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ORIGINAL PAPER

Effective technology and design teaching: getting it right in the classroom

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Abstract Technology and design was added to the Northern Ireland curriculum in September 1992 and through it, teachers seek to address the need for pupils to understand the ever-changing man-made world by developing skills and understanding in its four elements of designing, communicating, manufacturing and the use of energy and control. To be effective in attaining these goals, it is important that teachers allow pupils to have a voice in their learning. They should do this by taking account of pupil responses to the tasks they issue and using those responses as a basis for making choices about instruction and support strategies. This is particularly important in technology and design as pupils need to interpret instructions in light of their design ideas. This paper outlines how three case studies of technology and design teaching were used to identify a range of teaching and learning strategies and evaluate them for their potential to create a learning dialogue with pupils. Drawing on aspects of the effective teaching debate, this learning dialogue was then applied to how teachers exploited pupil histories, managed a range of collaboration strategies and provided effective task orientation. The case studies were based on observations, interviews and content analysis of work over a complete design-and-make project in each school. The paper outlines three continua for effectiveness in each of the three areas observed. The first continuum shows that teachers need a more individualised view of building on pupil histories, the second outlines a range of strategies for the management of pupil collaboration in learning and the third suggests that pupils need to be orientated into complex tasks in ways that support a progressively increasing level of independence in their thinking.

Keywords Collaborative learning · D&T · Effective teaching and learning · Northern Ireland schools · Pupil-centred learning · Teacher instructions

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Introduction

This paper examines how teachers can create a learning dialogue with Key Stage Three technology and design pupils. Specifically, the paper focuses on how teachers can use pupils' existing knowledge to support learning; how they can manage collaboration and how they can orientate pupils into complex activities such as designing, communicating, manufacturing or using energy and control in the products they make. When teaching technology and design, teacher interactions should support pupils in finding their voice to convert hazy impressions of reality (Kimbell, Stables, Wheeler, Woziniak, & Kelly, 1991) into well developed products or systems. Teaching in this context requires, among other things, guidance and support that enables pupils to dialogue with each other and with their teacher; the building of pupils' confidence to approach tasks with a full understanding of their purpose and the enabling of pupils to use their previous experiences as valid starting points for design thinking. The paper examines these interactions in the context of the Northern Ireland subject of technology and design and draws on elements of the effective teaching debate (Hay McBer 2000; Harris, 1998; Kyriacou, 1985; Wilson & Harris, 2003) which focuses on *interdependent* approaches to teaching. Interdependence in this context is where teacher actions are essentially a response to emerging information from pupils on their thinking about the tasks they are engaged in.

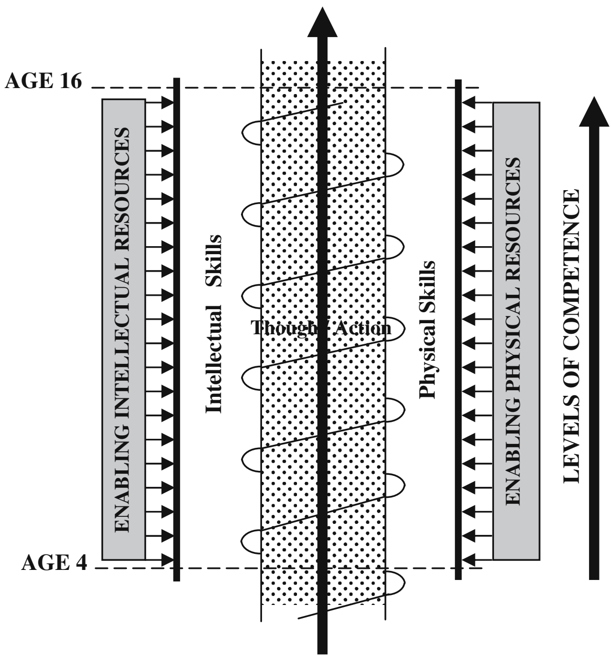
Technology and design: a brief overview

Technology and design in Northern Ireland, as in other parts of the UK, grew out of Craft Design and Technology (CDT). Prior to 1989, however, innovations that built on CDT were largely at the discretion of the school or were driven by visionary teachers. It was the legislative relationship between Northern Ireland and England from 1972 to 1998, direct rule, a consequence of political and civil unrest, which allowed the 1988 Education Reform Bill to herald the start of the Northern Ireland Curriculum. The Department of Education for Northern Ireland published its consultation paper, 'Education in Northern Ireland-Proposals for Reform' (Chitty, 2004, p. 51; DENI, 1988, p. 5) with the Task Group on Assessment and Testing (DES/WO, 1988) recommendations for Key Stages being implemented by Northern Ireland Schools Examination Council (NISEC) (DENI, 1988, p. 14). Following the Education Reform Order (NI) 1989 (ERO), the Northern Ireland Curriculum Council (NICC) set up Ministerial Working Groups for each subject that was to make up the curriculum. They developed draft programmes of study, which, after consultation, were implemented in a rolling programme. The Ministerial Technology and Design Working Group wanted to avoid the 'artefacts, products or systems' suggested for England and Wales in the Parkes Report (DES/WO, 1989). Instead, they took the view that technology and design should have a narrower focus on the design and manufacture of 3-dimensional products from the resistant materials of wood, metal and rigid plastic, with a strong emphasis on the use of energy and control. Its consultation document (NICC, 1991) also included more academic content than CDT ever claimed. This factor was, many believe, influenced partly by negative attitudes to CDT in many grammar schools. (Incidentally, academic selection at the end of primary education still dominates education policy (Burns, 2002; DE, 2004) and is now under intense debate). The Ministerial Technology and Design Working Group presented a model of technology and design capability as a progressive and iterative process which draws on '*the laws and principles of science*'... and 'physical resources' consisting of '*materials components, tools machines and equipment*' (NICC, 1991, p. 5, Fig. 1), with the core aim; '*...to enable all pupils to become confident and responsible in solving real life problems, striving for creative solutions, independent learning, product excellence and social consciousness*.' (NICC, 1991, p. 15).

