

The 2007 Professor John Eggleston Memorial Lecture Learning to Design: Investigating the 'Inner Activity' of the pupil.

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Abstract

This paper will address five questions that emerge from the title of the Design and Technology Association Education and International Research Conference 2007: 'Linking Learning': (a) How can we think about learning so that it informs our work in design and technology? (b) What is known about design and designing that might help pupils learn to think in a designerly way? (c) What do we know about the 'inner activity' of designers that can support pupils learning to design? (d) What does the pupil need to learn in order to think in a designerly way? and (e) What do we know about 'linking learning' and how can this inform our work in design education?

The paper begins with a review of learning, one of education's central concepts. This is followed by a discussion of the term 'design', the knowledge required by a designer, and how a designer comes to know. The third section of the paper examines the meaning of the term 'design' in the context of design and technology classrooms. The fourth section (a) discusses transfer theory of learning, and (b) identifies a variety of 'links' that have possible meaning for design education. The paper concludes with suggestions for approaches to research in design education. Throughout the paper, questions that could serve as the basis for both short and longitudinal research studies are identified.

Key words

learning, design, design education, design and technology, research

Introduction

The editorial board of the Design and Technology Association provided delegates at its 2007 Education and International Research Conference a tantalizing title for the conference: linking learning. Delegates were further intrigued by the website description of the purposes for the conference, in which the D&T

Association made a number of provocative claims. These claims (in italics below) led this author to ask a number of questions about each one, including those below:

- *That D&T provides a practical context for learning other subjects.* Does this mean that D&T is only applied [fill in the subject name]? Is this what we want as part of the rationale for our subject? How does this assumption correlate with what we consider the unique contribution of D&T?
- *That pupils in D&T classes will not only have requisite and appropriate science and math knowledge, but will also be able to access and use that knowledge as and when required.* Do pupils have the requisite and appropriate knowledge? What maths and science knowledge is requisite and appropriate? Why only knowledge from mathematics and science? What does 'access and use' mean? Is there evidence to support this assumption of transfer of learning?
- *That augmenting D&T with other subjects deepens understanding of the wider aspects of D&T.* What does the phrase 'wider aspects' mean? Do we have evidence to support this statement?
- *Secondary teachers provide an effective means to learn sophisticated mathematical and scientific concepts through practical making activities.* Which sophisticated concepts are being referred to? Why only knowledge from math and science? And again, what evidence do we have that this is both possible and desirable?

Yet perhaps more importantly, we must ask the questions: To what extent are these claims true? Are there theoretical frameworks to support them? Is there empirical research to support them? If not, does this reflect an inherent weakness with design and technology as a 'linkable' subject or simply reflect a lack of appropriate research? And so, the title of the conference and the website statements led this author to ask a number of fundamental questions

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about learning and about linking, five of which provide the focus for this paper:

1. How can we think about learning so that it informs our work in design and technology?
2. What is known about design and designing that might help pupils learn to think in a designerly way?
3. What do we know about the 'inner activity' of designers that can support pupils learning to design?
4. What does the pupil need to learn in order to think in a designerly way?
5. What do we know about 'linking learning' and how can this inform our work in design education?

But before I turn to the substance of the paper, a caveat. I have placed a limitation on the substance of the paper, which is suggested by its title: Learning to Design: Investigating the 'Inner Activity' of the pupil. Oser and Baeriswyl (2001) have talked about 'the sight-structure' and the 'basis-model' of learning. 'The sight-structure of learning' refers to the visible structure of teaching, that is, events initiated by the teacher. The 'basis-model' refers to the internal learning sequences that pupils follow to appropriate knowledge, develop socially, solve problems and acquire skill: in other words, what is happening in the mind of the pupil. An assumption is that learning consists of outer activities that stimulate inner activity. It is this latter aspect of learning, the 'basis-model', which provides the focus for this paper. And not just any pupil, but one engaged in design & technology; and even more specifically, one learning to design. And so my self-imposed limitation is to omit discussion of both teaching and assessment. I intend to limit the discussion to learning and the learner. Now I recognize that learning, teaching and assessment are intimately linked: that what I say about learning and designing will raise all sorts of issues and questions for teaching and assessment. But these will have to wait for another time.

