in English schools (Barlex & Pitt, 2000). In addition, part of the original intention was that D&T education would be less about "knowing that" than about "knowing how;" less "propositional knowledge" but rather "action knowledge;" not so much "man the understander" (*homo sapiens*) but rather "man the maker" (*homo faber*) (DFE/WO, 1988).

Davies (2000) suggested that what first distinguished D&T from other subjects was its framework of assessment (Attainment Targets) which were "process" rather than "content" based. Although the development of this proactive, process-centered view of D&T has been seen in other areas of the curriculum (e.g., process science and process mathematics), uniquely in D&T the process defines the discipline (Kimbell et al., 1996). D&T is about creating change in the made world, about understanding these processes and developing a capacity for bringing about changes; uniquely, D&T empowers us to change the made world (Kimbell & Perry, 2001).

The model devised by the Working Group was significantly different from what had previously been taught in schools in England and Wales, incorporating aspects from craft, design, and technology, home economics, business studies, art, and information technology into a design-focused, student-centered subject (Paechter, 1993). The Working Group distinguished D&T from other subjects such as science, stressing that the special qualities about D&T are that it is:

> . . . always purposeful, i.e. developed in response to perceived needs or opportunities, as opposed to being undertaken for its own sake), takes place within a context of specific constraints (e.g., deadlines, cash limits, ergonomic and environmental requirements as opposed to unconstrained, blue-sky research) and depends upon value judgments at almost every stage. (Interim Report, D&T Working Group, DES/WO, 1988, p. 4)

Similarly, what makes the educational experience of D&T different from science is the type of cognitive processes involved. The Working Group (DES/WO, 1988) emphasized that D&T is more about "what might be" than "what is," i.e., the conception and realization of the form of things unknown. They characterized this as a visionary activity. Drawings, diagrams, plans, models, prototypes, and computer representations are all employed in developing the imagined artefact, system or environment. It is this special type of creative thinking that is associated with designers and technologists and is different from and complementary to verbal modes of thinking (DFE/WO, 1988). In sum, the particular creative aspects unique to design activity in a technological context are that the person has to imagine a concrete object which does not yet exist, and has to determine spatial and temporal details which cannot yet be observed, but will have to be created by the designing and manufacturing process (Ropohl, 1997).

Kimbell et al. (1996) argued that the unique concrete language employed in D&T, such as graphics and models, strengthens its importance educationally as it facilitates pupils' cognitive development. Through this language pupils are empowered to identify failings in the "made world" and to do something to improve things. They suggest that such a capability encourages independence and resourcefulness; it also combines practical, intellectual, and emotional challenge in a way that is quite unique within the curriculum (Kimbell, 1997; Kimbell et al., 1996). However, others believe that insufficient attention was given to the potential for overlap between subjects, and thinking in the late 1990s was that the National Curriculum should be efficient, with little duplication between subjects (Barlex 2002; Barlex & Pitt, 2000).

Kimbell and Perry (2001) have gone on to argue that D&T has a distinctive pedagogy: its model of teaching and learning not only draws upon different learning styles than other National Curriculum subjects, but also employs a richer range of learning styles. D&T aims to develop capability in which the pupil is an active participant. The distinctive model of teaching and learning:

- is project based
- takes a task from inception to completion within the constraints of time, cost, and resources.

Students have to learn how to:

- deconstruct the complexity of tasks and the values inherent in the concept of improvement
- be creative, conceiving ideas and planning that which does not yet exist
- model their concepts of the future
- make informed judgments
- manage both complexity and uncertainty in their projects
- deal with multi-dimensional and value-laden tasks.