Change was far from over, however. The Dearing review (Dearing, 1994) that led to slimmed down versions of all Northern Ireland subjects (DENI circular 1996/20) also prompted Michael Ancram, the Minister of State for Education at the time, to make other changes. At Key Stages One and Two, technology and design was subsumed into a new subject of 'science and technology', effectively removing it from the primary curriculum (Ancram, 1994; DENI circular 1996/32). Also removed was the requirement for all pupils to undertake Key Stage Four technology and design (DENI circular 1995/28). Shortly after Labour came to power in 1997 Tony Worthington, the Minister for Education, took the view that motivating lower achievers could be better supported through a greater proportion of practical work in technology and design and home economics (DENI circular 1999/18). The programme of study was changed for the second time in 3 years.

Although at the time of writing this paper, technology and design is mandatory only at Key Stage Three, its central aim has changed little. It has one attainment target, *technology and design capability* with four specified elements, '*designing*', '*communicating*', '*manufacturing*' and '*using energy and control*' (ibid., 3). Teachers are expected to iteratively and holistically develop these elements, building on established models of designing (Eggleston, 1976; Kimbell et al., 1991; NICC, 1991).

Fig. 1 Curriculum model of technology and design capability (NICC, 1991)



The ERO brought massive funding to build or refurbish approximately 300 post-primary technology and design suites, along with extensive in-service training in all four elements for teachers. The funding has embedded an infrastructure within which resources and support have enabled technology and design to grow and develop. Since then, initiatives such as CAD/CAM, have revolutionised the *communication* and *manufacturing* element and the Educational Technology (ET) strategy (DENI, 1998) has allowed departments to benefit from a massive influx of ICT hardware and software, resulting in a growth in computer modelling in the *energy and control* element, and, of course, the ubiquitous use of the internet in planning, preparing, conducting and evaluating teaching and learning. But what comment can we make about how to provide good technology and design experiences for pupils in the classroom? Can we say that the curricular changes have brought with them any consensus about how technology and design teaching should be understood? What are the implications for teachers as they plan and manage the life-enhancing experiences we know the subject should offer? Teachers face constantly changing and often conflicting demands, yet are required to convert them into effective technology and design learning activities. It is therefore important to evaluate the extent to which the developments have impacted in our understanding of teaching in the classroom. In particular, how teachers facilitate pupils in taking part in their own learning and how classroom interactions actually provide authentic learning experiences. When discussing curricular implementation Goodson (1994) and Helsby and McCollough (1997) question the role of teachers as agents of reform and argue that what is seen in the classroom may not be what is intended at political level. Similarly, the growing body of research in technology education has provided a good overview of how teachers should approach the myriad of design-and-make tasks they need to involve pupils in. These include; how pupils acquire knowledge (McCormick, 1999); how they collaborate (Murphy & Hennessy, 2001); how teachers create and develop design activities (Doherty, Huxtable, Murray, & Gillett, 1994); how progressive and iterative designing should be conducted (Kimbell et al., 1991); how real-life contexts should support design activities (Hill, 1998) and how to promote design modelling (Garner, 1994). More generally, Harris (1998) challenges current notions of teacher effectiveness as a set of teacher behaviours and argues that effectiveness is a measure of the extent to which those behaviours are focused on and supportive of pupil learning (Bliss, Askew, & Macrea, 1996; Hay McBer, 2000; Harris, 1998; Kyriacou, 1985; Mc Nair, Dallat, & Clarke, 2000; Silcock, 1993; Wilson and Cameron, 1996). The Education and Training Inspectorate for Northern Ireland (ETI) surveyed technology and design between 1999 and 2000 and their report (DE, 2000), while generally positive and praising in its analysis of how the reforms had been implemented, made two observations about teaching and learning:

> *...in year 8* [the first year of secondary education in Northern Ireland]*almost all of the pupils enjoyed technology and design but by year 10 only a small majority of the pupils were enthusiastic about the subject.... Of the 5,467 pupils taking the subject at GCSE in 1999, 83% were boys and 17 % were girls*. (DE, 2000, p. 27)

ETI further showed that this situation is likely to have its origins in teaching. They observed a total of 379 lessons and rated 17% as having significant strengths; 41% as having more strengths than weaknesses; 29% as having more weaknesses than strengths and 12% as having significant weaknesses (ibid., 30). The major factor in assessing these lessons related to how the teachers organised their activities and how they facilitated pupil learning within the tasks they assigned. While encouraging, it is clear that teachers still need support in analysing and improving their teaching. A possible explanation for ETI's findings may be that teachers' natural concerns about accountability, management and assessment may constrain their freedom to allow more pupil autonomy in their activities. Research has also shown that teaching can be influenced by factors such as prioritising management and accountability (McCormick, Murphy, & Hennessy, 1994); teacher beliefs and histories (McCormick, 1990, p. 41); teachers' pedagogic knowledge (Banks et al., 1999, p. 94); problems of curricular choice and coverage (Anning et al., 1996, p. 6) and classroom and school administration expectations (Banks et al., 1999, p. 90). Similarly, notions of quality when referring to pupil work are important but these can be reduced to modes of presentation and a focus on outcomes such as neat and well presented drawings and well manufactured products, a result of pupils '*mechanically following the* [teacher's]*prescribed procedures*...' (Hennessy, Mc Cormick, & Murphy, 1993, p. 3). Simultaneously, the emerging effective teaching debate with its increasing focus on how teachers should support pupils and their learning is turning attention away from teacher actions to pupil learning (Harris, 1998). Watkins and Mortimore (1999, p. 8), writing in a non subject-specific context, describe effectiveness as engagement in a highly interactive process that '*offers an increasingly integrated conceptualisation*...[of teaching and learning]' where '*teachers who actively accept the complexity of the classroom orchestrate events in their classes more successfully that those who do not*'. This complexity is viewed as a constantly interdependent relationship where pupils' responses to teachers' instructions dictate, in turn, teachers' subsequent actions. The agenda in the classroom therefore shifts from teacher actions to pupil reactions and how support is offered to assist pupils in terms of their responses to instructions. Hallam and Ireson (1999, p. 79) illustrate the highly interactive nature