Learning

How should we define and think about one of education's central concepts? In the first section of this paper I will address three questions: (a) What is this thing called 'learning'? (b) What happens when learning takes place? and (c) How does learning come about?

What is this thing called 'learning'?

Learning has, for most of education's existence, been conceived of as the acquisition of something. The Oxford Dictionary of English (Soanes & Stevenson, 2003) defines learning as 'the acquisition of knowledge or skills.' Adey (2002) talks about learning as 'some kind of acquisition or development of knowledge, skills and understanding' (p 2).

However, for many authors learning is characterized as a non-maturational change (Swann, 1999) resulting from the transformation of experience. For example, Kolb (1984) defined learning as 'the process whereby knowledge is created through the transformation of experience' (p 41). More recently, Woolfolk, Winne and Perry (2003) wrote that, 'to qualify as learning, change [in an individual's knowledge or behaviour] must be brought about by experience – by the interaction of a person with his or her environment' (p 196). Sfard (1998) writes that the very essence of learning is 'our ability to prepare ourselves today to deal with new situations we are going to encounter tomorrow' (p 9). According to Jarvis, Holford and Griffin (1998), "learning...is the process through which we become the human beings we are and by which we internalize the world and construct our experiences" (p vii).

What happens when learning takes place?

Drawing on the work of Karl Popper, Swann (1999) posits that "learning takes place when a human...has a problem, attempts to solve it and survives, creating changes in the world and the learner" (p 260). This notion implies that there are characteristic elements and an identifiable process common to any incidence of learning. Popper (1979) developed a schema to describe this:

P1 TS EE P2

According to Swann (1999):

In this schema, P1 represents an initial problem. TS is a trial solution applied to this problem, and EE is the process of error elimination to which the trial solution is subject, leading to P2. P2 is the new problem that emerges from the attempt to solve the initial problem, and it is always different from P1. What I find interesting about this schema is that it

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incorporates the idea of feedback without implying a cyclical process: learning begins and ends with problems, but the problems that learning generates are never identical to the initial problems. Once there has been an attempt to solve a problem, the trial solution exists within the history of the situation. (p 260)

Now I am reminded that Popper was talking about science, not design and technology, and the nature of problems in science is quite different to the nature of problems in design and technology. And also, that the nature of problems in design & technology is not unproblematic. Kimbell (2006), for example, has talked about "the difference between *creative problem solving* and intervening creatively to *improve the quality of life*" (p 105).

Swann's reference to Popper is reflected in the findings of research I conducted which investigated the tacit strategies pupils, with no formal design and technology experience, bring to a design and make task (Welch, 1996). Analysis of the data revealed that pupils engaged in what I termed "the serial development of solutions" (p 155) to a design problem. An idea was generated, developed as a model, evaluated and, if found unsatisfactory for any reason, abandoned. A second idea, sometimes although not always informed by the experience and knowledge gained from the first model, was similarly developed (Figure 1).

When designing, pupils appear to be engaged in 'a kind of experimentation that consists in reflective

'conversation' with the materials of the design situation' (Schön & Wiggins, 1992, p 135). Repeated "move experiments" lead to an understanding of the design problem, which in turn informs, guides and stimulates further designing. As Schön and Wiggins conclude, this is important, for it creates the "notion of designing as an educational process in its own right" (p 155). Sim and Duffy (2004) have described the "inextricable link between learning and design" (p.59). There would appear to be a certain kind of knowledge and understanding that is very hard to attain in any way other than by actually designing. Designing has to be learned by doing rather than reading a textbook.

How does learning come about?