This inter-relationship between conceptual knowledge and procedural knowledge was highlighted by others (McCormick, Murphy, & Hennessy, 1994; SEAC, 1991). Levinson et al. (1997) charted the changes from the early 1990s when there was a greater emphasis on (conceptual) knowledge in D&T. Smithers and Robinson (1992) argued that suggestions by the UK Engineering Council that design and technology students should adopt a mix of problem solving and knowledge and skills had been influential. They also pointed out that the Council believed that electronic solutions could not be applied until students had learned about electronics. Prior to the Revised Order of 1995, the preferred method within D&T was to pass on appropriate knowledge as and when needed (McCormick & Murphy, 1994). The emphasis now is on knowledge likely to be useful to developing particular solutions (through focused practical tasks and investigation, disassembly, and evaluation activities) before pupils tackle a designing and making assignment (Barlex, personal communication, 2003). Although others (e.g., Kimbell & Perry, 2001) point out that the issue now has shifted from "passing on knowledge" to pupils "learning how to learn."

Many point to the importance of co-operative learning. Some (Hendley & Lyle, 1995; Hennessy & Murphy, 1999) identified D&T as a rich environment for cooperative learning in which a range of designing skills can be developed (Koutsides, 2001). And Hennessy and Murphy argue that D&T is a unique subject for involving procedural problem solving activity where cooperative learning between peers relates to physical manipulation and feedback, and in which concrete models and graphical representations play an important mediating role.

Summary

Advocates suggest that Design and Technology is:

- a process-based subject
- based upon "knowing how" rather than "knowing that"
- empowering
- a visionary activity
- purposeful.

In addition, Design and Technology:

- Draws on a richer range of learning styles than other curriculum subjects, mainly through project-based learning.
- Requires students to be creative but reflective problem solvers, either individually or in teams.

What Has Been the Impact of Design and Technology?

Despite this innovative vision for D &T, disappointingly, in many cases it has not been possible to identify the effects of introducing the subject into the school curriculum, either because research has not been undertaken or relevant data (e.g., statistics) are not available. School inspections (OfSTED) of D&T record less satisfaction with teaching at Key Stage 3 (age 14 years) during the early years of its introduction (DES, 1992, pp. 18-19). Partly this was due to the fact that at secondary school level (ages 11-18 years) the new D&T subject grew out of an amalgam of five separate disciplines:

- art and design

- business studies
- craft, design, and technology
- home economics
- information technology

Kimbell (1996) described three ways in which schools began to implement this change: one, a "status quo—single-subject approach" where delivery continued much as before, with each individual discipline making its contribution; two, "a federated approach," which necessitated active planning, liaison, and discussion between departments; and three, "an integrated approach," which accepted D&T as a new construct where the emphasis was more on a whole new technology team. However, over the past decade, revisions of D&T curriculum have resulted in more understanding of what can be achieved (Kimbell, 1999) and contributed to other areas (Davies, 2000). Advocates of D&T suggest that it impacts pupils in a number of ways:

Key Skills Development

Some suggest that key skills occur naturally in group-based working within D&T (Summer, 1998, in Barlex, 1998; Davies, L., 2000). D&T has added to the development of Key Skills (Davies). Key Skills provide a foundation for common areas of learning through the six areas of competence. Davies has outlined how D&T specifically contributes to these. With specific reference to Key Stage 3, she argues that D&T aids communication, and improves numeracy, information technology, working with others, improving performance, problem solving, and creativity. Furthermore, Davies stresses that if pupils are aware of the key skills they are learning in D&T, they will understand the wider contribution this subject is making to their education.

Cognitive Development

There is clear evidence that the different teaching methods and the range of pupil activities within D&T assignments provide opportunities for cognitive development. From a study, which included classroom observation, Twyford and Jarvinen (2000) concluded that much of pupils' knowledge of D&T was learned through social interactions. Pupils' capabilities were enhanced through their direct active socio-cultural interactions within a range of classroom settings involving different teaching methods. However, McCormick and Davidson (1996) have indicated that concentration on product outcomes may undermine the design process and problem-solving activity that teachers wish to foster. In this study, it was found that the desire to ensure successful product outcomes prevented students from failing to produce outcomes, reduced the risk involved in the process, and thus prevented students learning from failure.