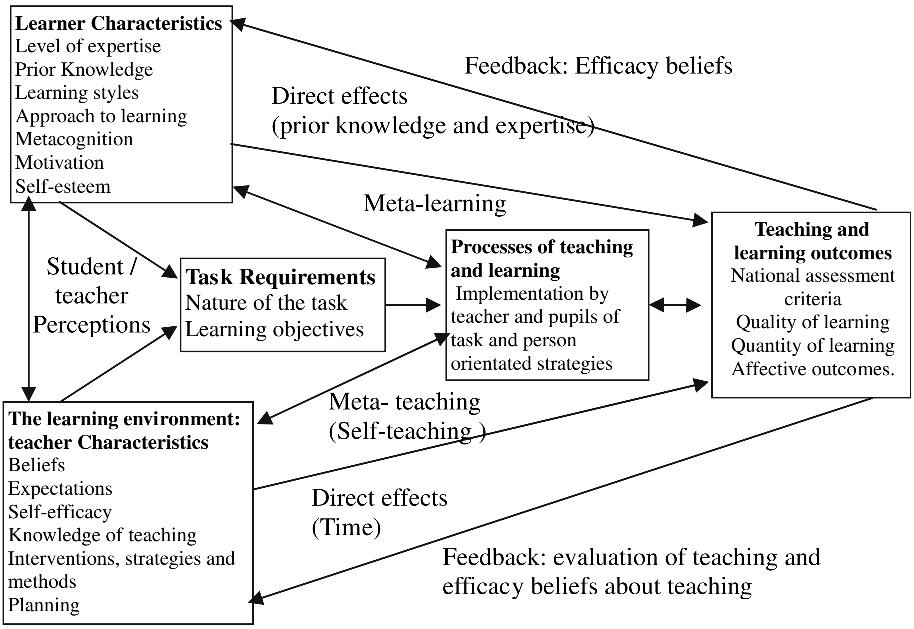


Fig. 2 A model of teaching and learning (Hallam and Ireson, 1999, p. 79)

of teaching in their model of teaching and learning (Fig. 2). It illustrates the reciprocity of teaching in a way that previous 'process' models of teaching seem to miss (Harris, 1998; Hay McBer, 2000; Kyriacou, 1985), and provides a basis for understanding how a learning dialogue might work. For example, they illustrate effective teaching as a complex cycle of action and reaction by the teacher, based on a clear understanding of where pupils are starting from in their learning (the left side of the model). All aspects of teaching inform and are informed by the interplay between teacher, learner, teaching actions and learning outcomes. Effective teaching therefore depends on how the teacher facilitates such interplay and how learning tasks are ordered to ensure that the needs and predispositions of the pupils are voiced, explored and fed back into the learning activities.

We have taken the view that the model can be interpreted as a long-term analysis of teaching (over say, a design-and-make project or a school year) or as an approach to understanding the dynamics of an individual lesson. Based on the former, the model is particularly appropriate to the integration of the four elements of technology and design in that the outcomes of task requirements such as a design activity can be used to initiate activities in communication, manufacturing or the use of energy and control. Similarly, as a description of how teaching should support learning, the model facilitates movement from traditional teacher-dominated learning activities, to a situation where pupils' voices are used to inform and support teacher actions that allow pupils to keep a watch on how their learning is developing (shown by the upper arrows). Teachers can read and act on the emerging information from pupils as they engage in activities and therefore, give pupil voices a central role in learning. In short, its interactivity is a description of a learning dialogue. This model is generic and therefore requires careful interpretation in a technology and design context. For example, effective planning might provide an efficient framework for starting, developing, applying and concluding lesson content (Owen-Jackson, 2000) but still miss the essential role of other stages in designing usually conducted in a long-term programme of work (McCormick & Davidson, 1996). Teachers might create, for example, isolated design activities (Doherty et al., 1994) rather than the progressive and iterative activities characteristic of designing (Kimbell et al., 1991), even though those activities themselves are well managed and produce outcomes that are visually attractive, well written and understood. Similarly, in non-design situations where pupils learn about content or processes, teachers might display very well delivered task instructions and management strategies yet leave pupils with limited understanding. Such teaching impedes the development of capabilities such as problem solving (Hennessy et al., 1993); design thinking (McCormick & Davidson, 1996); examining real-life contexts (Hill, 1998); and modelling (Garner, 1994). In spite of these misgivings, Hallam and Ireson (ibid.) provide a basis on which to make an analysis of teaching and learning in technology and design. In summary, therefore, the starting point for effective technology and design teaching is, we believe, the establishment of a teacher–pupil *learning dialogue*. Such a dialogue is characteristic of the *dialectical relationship* promoted by Vadeboncoeur (1997, p. 30). In this relationship meanings are not dictated but jointly agreed and there are joint teacher–pupil decision-making processes about what has been learned (Rogoff, 1999). Pupils are introduced to and supported in each task in ways that assist their understanding of its purpose (Hallam & Ireson, 1999, p. 78) and activities take account of their skills, experiences and preferences and therefore assist them to learn. Tasks are relevant to their world and are presented to them in ways that they can apply to the world beyond the classroom. In short, a dialectical relationship is one where there is a constant move away from teacher-dependant learning to independent pupil learning (Roth, 1999, p. 13). Drawing on all these elements we make some observations about how teachers in the study provided learning experiences and supported interdependence in their teaching. Our analysis seeks to penetrate the ambiguity that may characterise technology and design, where pupils can produce artefacts and drawings without developing technology and design capability. The study is intended to provide an insight into the reality of the classroom that teachers might find informative when addressing the issues raised above and may provide a model for evaluation of their own practice as well as a platform for analysing their effectiveness.