Even a cursory examination of educational materials, debate, policy or practice reveals the widely held view that learning (at least that which is supposed to occur in schools) is the outcome of a simple process of teacher-to-pupil transmission. While the transmission theory takes a number of forms, in all its versions knowledge consists of ideas which are in some sense taken to be true and certain, and 'being taught' is a means by which these certainties are thought to accumulate in the learner's mind. According to (Swann, 1998) 'the process of transmission is implicitly understood to involve the learner in a passive initial state in which he or she is not particularly responsible for what happens, apart from a willingness to be alert to the input of information' (p211).

Sfard (1998) describes how current theories of learning draw "on two radically different answers to

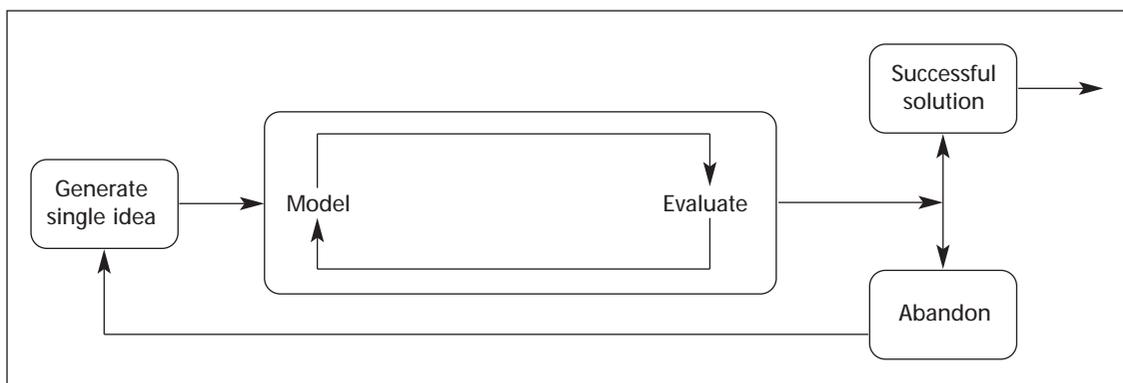


Figure 1. The serial development of solutions.

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the fundamental question, 'What is this thing called learning?' (p7). According to Sfard, the *learning as acquisition* metaphor implies that knowledge is something that is transmitted and acquired, a view that is deeply embedded in the literature about learning. Skills and knowledge are viewed as a commodity that can be accumulated and learning amounts to the acquisition of this commodity. However, there is now a shift in the language of learning to a metaphor of learning-as-participation, that is, learning is socially constructed: the *participation metaphor* (Sfard). Learning as participation highlights the importance of the learner as actively engaged. As Sfard suggests, 'the learner should be viewed as a person interested in participation in certain kinds of activities rather than in accumulating private possessions' (p6). From this perspective, learning is also the 'process of becoming a member of a certain community' (Sfard, p6), about learning the language of that community, and participating according to the expected social and cultural norms. As Sfard notes, in the image of learning that emerges...the permanence of *having* [author's italics] gives way to the constant flux of doing. While the concept of acquisition implies that there is a clear end point to the process of learning, the new terminology leaves no room for halting signals (p6). Indeed, constructivism is founded on the premise that pupils recursively construct their understanding of the world in which they live. Smith (1995) has pointed out that constructivist authors 'restrict the use of the term knowledge...[and] focus on knowing' (pp23-24).

At the outset of this paper I commented that the title of the conference raised many questions in my mind, five of which are providing the focus for this paper. I am now going to add one more general question: What don't we know? I will raise this question at the end of each section of the paper as a way to suggest avenues of inquiry for the design and technology research community.

Some questions about learning

- How do Sfard's acquisition and participation metaphors help us think about pupils learning to design?
- What new theoretical perspectives on learning might be generated by studying pupil designers?

- How do designers come to know what they need to know in order to design?
- How does a designer learn to design?

The 'inner activity of the designer'

Having identified some issues and questions arising from thinking about learning, I now turn to thinking about learning to design. And so the next section of the paper addresses three questions: (a) What is 'design'? (b) What does a designer need to know? and (c) How does a designer come to know what he or she needs to know?

What is 'design'?