Various researchers have claimed that D&T has the potential to be a rich environment for co-operative learning (Hendley & Lyle, 1995; Hennessy & Murphy, 1999). In addition, D&T is believed to be a unique subject for involving procedural problem solving activities where co-operative learning and talk between peers "relates to physical manipulation and feedback," and where "concrete models and graphical representations play an important mediating role" (Hennessy & Murphy). However, they go on to point out the crucial role played by the teacher in fostering this collaboration—a role which has been underplayed in research literature on collaboration. Positive collaborative experiences mentioned include, for instance, that (intellectually) matched pairs of pupils learn better than asymmetrical pairs.

Linton and Rutland (1998) found improvements among less able children. Not only did their behavior improve during D&T activities, but they seemed to excel in practical problem-solving tasks, while practicing and developing more academic skills, such as measurement, speaking, listening, etc.

In contrast to these positive examples, Elmer (2002) laments the peripheral status of meta-cognition in the D&T literature (e.g., Eggleston, 2000, but with notable exceptions, e.g., Lawler, 1997; Kimbell & Perry, 2001; and to some extent, Hennessy & McCormick, 1994). And Atkinson (2000) discovered that high order thinking, such as creativity, problem solving and analytical thinking, impact upon pupils' General Certificate of Secondary Education (GCSE) D&T performance. Results of a relatively small study of 27 pupils taking GCSE suggest that D&T is not capitalizing on its potential for pupil learning because of the need for high levels of performance at public examinations which fail to reward creativity (Atkinson, 1994). Atkinson (2000) found surprising evidence that such capabilities are not necessarily required and that being highly creative could be a hindrance in terms of examination grades.

Nevertheless, the D&T curriculum does actually provide *opportunities* for pupils to develop their high order thinking skills (e.g., creative thinking, critical thinking, analytical thinking) and problem-solving skills which they will need to participate in our technological society (Lewis, 1999; Atkinson, 2000).

Raising Standards of Achievement in Literacy and Numeracy

Some advocates of D&T believe that it has an impact on literacy and numeracy. However, OfSTED (2001a) reported that the teaching of literacy and numeracy through D&T is weaker than in most other subjects in primary schools. Nonetheless, there are some positive examples. The use of language across the curriculum is a requirement of the National Curriculum 2000, and D&T contributes to this aim by developing the ability of pupils to:

- use technical terms
- clarify specifications and plan manufacture
- evaluate both the product and process (Davies, L., 2000).

Moreover, the use of technical terms and concepts in D&T is essential for effective participation in the subject. These include:

- expression of ideas
- terms relating to materials and making processes
- descriptions
- the language of evaluation.

Nevertheless, there is some suggestion (Parkinson, 1999) based on classroom observations of 49 children aged 3–6 years and 28 teachers, that the use of technical vocabulary from an early age can be undesirable, and specialized terminology should be delayed until secondary school, where more technically able staff can use appropriate terms consistently within relevant contexts. Also Stables and Rogers (2001) found that boys' thinking and reflective skills can be enhanced by literacy interventions in D&T.

Direct research relating to the effects of D&T on numeracy was not evident. However, D&T has an obvious link with mathematics (Davies, L., 2000). For instance, during the planning, realization, and evaluation of processes and products in D&T, opportunities arise for the collection, sorting, representation, and analysis of data in lists, diagrams and graphs, estimation, measurement of lengths and angles, and for calculation for drawing to scale or for the effects of loads.

Key Stage Tests

There was some evidence showing how pupils perform in D&T on national tests. For instance, OfSTED Primary Subject Reports (2002a) show that although pupils' achievement in D&T generally is at least satisfactory in the great majority of schools and is rated "good" in one school out of four, it is unsatisfactory in one school out of six at Key Stage 2 (age 11). Similarly, pupils' achievement in Key Stages 1 (age 7) and 2 (age 11) continues to be better in "making" than in "designing," but their knowledge and understanding of the materials, components, and processes that they use continue to improve steadily.