The study

A case study method was adopted for its suitability as a naturalistic approach that allowed for a systematic description of the reality of the classroom. It was important to understand that reality, rather than what teachers or pupils *said* about the reality (Cohen & Manion, 1994; Dey, 1993; Schofield, 1993; Stake, 1995). This approach also allowed close scrutiny of the teacher–pupil and pupil–pupil interactions that took place over an entire project so that we could obtain a holistic view of what elements made up effectiveness. We selected three schools based on the teachers' levels of experience, their willingness to be involved in the study and the classes they could offer for investigation. All three teachers had been Heads of Department for at least 5 years and each had been involved in teacher support roles outside the school. The schools were, respectively, a co-educational grammar school (School A), a girls maintained (mainly Catholic) school (School B), and a co-educational controlled (mainly Protestant) school (School C). In each school, pupils were nearing the end of Key Stage Three (Year 10, aged 13–14 years) and their design-and-make project used electronics as the energy and control element of the programme of study. The studies were therefore homogeneous in that we compared similar activities at similar stages across the schools (Stake, 1995), but also heterogeneous in that they reflected the academic and religious division that still exists in schooling in Northern Ireland. Taken together, the cases reflected a range of socio-economic, cultural and geographical contexts. They included observation of 76 designing, communicating, manufacturing and electronics tasks, spanning a total of 2,047 min over 32 lessons. Projects included a simple electronic timer, a latching alarm circuit and a moisture sensor, each being housed in a wooden, metal or rigid polystyrene manufactured case. We observed all stages of each project using a video camera to record the lesson for subsequent transcription and analysis. Each teacher was interviewed at the start and mid-point of each project to add depth to the observations and to allow us to probe emerging issues (Cohen & Manion, 1994); to clarify and add meaning to observations (Marshall & Rossman, 1994); to gain insights into the lives of the participants (Silverman, 1993) and follow-up questions if needed (Bassey, 1999; Denscombe, 1998; Strauss & Corbin, 1998). Pupil interviews provided supporting and explanatory material for our observations and these were organised in conjunction with the teacher to represent the range of ability and motivation present in the class, (and in the co-educational schools, the gender divide). All interviews were conducted with groups of pupils (usually four) to avoid pupil anxiety that might result from one-to-one interviews (with a stranger). Finally, samples of pupils' design, written and practical work were examined to see if possible alternative interpretations of observations could be ruled out (Bassy, 1999; Yin, 1994). Once data had been gathered, codes were developed that allowed us to conceptualise and classify events and progressively establish patterns, verify, refine and redirect our initial thoughts, and in some cases, refute early conceptions. Coding was undertaken with the help N-Vivo (Frazer, 1999), which facilitated indexing, searching and theorising from video and interview data. From the codes, relationships between data sets were established to develop a structured understanding of what the data were saying. We have distilled these into three simple questions. How should teachers build on pupil histories and experiences? How should they best manage collaboration when learning? How should they orientate pupils into tasks in ways that support effective learning? These questions, we argue, make up the key elements of a learning dialogue.

Our observations

In general, each of the three teachers cited conformity to the programme of study (DENI, 1992, 1996, 1999) as their main planning criterion, with a second factor being concern about management, typically expressed as control of pace and sequence in designing so that pupils could '*get a notion of how this rolls along to the completed project*' (Teacher A); or experience '*continuity in the design process*' (Teacher B), so that they will have a well completed project '*that they can be proud of*' (Teacher C). As all three projects were nearing the end of Key Stage Three, teachers considered pupils' previous experiences in making decisions about content. For Teachers A and B previous experiences related to their 'coverage' of the programme of study, '[a planning] *overview ... found that for example metal wasn't being addressed... we chose to develop a project in which the pupils would house the electronic circuit in a metal container*' (Teacher B). Teacher C hoped to build on previous electronic projects and knowledge. When observing the lessons, we were struck by the warm and friendly relationships teachers had established with their classes.

Building on pupil histories

Teachers used a range of starting points for activities, from simple reminders *that* pupils had undertaken similar activities (such as using specific electronic components, creating drawings and using certain tools); to extended opportunities to *review* previously learned skills in preparation for more complex tasks (such as constructing 3-dimensional drawings and modelling electronic circuits on prototyping boards). The range of strategies is illustrated in Fig. 5 below.

'*Reminding that*' pupils had previously completed work similar to their current activity consisted of teachers mentioning, listing or drawing previously used components or processes. For example, in an electronics activity pupil groups had to analyse in turn, the different behaviours of four pre-built circuits to determine their appropriateness as security devices (School B). In support of their investigation, pupils were given worksheets showing electronic components they had used, such as a transistor for use as an electronic switch, resistors and some unfamiliar components such as capacitors and thyristors. The teacher's instruction was, '*There will be a sheet with all the circuit symbols and the names. Use that sheet to identify the various components.'* When touring the groups, however, it became apparent to the teacher that supplementary instructions were needed in the form of questions, as pupils could not use the information to complete the task. The transcript shows how the teacher, when realising this, reviewed pupils' previous work:

Teacher B: You didn't do the plant [moisture sensing project]*last year did you?*
Pupil We did
Teacher B You did. Do you remember the plant? ... The moisture [sensor] switched on your transistor and the transistor switched on your LED and the reason we used a transistor is that it is very sensitive to switch on the LED. You put that into some form of words there at the bottom of the page.

The teacher's re-application of previous information in the new context was an important step to understanding the current task although in this case, the reminder *that* pupils had used a transistor, while sufficient to complete the task, did not provide any useful information to them as a starting point for learning in the current situation.

'*Reminding about*' pupils' previous work included a complete review of the activity they were about to engage in. This was seen for example in School A where, as preparation for a 3-dimensional drawing activity, pupils were reminded about how to draw through a 10-min video, '*Now to help you with this, I'm going to show you a clip of a video*[on how to sketch] *which I showed you last year...*'. Following the viewing, pupils undertook 3-dimensional drawing tasks. Thus, the video reminded pupils about the details of previous skills used. The reminder undoubtedly assisted in reducing memory shortfall created by the time-lapse between current and previous work and was an important step in obtaining accurate representation of shape and form, as the illustration in Fig. 3 shows.