In his now classic book *Designing for people* (2003/1955) Henry Dreyfuss claimed:

[Designers] bear in mind that the object being worked on is going to be ridden in, sat upon, looked at, talked into, activated, operated, or in some other way used by people individually or en masse. When the point of contact between the product and the people become [sic] a point of friction, then the...designer has failed. On the other hand if people are made safer, more comfortable, more eager to purchase, more efficient – or just plain happier – by contact with the product, then the designer has succeeded. (p8)

The general population encounters the word 'design' in a wide variety of everyday contexts, largely through advertising and the mass media: design-er sunglasses, interior design-er, environmental design, floral design, design for sustainability, modern design and so on. Working as specialists in the field of design and technology readers of this journal may also encounter other uses, including human-centred design, furniture design-er, and iconic design.

Given the range of contexts in which it is used, is it possible to define the word 'design.' Richard Seymour, the industrial designer, has suggested that design is 'a word you think you know the meaning of until you try to define it...the lack of a specific clear definition is one of the reasons why there is so much misunderstanding between...your mum and her VCR' (quoted in Peto, 1999, pp11-12).

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Simon (1969) wrote that, '[design is] devising courses of action aimed at changing existing situations into preferred ones' (p. 129). Note the salient words 'aimed' and 'preferred.' 'Aimed' implies intent, which implies accountability. What the designer does on purpose should be done with a full consideration of the consequences. 'Preferred' implies judgement, which implies values. Design therefore has ethical meaning intrinsic to it. Heskett (2002) wrote that, 'design [is] the crucial anvil on which the human environment, in all its detail, is shaped and constructed for the betterment and *delight* [italics added] of all.... Design is one of the basic characteristics of what it means to be human, and an essential determinant of the quality of human life' (pp2-4). And in the introduction to his book with the intriguing title *By design: Why there are no locks on the bathroom in the Hotel Louis XIV and other object lessons* Caplan (2005) writes, 'design is a process for making things right, for shaping what people need' (p. xx). Caplan's use of the word 'right' implies that designed products and places must work, that is, function as they were intended to.

Seymour (1999) takes the concept of 'right' one step further when he introduces the idea of emotional ergonomics and asks, 'Why shouldn't things be a joy to own and use? Why shouldn't they bring emotional satisfaction?' (p. 14). Figure 2 shows two bottle openers. The Alessi devil bottle opener works as well as, but no better than, the other bottle opener. But doesn't it make you smile just a little bit? Doesn't it engage your emotions? Doesn't it delight the senses as well as function well?



Figure 2. Emotional ergonomics in action.

What does a designer need to know?

Lawson (2004) begins his book, *What designers know*, by asking a series of questions: Is there such a thing as 'design knowledge'? What is it that designers know? Does design knowledge involve a special way of knowing? How do designers acquire and make use of their knowledge?

Korobkin (1976) provides one answer to the first question by grouping the knowledge used by designers into two categories. First, designers use 'image information...[that] provides a general understanding of important issues and of physical ideas pertinent to their resolution' (p20). Second, designers use 'test information...[that is] directly pertinent to evaluating the good and bad points of a given hypothesis design'. In other words, according to Korobkin, a designer relies on one body of knowledge that tells him or her how the world might be and a second body of knowledge that indicates how well things might work. Korobkin notes that the distinction between image information and test information is not necessarily one of information content. It primarily clarifies different purposes that the information serves. Goel and Pirolli, (1992) contend that, 'the kinds of knowledge that may enter into a design solution are practically limitless' (p396). In other words, knowledge used by a pupil when designing may originate from people and places and experiences far removed from the immediate classroom experience.