General Certificate of Secondary Education (GCSE) (Age 16)

We found no research literature to show the impact of D&T on GCSE results in other subjects. However, greater numbers of pupils have been entered for D&T GCSE examinations over the past decade, with annual improvements in the proportions of pupils attaining grades A* (a starred A being the highest grade awarded) through C, and D&T is the fifth most common subject to be taken at GCSE. In common with other subjects, girls outperform boys in GCSE D&T examinations at grades A*–C. However, there was some criticism in the literature. For example, Atkinson (2000) found that examples of highly structured, inflexible models provided by teachers (in 8 schools studied) while enabling pupils to achieve success in examinations, limited the development of high order thinking skills.

General Certificate in Education Advanced Level (Age 18)

Again, we found no research literature on the effect of D&T on performance generally, but achievement in D&T is rising at a rate well above the average of all subjects (OfSTED, 2002b). Changes in post-16 participation levels and the broadening range of subjects both increase the number and range of students involved in D&T manufacturing courses (Perry, Davies, Booth, & Sage, 1998). Broadening the range of students has resulted in those who are more academically successful joining D&T manufacturing courses, thus adding to the demands on teachers versatility (Perry et al.).

Enhancing Attendance Patterns

There appeared to be no published research on the impact of D&T on truancy or attendance in the UK. Although official publications (e.g., DfES) compared unauthorized truancy rates to authorized ones by school characteristics, there were no tables showing unauthorized absences by subject. Similarly, there were no research papers directly exploring the possible effects of D&T on improving attendance rates. Two papers relating to D&T and motivation (Denton, 1993; Hine, 1997) suggest that group work within D&T may make a positive contribution to pupils' attitudes. Kimbell and Perry (2001) mentioned low truancy rates in D&T reported by OfSTED. However, OfSTED (2001b, para. 127) warned that a "vocationally-oriented curriculum was not a panacea" for coping with disaffected young people.

Cross-curricular Learning

There is sufficient evidence to confirm that cross-curricular learning is recognized as fundamental to D&T activity, especially in primary schools (Makiya & Rogers, 1992; Cross, 1998). However, the effects of cross-curricular learning are less clear. Current National Curriculum Requirements (Department for Education and Skills [DfEE/QCA], 1999) indicate areas of language which are to be used in all subject teaching. However, the national strategies for literacy and numeracy appear to have had mixed effects in primary schools as they have impinged on the time available for D&T activities. Nevertheless, despite the frequent mention of art work in D&T activities, Howe (1999) believes that the fundamental connection between "art and design" and "D&T" has not been fully recognized or exploited in primary schools.

Over the past decade, especially during the earlier stages of D&T inception, some thought that (design and) technology and science were almost indistinguishable (Gardner, 1994), especially at the primary level (Davies, D., 1997). Yet others consider science to be a resource for technology (Kimbell et al., 1996). Many science teachers have been opposed to the separate teaching of what they considered to be the "applied science" of D&T (Layton, 1993; Gardner, 1994; De Vries, 1996). The limited research relating to cross-curricular links between science and D&T has been somewhat equivocal. Levinson et al. (1997) pointed out that the National Curriculum for D&T assumed that technological conceptual knowledge and knowledge learned in subjects such as science could be used in D&T tasks. Yet, their pilot study of Key Stage 3 showed that pupils were not drawing on prior scientific knowledge for design purposes, and therefore, science knowledge developed in science lessons could not readily be used in technology lessons. This cast doubt on children's ability to transfer knowledge learned in one context to another. On the other hand, this may not be such a problem, as the more usual approach in D&T is to introduce knowledge as and when needed (McCormick & Murphy, 1994).

Summary

Despite the lack of studies charting the impact of D&T in the National Curriculum, some effects were identified. Researchers argue that D&T:

- demonstrates the potential to develop key skills
- provides opportunities for pupils to develop high order thinking and problem-solving skills
- improves pupils' technical vocabulary
- links with mathematics
- is associated with a rising rate of achievement well above the average of all school subjects
- may have a positive effect on truancy
- develops cross-curricular learning in primary schools.