We take the view, however, that this detailed reminder alone cannot be more than a means of maintaining the *status quo* in 3-dimensional drawing. While we acknowledge that the teacher's intention may have been to maintain the levels of drawing competence, we saw this as an opportunity for pupils to review their previous attempts *and* to build on them by analysing their previous drawings, particularly at the end of the Key Stage, when pupils might have been expected to have acquired all the planned communication skills. We then looked for more detailed use of pupil histories.

'*Remind and review*' consisted of identifying previous work and allowing time to review and extend that work. For example, when, prior to building electronic circuits, Teachers A and C provided practice opportunities with prototyping boards (plug-in boards for positioning, modelling and testing electronic circuits). This activity had the effect of allowing pupils to re-establish their own knowledge by reviewing their understanding of how to use the boards, thus identifying their knowledge deficits and practising previously learned skills prior to commencing the new activity (Fig. 4).

The field note from our observation shows that the subsequent pupil activities were successful in that the teacher did not have to use supervision strategies for extensive remedial action as a result of pupil misunderstandings:

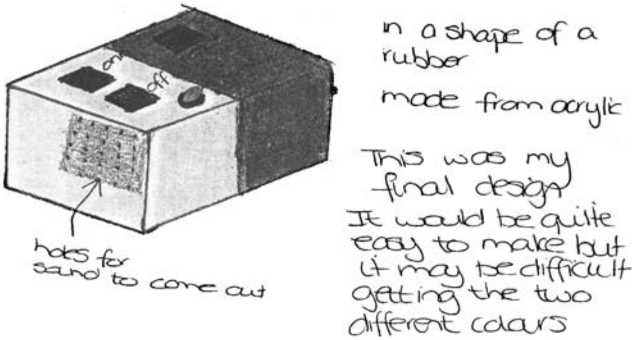


Fig. 3 An example of an accurately drawn 3-dimensional shape

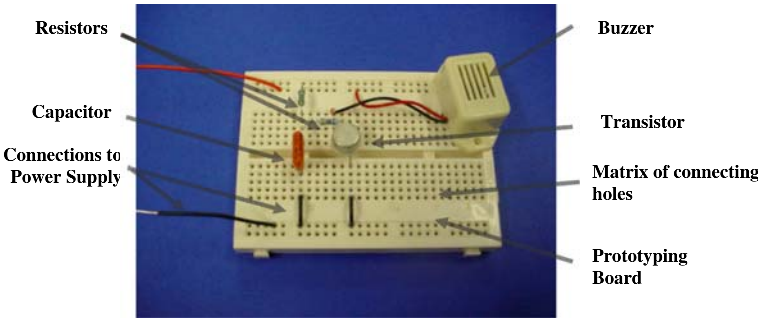


Fig. 4 A typical prototyping board layout for physically modelling circuit behaviour

> *This worked reasonably well* ...[it]*was a simple task with few components and little to remember second, there was the fact that the teacher had presented the information on the OHP and supported the work individually ... supervision was in support of successful completion of the task and not, as can happen in such cases, to react to a host of problems.*

Our findings have been augmented by two end-points on a continuum of effective practice observed (Fig. 5). At the left, illustrating ineffective practice (and not seen in the data) pupils are led into new tasks without any attempt to build on their prior experiences. At the right, illustrating what we believe would be best practice (again, not seen in the data), teachers review pupils' strengths and weaknesses either individually, in groups or on a whole class basis. The shaded area shows the data range.

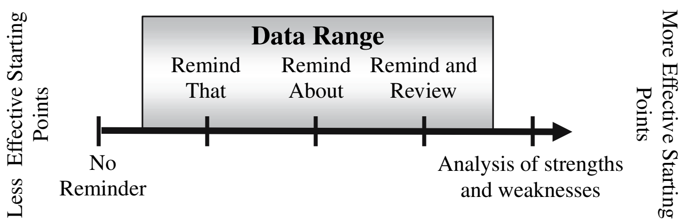


Fig. 5 A continuum of starting points for technology and design teaching

Analysis of strengths and weaknesses, particularly in the latter activities of Key Stage Three would involve pupils in analysing how they engaged in previous work. The last point on the continuum proposes that pupils are explicitly guided in making judgements about their work and identifying where their strengths and weaknesses lie, and how they can build on them. Teachers, of course, are likely to argue that such a strategy involves keeping previous work as a record and would involve additional management or that expecting pupils to keep and present previous work on demand for reference purposes would be unrealistic. Nevertheless, we suggest that this continuum provides teachers with a set of reference points that allow them to identify current practice and lead to more effective use of pupil histories and we will propose possible solutions in our discussion.

Effective collaboration management

Hennessy and Murphy (1999, p. 1) have established the learning benefits of pupil collaboration, which they defined as, '*talking and sharing cognitive resources to establish joint goals and referents, to make joint decisions* ....' Analysis of data from this area of teaching focused on how teachers managed collaboration and included *ad hoc* peer dialogue and *whole-class discussions*, each of which had elements of the above definition. *Ad hoc discussion*, which was a frequent occurrence in all three schools, was undoubtedly a product of the good relationships established over the 3 years. These discussions consisted of groups of pupils clarifying their understanding of instructions, finding materials and components and assessing their own pace. Discussions were supported by pupils sharing references to textbooks, comparing and contrasting the work of others, reading each other's work and requesting information from other groups. While these discussions were random and unpredictable, their widespread use was tacit acceptance by the teachers that they were an essential part of task completion. For example, in a textbook-based activity where pupils were expected to work individually to complete an summary of electronic components they would later use, success depended almost completely on the *ad hoc* discussion, as our field note from School C shows:

> *During this discussion it was noticeable that pupils needed the support of each other during the task and there was some discussion among pupils. It was unclear what this was but from their gestures and focus on the textbooks it was clear that they were discussing the task (as opposed to just chatting generally).*

While in the above instance discussion was essential and allowed pupils to complete the task, other discussions simply reinforced a limited understanding of the task. In the example quoted earlier (School B), ad hoc collaboration moved pupil understanding little beyond switching the circuit on and off without any real understanding of how a switch used a conductor to make an electrical connection (the aim of the activity):

Teacher B: *Well then tell me what*[this circuit]*does* [pupils begin to refer to books]*What do the sheets say?*

Pupil: *Set a conductor on the circuit.*

Teacher B: *You place a conductor: what happens when you place a conductor* [teacher does this on the circuit]—*What happens when you take the conductor away?* [teacher removes the conductor]

Pupil: It switches on and off.
Teacher B: So it's a very simple what?
Pupil: Conductor.
Teacher B: What happens when you press the conductor down, what did you see happening?
Pupil: It switches
Teacher B: That's right, the same as a switch that's what a switch does. A switch bridges the gap using a conductor. [teacher shows his finger as a conductor]

All three teachers used *whole class discussion* to support collaborative learning, mainly through the use of brainstorming. These sessions had elements of the types of discussions suggested by Bliss et al. (1996, p. 39), Hennessy and Murphy (1999, p. 1) and Bruner (1999, p. 11) and had high levels of pupil participation. The example below typifies its use as a stimulus to thinking about design situations, in this case, identifying examples where an electronic 2-min timing device (their project) might be of use:

Teacher A: Ok, now you're beginning to think of one or two timed activities or you might be a fitness fanatic and how many sit-ups can you do in two minutes ... can you see where were looking, what theory are we looking at now, the theory of....?
Pupil: Sport!
Teacher A: Sport, ok, now let's put this in. What areas of sport in two minutes would be important, you mentioned?
Pupil: Swimming.
Teacher A: Is it similar to, (the teacher points to Football already on the board). Two minutes, what was the one I said a few moments ago, the fitness training.
Pupil: Two minutes to do sit-ups.
Teacher A: Ok, we'll use that one as well.

The high frequency of pupil contributions in brainstorming suggests that each new contribution sparked off others, possibly because pupils related to each other's contributions more easily than in discussions initiated by the teacher. Another effect was that the breadth of contributions offered by pupils suggests their comfort in using their own terms and meanings to develop the particular concept under exploration. However, having established what '2 min' meant, following-up the suggestions was more problematic. The teacher asked pupils to record four situations where 2-min timing would be important, the aim being to determine if their understanding had been established. An examination of eleven pupil folders from this class showed that some spurious suggestions were included. When interviewed, pupils presented a light-hearted view these spurious ideas, '*...well it was just sort of fun and ... It will help me finish the sheet.'* (Pupil interview transcript: School A). Collaboration in this instance, therefore, facilitated pupils' acceptance of ideas but did not provide opportunities for pupils to discriminate further regarding the usefulness of these ideas. Only one instance of pupils not being able to collaborate was observed and this was not included in the analysis although we have included it in the continuum (Fig. 6).

Data did not reveal any examples of teachers structuring collaboration as described by Bruner (*ibid.*) where pupils collaborated to, '*organise their own learning'*

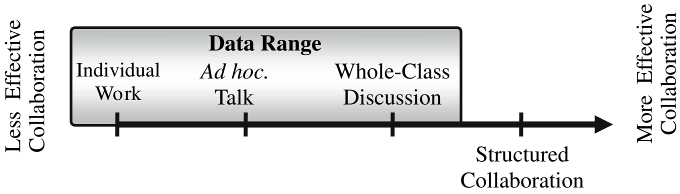


Fig. 6 Continuum of collaborative strategies

nor were there examples of pupils *'developing collaboration skills'* as suggested by Hennessy and Murphy (1999, p. 1). We suggest that the continuum (Fig. 6) will allow teachers to identify their own practice and move from the management of unstructured (the area enclosed by the solid rectangle) to structured collaborative strategies indicated by the arrow.

Task orientation

The third and final area of effectiveness we explored is that of orientation into complex tasks. Typically, complex tasks are those that involve simultaneously interpreting, applying and evaluating sets of instructions. For example, in the electronic activities we observed, pupils had to identify components, review their functions, test and evaluate circuit behaviour and make predictions about circuit applications. Similarly, complex designing tasks involved applying design criteria, drawing, evaluating and changing design intentions while complex tasks in manufacturing occurred in processes such as vacuum-forming, which involved correct positioning of the mould and the polystyrene sheet to be formed, judging the appropriate amount of heat, operating the machine's controls at the appropriate time and removing the formed object from the machine. In all these tasks, pupils had to rely on observation, make judgements about which visual clues were appropriate, make decisions and perform appropriate actions. In contrast, simple tasks such as drilling, cutting, bending, filing, soldering involved single operations and once started were seldom problematic. When observation data from complex tasks were analysed, pupils were observed going through stages in orientation into the task, starting with *visual orientation* (momentarily examining the work of other pupils to assess the appropriateness of their own intended response); '*initial engagement*', sometimes without a complete understanding of whether their activity was appropriate; *peer-mediated orientation* where pupils sought the support of other pupils and seeking teacher intervention. An illustration of the data range is shown in Fig. 7 below. We have placed how teachers reacted to pupils (Teachers' Reactive Strategies) where it

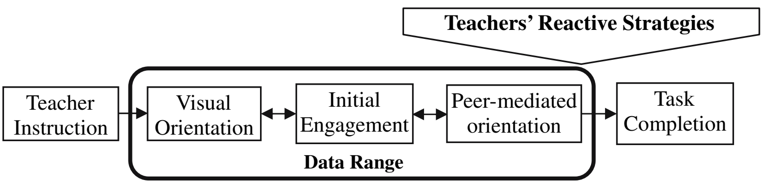


Fig. 7 Pupil engagement during complex tasks

was most commonly observed. It is not intended to suggest that there was no teacher support at the initial stages of complex tasks. Rather, that there was an observable trend towards *reaction* to pupil response when engaged in complex tasks, rather than the development of strategies to support pupils through them.