Lawson (2004) suggests that it is a way of seeing or perceiving that may be the crucial ability in design. What is this 'way of seeing'? What is the nature of this seeing or perceiving? Cross provides an answer when, in the title of a paper published in 1982 (now republished in 2006 as the title of a book), he introduced the phrase 'designerly ways of knowing.' Cross described five aspects of designerly ways of knowing:

1. Designers tackle 'ill-defined' problems;
2. their mode of problem-solving is 'solution-focused';
3. their mode of thinking is 'constructive';
4. they use 'codes' that translate abstract requirements into concrete objects;
5. they use these codes to both 'read' and 'write' in 'object languages.' (p226)

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We could ask the question: 'Are these skills that we want pupils to acquire?' Cross (1982) argues that these ways of knowing justify the inclusion of design in general education for the following three reasons:

1. Design develops innate abilities in solving real-world problems, ill-defined problems;
2. Design sustains cognitive development in the concrete/iconic modes of cognition;
3. Design offers opportunities for development of a wide range of abilities in nonverbal thought and communication. (p226)

How does a designer come to know what he or she needs to know?

According to Lawson (2004) 'designers commonly and frequently make great use of what they often refer to as 'precedent'' (p.96). However, as Goldschmidt (1998) has pointed out, the term is not used in the same way as when used by, for example, a lawyer, who attempts to demonstrate a close parallel with a precedent. Goldschmidt argues that the designer, rather than looking for parallels, is looking for something that is sufficiently similar in some respects as to become a useful point of departure. She therefore argues that the term 'reference' is preferable to 'precedent.' So we may ask: How will the pupil-designer accumulate precedents or references? According to Hope (2007) this begins in early childhood:

Children's early play styles and role-playing experiences impact on their emerging design abilities. ...[The] improvisational aspects of children's play, in which reality and fantasy are blended and stretched, often collectively also parallels the best of design practice. (p55)

Harrison (2000) has argued that design education is a continuum, beginning when children first interact with their environment and continuing through formal years of elementary and secondary schooling and on into undergraduate, graduate and professional training. For Harrison, design ability involves a seamless development in which:

Knowledge and understanding progress from the intuitive to the articulate; skills develop from the innate to the disciplined; creativity develops from

the casual to the harnessed; capability develops from the natural to the disciplined combination of creativity, skills and understanding; [and] motivation develops from pure pleasure from making something to excitement and determination to be creative and effective' [*author's italics*] (p4).

In reference to the education of professional designers, Lawson (2004) argues that it is crucial to both inculcate an attitude that encourages gathering precedents, 'whole or partial pieces of designs that the designer is aware of' (p96) and also to develop appropriate skills to do so. This is why design students are encouraged to maintain a sketchbook, the traditional way in which designers have 'accumulated' visual experiences, and to learn to draw in order to record what they see. But is this sufficient? 'Seeing' and subsequently sketching is just one way in which pupils 'sense' and record their environment and therefore accumulate experience. How do we encourage pupils to use all their senses to create a bank of precedents?

Some questions about design and design knowledge

- How do we help pupils acquire and use image information and test information?
- What school experiences are required that enable pupils to acquire and use a bank of precedents?
- At what point should pupils be required to begin using a sketchbook?
- How could pupils be encouraged to maintain a sketchbook that 'travels' with them throughout elementary and secondary schooling?

The 'inner activity of the pupil-designer'

What does the term 'design' mean in the context of design education for elementary and secondary pupils, as well as in the context of our subject 'design and technology'? The images in Figures 3 – 6 each illustrate a definition of 'design.' In Figure 3, the term 'design' is being used as a noun to describe a tangible outcome, in this case, Philippe Starck's Vitra Stool.

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Figure 3. *The Vitra Stool.*

In Figures 4 and 5, the term 'design' is being used as a verb to describe a creative activity – designing. The pupils are engaged in generating, developing, communicating and evaluating ideas using two-dimensional (sketches) and three-dimensional models. Designing is seen to be a conscious process through which a designer transforms ideas into a tangible outcome.



Figure 4. *Two-dimensional modelling.*



Figure 5. *Three-dimensional modelling.*

In Figure 6 the term is again being used as a noun, but in this case to indicate a field of human endeavour that results in all the products found in the made world, including fashion design, product design, graphic design and architectural design.