Discussion

Key Findings

During the course of this review, we found:

- many published papers referring to the teaching of D&T in schools in England
- a consensus about the concept and aims of D&T
- few well-designed evaluations of the effects or impact of teaching D&T
- gaps in the research evidence regarding the most effective ways of teaching and learning D&T in schools, in particular the use of ICT, methods of assessment, individual and collaborative learning, and ways of strengthening designing.

Over a decade ago, D&T was introduced as a new subject in all primary and secondary schools in England. At that time, it was clearly thought to be an innovative concept that combined separate school subjects into a unified approach to teaching design and technology. Though the concept is now widely accepted, identifying the impact of D&T on pupils is difficult to determine. As reviewers we were impressed, and somewhat overwhelmed, by the number of references to D&T in the literature in the English language. However, many references were produced by the community of practice, and few were research-based or peer-reviewed. Our criteria for inclusion excluded much action research and also curriculum development undertaken by the "user" community. Therefore, the fact that we found little peer-reviewed research in D&T is no reflection on the activities being undertaken by practitioners in schools and colleges. It is more likely related to the amount of research commissioned and/or the interest of professional researchers in this topic area.

Gaps in existing research emerged. Some have argued (Kimbell, 1996; Atkinson, 2000) that the inflexible assessment methods used to judge pupils' D&T project work have dictated the processes used by those pupils. Atkinson would like to see teachers offered more encouragement in the documentation which accompanies the National Curriculum to adopt strategies which are less formulaic and ones in which the thinking associated with design is not outweighed by the stages in the design process. More research into the area of effective learning and teaching of D&T is clearly required.

In addition, more research is required on the role of ICT. Weaknesses in designing activity led OfSTED (2002b) to suggest that more work needs to be done to discover the most effective ways of teaching pupils to use computer software to help them in solving design tasks. Suitable curriculum materials need to be developed that foster creative responses from pupils using these new designing and manufacturing resources. These findings highlight the need for further research into the impact of assessment on design and the use of ICT. In addition, research is needed to explore how design might more effectively be encouraged within D&T.

The UK Design and Technology Association (DATA) is aware of the inadequate advice and resources available for teaching CAD/CAM in schools and has introduced a design awareness competition that it hopes will help to stimulate debate. Similarly, DATA is currently conducting research on the influence of CAD/CAM on teaching and learning. Further research in this area is needed, especially as there are considerable economic issues involved in the effective use of ICT.

Hennessy and Murphy (1999) have been critical of D&T research and call for more classroom-based research to explore the role of collaboration in facilitating technological problem solving rather than the teacher-led problem solving which they claim is typical. The finding that intellectually matched pairs of pupils learn better than asymmetrically matched pairs (Hennessy & Murphy) needs further exploration as this has important implications for group work in mixed ability classes. Observations that some children are inhibited from showing what they know or from developing their skills when in the presence of more able children, yet are more encouraged by working with children whom they can help, point to the need for further investigation (Burgess, 1998).

Denton (1994) has also criticised D&T research, and has called for appropriate methodologies that recognize the difficulties in separating out the variables in live learning situations—a problem shared with other curricular subjects.

Anning (1994) has demonstrated that D&T in the elementary school provides a learning environment which highlights children's previously un-noted capabilities and deficiencies in areas such as graphicacy, evaluation processes, and the manipulation of tools. However, much more research is needed in order to substantiate these claims.

Shield (1996) considers that many of the problems associated with D&T were related to the fact that a complex curriculum was introduced via a topdown strategy, i.e., from the Department of Education to schools, and he believes that a deeper understanding of the professional issues is required. Essentially, he argues that having been told what the concept of D&T means by those introducing this new subject into the curriculum, teachers endeavored to make this a reality. In 1996 Shield was pressing for researchers to test the validity of claims that D&T in schools could enhance problem solving, craft skills, knowledge, aesthetic awareness, graphical and broader communication skills, social awareness and teamwork, scientific and technical literacy, industrial and economic understanding, environmental activism, and life skills and vocational training. Our overall conclusion is that despite the number of references to D&T in the published literature, the impact of Design and Technology has not been proven. This remains a challenge for the research community.

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