In Schools A and C a typical complex task was the requirement to model an electronic circuit on a proto-typing board (a similar example is shown in Fig. 4 above) where pupils had to understand the matrix of holes to connect the components together. Modelling allowed pupils to become familiar with the components, their positions relative to each other, and the circuit function.

Visual orientation was universally used by pupils even in situations where seemingly copious information was provided by teachers and consisted of checking with other pupils that their interpretation of the instruction was appropriate, as the field notes from each school illustrate:

> ... [the pupils] *seem to lack understanding and may not be confident in the application of electronic principles and concepts to the circuit. Some are not fully familiar with the components themselves*. (School A)
> ... [there were] *the visual clues that pupils were looking for when starting the task. There was some evidence of confusion and looking around, seemingly to see if others were doing similar activities*. (School B)
> *The teacher toured the groups and offered assistance in connecting the circuit components on the breadboard* [as there was some doubt among pupils]. (School C)

The field notes show that instructions about complex tasks need time to be assimilated. Successful visual orientation was important for subsequent activity and for some complex tasks this continued throughout the activity.

Initial engagement was characterised by pupils mixing their visual orientations with task engagement. In some cases, the pattern of initial engagement and orientation was unsuccessful and resulted in pupils delaying their work, waiting for the teacher and in extreme cases, failing to complete the task. In one such case where pupils had to wait for the teacher to support them there was a visible loss of interest, '*...almost all the groups had ... to have* [the positions of] *these* [resistors]*changed around..*[in their prototyping boards]'. While we acknowledge that support such as this is fundamental to the teacher's role in learning, the complex nature of technology and design tasks requires teachers to recognise and plan for pupils to overcome struggles with orientation. Such strategies might include an expectation that pupils should have questions once they have initially engaged in the task, to address these questions to each other, to provide and evaluate answers to those questions. The task of the teacher, therefore, may be to facilitate the questions and to validate pupil responses rather than provide all the answers.

Peer-mediated orientation was used in all three schools. Pupils supplemented the initial information given by using opportunities for support from peers in the initial stages of tasks so that their successful completion was more likely. Data above has highlighted the use pupils made of each other's reactions and teachers should recognise the benefits of such orientation strategies. However, pupil orientation should include strategies to support the depth of engagement with the task that teachers expected. For example, in School B, orientation reinforced pupils' superficial understanding of the circuit in the group activity already cited. The field note shows how pupils, in spite of their orientation strategies, still needed support from the teacher:

> *The teaching style was to pose questions on the worksheets and then to supervise the pupils as they answered them in discussion groups. This meant that the teacher was touring the groups and imposing his meaning on the responses, he therefore seemed to overcome to some extent the differences in meaning between teacher and pupil as well as dealing with the inability of some of the pupils to understand the requirements of the descriptive questions.* (School B)

These data show that effective task orientation needs to be *structured* so that initial task engagement can limit the mismatch between teacher expectations and pupil actions. We argue that teachers should recognise these orientation stages and pro-actively support them. A more detailed model of pupil initiation into complex tasks is suggested in Fig. 8 below. Strong teacher support can be structured through the visual orientation and initial engagement phases of the task (as shown by darker shading) and this support is progressively validated by the teacher as pupils demonstrate more familiarity and confidence with the task requirements (as shown by the lighter shading).

Discussion

Our data have highlighted a range of interdependence levels in each of the three teaching areas observed. Where interdependence was less prevalent, teachers tended to over-emphasise curricular content and task completion at the expense of understanding the activity, its purpose and its learning outcomes. Where interdependence was more marked, there was active engagement by pupils and a seemingly closer adherence to the subject aims with increased motivation. Our illustrations, in the form of continua, model for teachers a sliding scale of interdependence levels that they could use to identify their own practice. Used this way, the continua could be considered as an analysis tool to support lines of development in their teaching and to identify where learning dialogue should take place. We argue this on the basis that one teacher seldom displayed all strategies. Rather, each continuum is a composite picture built from the practices of all.

In the first area of observation, starting tasks, we have illustrated opportunities for teachers to develop more individualised reference points. Pupils' previous work (in the form of explicit references to past design work, projects and assessment archives) could be used to locate these starting points but they could also be used to plot appropriate *directions* for learning. The only way to plot directions is for pupils to be made aware of their own starting points through a dialogue with the teacher. This is

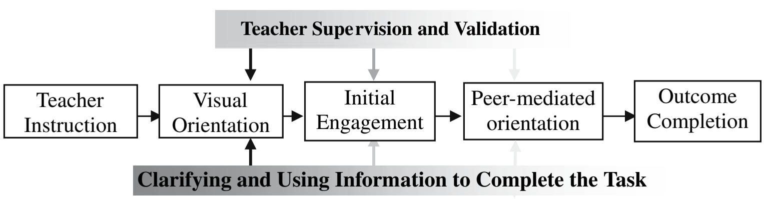


Fig. 8 A model of task orientation in technology and design

illustrated in the graphics example we cited, (Fig. 3). Pupils could use their previous work to highlight their strengths and weaknesses and pinpoint skills that have been established and those that need to be developed. However, such a strategy depends on teachers themselves taking a developmental approach to such skills as well as managing the satisfactory completion of the elements of the design-and-make work. While the continuum has highlighted the dominant practice of reminding pupils that they had undertaken previous work we suggest that pupils' previous work should be made more use of, particularly in light of the ETI observation that there is a significant drop in interest towards the end of Key Stage Three (DE, 2000). Also, we argue that one way of preventing a loss in interest is to show pupils how far their skills and understanding have developed and to allow them to have a voice in the analysis of their own strengths and weaknesses by referencing their needs to their own established level of competence as evidenced by their work. To do this, teachers (rather than pupils) need to archive work throughout the Key Stage. We have already highlighted possible objections about management, storage, time commitment and access rights to such work. However, we take the view that school computer networks with electronic data storage capability, along with growing ICT capability among pupils, should be exploited for their potential to support such individualised reference points. Pupils should have flexible access to their archives so that they, not the teacher, can call up previous work. The availability of such archives would provide a basis for teachers to plan how to match their interactions more closely to the needs of pupils. Pupils could then make an analysis of their learning needs and plot current and future directions in the development of their own capability. Such an approach to technology and design would allow teachers to prove that their teaching strategies are consistent with effective teaching models.