Heskett (2002) uses a seemingly nonsensical sentence to illustrate these points. He says, 'design is to design a design to produce a design.' Yet, as Heskett goes on to explain:

Every use of the word is grammatically correct. The first is a noun indicating a general concept of a field as a whole, as in: 'Design is important to the national economy.' The second is a verb, indicating action or process: 'She is commissioned to design a new kitchen blender.' The third is also a noun, meaning a concept or proposal: 'The design was presented to the client for approval.' The final use is again a noun, indicating a finished product of some kind, the concept made actual: 'The new VW Beetle revives a classic design!' (pp5-6)

Some questions about the pupil as designer

- What examples do we show pupils to help them understand the term 'design'?
- How can we engage pupils with the work of famous designers and iconic designs?
- In what ways would this engagement impact on pupils' designerly thinking?
- How do we engage pupils with the concept of emotional ergonomics?
- How do we engage pupils in the aesthetic elements

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Figure 6. Design as a field of human endeavour.



of designed objects to the same extent that we engage them in the functional and constructional elements?

- What can be our educative response to Caplan's (2005, p xv) claim that 'design is now directed to largely superficial ends'?
- How do pupil-designers use image information and test information?
- How do pupil-designers acquire and make use of precedents or references when designing?

Linking Learning

As I noted at the outset of this paper, the title of the conference 'linking learning' is intriguing. The term 'linking' raised for this author two central questions: (a) Linking what to what? and (b) What is the nature of linked learning in design education? But before I address these two questions, I want to talk about the transfer theory of learning, which has been, and remains, a ubiquitous pillar of learning theory in education and, I consider, a potentially major talking point for this conference.

The transfer dilemma

Transfer theory is a prominent idea in the advertising for this conference, which states, 'that pupils in D&T classes will not only have requisite and appropriate science and math knowledge, but will also be able to access and use that knowledge as and when required.' In other words, pupils will be able to transfer knowledge from science and math classrooms to design and technology classrooms, or vice versa. I deliberately used the term 'dilemma' for this section of the paper, for there is little agreement in the scholarly community about the nature of transfer, the

extent to which it occurs, and the nature of its underlying mechanisms.

Transfer theory has a long history. For example, as far back as 1901 Thorndike and Woodworth hypothesized the concept of 'identical elements.' This hypothesis views the learner as a passive agent whose learning is dependent upon the similarity between an original learning situation and a present situation. Transfer was thought to occur to the extent to which original learning and transfer situations share identical elements, that is, share features of physical environments or common stimulus elements. Learning was conceived of as a generalization of response based on the inherent similarity between stimuli. Yet as Carraher and Schliemann (2002) identify, 'there is little evidence for some monolithic skill or piece of knowledge being carried over intact from a unique prior situation to the present one' (p19). In fact, such is the uncertainty surrounding the issue of transfer that in 2006 The Journal of the Learning Sciences began a three-year strand on the topic. The journal has invited both empirical and theoretical papers that respond to the challenges regarding the conceptualization of transfer, noting that there is a need to resolve 'persistent and thorny issues and...further develop alternative approaches to transfer' (Lobato, 2006, p444). In an earlier issue of the same journal, Packer (2001) 'traced the argument, forged by both Lave (1988) and Dewey (1916), that conceptions of transfer rest on mistaken assumptions about mind, about knowledge, about society, and about what it is to be human' (pp510-511). So the issue of transfer, of 'how knowledge acquired in one situation applies (or fails to apply) in

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other situations' (Singley & Anderson, 1989, p1), is a thorny one.

Furthermore, constructivist theories of learning do not support the historical concept of 'identical elements.' As Lave (1988) has written, learning and thinking take place in specific contexts that are essential to what is learned and thought. Hence situated learning theories cause us to ask how a learner's understandings are generalized beyond the specificity of their originating context and how previous understandings are applied to new situations. Tennant (2005) writes that, 'transfer is not a matter of learners acquiring abstract knowledge and procedures which are applied to many situations' (p111). Rather, as Greeno (1997) writes, it is a matter of 'learning to participate in interactions in ways that succeed over a broad range of situations' (p7).

Some questions about transfer theory

- How are an individual's understandings generalized beyond the specificity of their originating contexts? How are previous understandings brought into play in design education?
- To what extent is and can learning from other domains be 'carried over' to design education and, more broadly, to design and technology?
- To what extent do pupils in D&T classes have requisite and appropriate science and math knowledge?
- To what extent can pupils access and use that knowledge as and when required?

Linking what to what?

The question 'Linking what to what?' prompts me to think about five sorts of links:

1. Linking subjects to the broad aims of education.
2. Linking learning between subjects.
3. Linking school learning with the world outside school.
4. Linking the learning pupils bring to school with learning they do inside school.
5. Linking learning within design education.

Space limitations in this paper mean that I can mention only briefly the first four of these. But the last question I will examine in more detail.

Linking subjects to the broad aims of education

An entire conference could be devoted to a discussion of the aims of education and the place of design education within them. For example, at the *2007 International Primary School D&T conference*, Ian Williams from the Qualifications and Curriculum Authority (QCA) told us that in the review of the National Curriculum for England the aims of education are to 'enable all young people to become: successful learners who enjoy learning, make progress and achieve; confident individuals who are able to live safe, healthy and fulfilling lives; responsible citizens who make a positive contribution to society' (Qualifications and Curriculum Authority, 2007). The QCA will identify, for each subject in the curriculum, the ways in which it contributes to these aims. So the obvious question is: How does design education contribute?

Linking learning between subjects

There are several existing models for linking design and technology to other subjects, including (a) Science, Technology and Society (Aikenhead, 1994; Solomon, 1993), (b) Mathematics, Science and Technology Education (Scarborough, 1993; Wicklein & Schell, 1995), and (c) Science, Technology, Engineering and Mathematics (Department for Education and Skills, 2006).

In addition to these three models, there are a number of investigations into specific links between design and technology and other subjects. For example, Stables and her colleagues at Goldsmiths College investigated 'the potential for using design and technology (D&T) related activities as a vehicle for developing children's levels of attainment in literacy [writing only] and D&T' (p1). They reported that, 'where literacy and D&T had been blended together in a project where each was mutually supportive of the other the value, both in terms of the learning and of the comprehensive engagement of the children, was at its greatest' (p46). One further positive outcome was 'evidence of how curriculum time can be maximized and how much more time has been made available for D&T' (Stables et al., 2001, p46). As a second example, Barlex and Pitt (2000) investigated the relationship between science and design & technology in secondary schools. These authors concluded that there is very little linking between the two subjects, but

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made recommendations 'for improving the situation by identifying measures which might help to bring school science and school design and technology into a relationship that is more fruitful and also reflects 'real world' practice' (p9). This suggests a rich field in which to conduct research.

Linking school learning with the world outside school

Linking the learning that occurs in school to the world that exists outside school can take a number of forms, including:

- Environmental Education, which aims to teach pupils about how natural environments function and, particularly, how human beings can manage their behavior and ecosystems in order to live sustainably (Cole, 2007; Disinger, 2001).
- Global Education, which emphasizes the communication and interaction among people throughout the world. This subject stresses issues such as human conflict, economic development, human rights and social justice, human similarity and diversity, literatures and cultures, and the impact of technological progress. Global education also teaches pupils about different perspectives that people around the world have on the same issues and events (Kubow & Fossum, 2006; Tye, 1990)
- Vocational education and Training, also referred to as Career and Technical Education, prepares learners for careers based in manual or practical activities, traditionally non-academic and totally related to a specific trade, occupation or vocation (Karmel & Nguyen, 2007).

Linking the learning pupils bring to school with learning they do inside school

Should we be thinking about the prior knowledge of design and designing pupils bring with them to the classroom? Prior knowledge is comprised of a pupil's images, reminiscences, experiences and intuitions that are lodged in the subconscious – what Polanyi (1966) refers to as 'implicit knowledge.' In the past, an assumption has been that the pupil arrives at the design class with little or no relevant prior knowledge, what Vygotsky refers to as 'spontaneous concepts' (Vygotsky, 1986/1934, p.146). But ongoing research being conducted with David Barlex and Erin O'Donnell (2006) indicates that this may not be the case.