The continuum related to the second area, collaboration management, highlights the value pupils attach to ad hoc collaboration. This was shown to play an important role in orientating pupils into their activities by agreeing and establishing the meanings and procedures needed to aid task completion. While these were related to getting the task done without reference to quality or to learning, we saw these discussions as an important first step in providing a more in-depth view of collaboration. The fact that all three teachers allowed such discussion indicates that they implicitly facilitated it. Indeed, in the first example cited, the teacher built his questioning strategy on the discussion that had taken place. However, our continuum has highlighted the need for teachers to move beyond facilitation and to establish ways of helping pupils to collaborate about understanding the purpose of the task and the intended learning outcomes. To do this, teachers need to rethink their task instructions and include both ad hoc and structured discussions that focus on both procedural information and learning outcomes. Such instructions might include a periodic review of a task and the evaluation of which questions are most likely to support the learning outcomes. Teachers may need to review their own role in achieving those outcomes and take on the role of facilitator rather than production manager. Similarly, they may need to support pupils in deciding how the activity fits with other elements of the design-and-make project. The continuum (Fig. 6) is based on notions of Social Constructivism (Vygotsky, 1978) where learners' understanding is gained through social interaction. In this case, peer interaction was seen as being as important as teacher–pupil interaction in how they redefined the task for themselves. Teachers therefore need to develop these strategies to incorporate collaboration that addresses pupils' learning needs as well as their obvious priority to complete the task successfully. Again, we propose that the continuum should be used as a means of helping teachers to identify where their current strategies lie and to support them in developing more reciprocal approaches. Such strategies would address Bruner's (1999, p. 11) concern that teachers need to provide collaboration that supports pupils in deciding which questions to ask of teachers, what answers they need to know and how those answers confirm or refute assertions. It would also address McNair et al. (2000) who argue that the dearth of pupil questions when engaged in technology and design activities and a resulting passive acceptance of the teacher's agenda on the part of pupils, should be challenged. Muijs and Reynolds (2001, p. 87) suggest that learning to collaborate in this way will support the development of metacognitive skills and in particular, the analysis of pupils' own thought processes. These findings are consistent with Murphy and Hennessy's (2001, p. 2) view that learning *to* collaborate contributes significantly to learning subject content and as such is an important element of effective teaching. We believe that the continuum may also help teachers to quantify those strategies that dominate their teaching styles and reduce their dominance.

In distinguishing between simple and complex tasks we have provided teachers with a more comprehensive view of how pupils might react to their instructions. Teachers need to provide a structured orientation into tasks with a gradual increase in independence as pupils gain an appreciation of which elements of each task they need to treat as significant and which they can ignore. We acknowledge that the nature and level of support needed will depend on the pupils, their levels of motivation, their maturity and ability, and the nature of the work they are engaged in. However, teachers should interpret our model within their own context and identify their own individual approaches within the continuum. We hope that the continuum more clearly anticipates pupils' responses to instructions and allows teachers better identify the range of possible pupil reactions to tasks. Teachers should therefore be able to plan these immediate reactions and build strategies for allowing pupils to articulate, discuss and validate responses.

Conclusion

In summary, we have taken what we believe to be the most appropriate illustration of teacher effectiveness in the form of Hallam and Ireson's (1999) model of teaching and learning and used it as a basis for constructing a set of continua for describing and analysing teaching and learning. We suggest that the continua may contribute to an understanding of how specific teaching situations can be understood within the wider effective teaching debate. The continua may also help teachers to address some of the concerns highlighted by the ETI and may provide a response to many of the teaching and learning concerns raised in national and international journals. While these findings cannot be said to be representative of technology and design in Northern Ireland, nonetheless they give a picture of classroom interaction that may help teachers to identify their current practice and provide a learning dialogue with pupils. It is clear from the data that strong management and clarity of instruction are in themselves insufficient to secure pupil learning and pupils' voices need to be brought to the fore in establishing learning. We hope that our data allow teachers to move from the left to the right of our continua. Used appropriately as a model for building on histories, managing collaboration and orientating pupils into complex tasks, we predict that pupils will engage in technology and design with a better understanding of its central aim. This aim needs to be fostered not only within each of the four individual elements that make up technology and design, but also as pupils see that the elements themselves are interlinked together. Ultimately, however, technology and design is not as much about the designing and making as it is about the development of learners in a design-and-make context. While the research was conduced with Key Stage Three children, we acknowledge the need for a wider view of these continua and their implications for differing age-ranges. Similarly, there are implications for teachers as they plan their long-term strategies, say, over a whole Key Stage and we have hinted at the need for electronic storage and retrieval technology to be made available to pupils so that they can analyse their own development throughout the Key Stage. Our research has highlighted the need for teachers to engage in the effective teaching debate and in particular to address the issue of translating the research into classroom practice and the study highlights the need for more research on how to apply the growing body of literature on effective teaching to individual subjects. Finally, we have been intrigued at the levels of enthusiasm many pupils and most teachers show for technology and design, as well as the quality of the debate surrounding its place in the school curriculum. We detect, however, the need to develop the debate towards how, and under what conditions pupils can be guided into effective learning activities. We believe that pupil learning, and hence effective teaching of technology education should be a central element of any research agenda. Our belief is that in keeping this focus central, pupils may show more motivation and may indicate higher levels of interest at the latter stages of the Key Stage.

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