In our study, Year 6 pupils were asked questions about the skills needed by a designer and what designers need to know in order to design particular products. Analysis of the data has revealed that students, who had no previous experience of technology education, have considerable knowledge of not only what designers do, what skills they need to have and their personal characteristics, but also substantial knowledge of what designers need to know in order to design a range of products. It appears as though elementary students' bring to schooling a significant fund of knowledge about designers and what designers do that is relevant to learning to design.

The findings of this research should not be surprising, for a constructivist view of learning argues that pupils do not arrive at any classroom empty-headed, with a tabula rasa. Rather, they arrive with lots of strongly formed ideas about how the world works (Brown, Collins, & Duguid, 1989). This is important, for as long ago as 1978 Ausubel, Novak, and Hanesian, identified and described the need to begin instruction 'where the pupil is', because for meaningful learning to occur new knowledge must be related by the learner to relevant existing concepts in that learner's cognitive structure.

Linking learning within design education

Lawson (2004) has described how 'it is quite possible to teach design students some technical or theoretical subjects in such a way that [the students] acquire knowledge but appear to show little or no understanding or appreciation of this when they design' (p104). How many of us have experienced in our own classrooms pupils who exhibit high levels of propositional knowledge that they find difficult to appreciate as useful knowledge when designing?

It was Dewey (1933) who helped us think about and understand the importance of knowledge as a tool. As Dewey noted, when a pupil learns about a tool they also learn what it is for and when and how to use it. When people learn new information in the context of meaningful activities, they are more likely to perceive the new information as a tool rather than as an arbitrary set of procedures or facts. Ainley, Pratt, & Hansen (2006) talk about the 'utility of learning' (p30). By 'utility' they mean 'not just the ability to

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carry out procedures, but the construction of meaning for the ways in which...ideas are useful' (p30). In other words, while engaged in a purposeful task, the learner learns to use knowledge in ways that allows him or her to understand how and why that knowledge is useful by applying it in a purposeful context.

Research I conducted in 2004 as part of the Elementary Science and Technology project at Queen's University and also current research with David Barlex has investigated a way to make transparent to pupils how knowledge acquired in one context has utility in a different context. This research has shown that the way in which the teacher conducts an end-of-lesson review is critical to the success of a curriculum unit that uses pupils' learning from a sequence of Resource Tasks to empower them to successfully tackle a Capability Task (Lee & Welch, 2005). The research has demonstrated that when the teacher first asks the pupils 'What have you learned today about [topic of Resource Task]?' and then asks them 'How will what you learned today about [topic of Resource Task] help you in your Capability Task?' the utility of the learning is made manifest to the pupils. Ongoing research with David Barlex is showing that use of these two questions leads to a wide range of creative responses to a design brief (Barlex, Welch, & O'Donnell, 2007).

Some questions about linking learning

- What contributions could design education research make to transfer theory?
- Does transfer occur between design education and other subjects? If so, what transfers and how is it accomplished? If not, why not? How does it help?
- What is the nature of the transfer that occurs between design and technology and other subjects?
- What sorts of links between design and technology and other subjects will support the unique contribution of D&T to pupils' learning?
- To what extent, and how, does design and technology link to the broad aims of education?
- Are there educational benefits derived from linking? If so, what are they? What, if any, are the disadvantages?

Research

In this final section of the paper I want to turn to the issue of research, that systematic process of inquiry in which we attempt to develop or contribute to generalizable knowledge. There is now a considerable body of literature about design research (see, for example, Cross, Christiaans, & Dorst, 1994; Cross, Dorst & Roozenburg, 1992). The journal *Design Studies* is replete with not only the results of research but also with descriptions and analyses of research methods.

Cross (2006) has suggested that design knowledge has three sources: people, processes and products:

Designing is a natural human ability: everyone does it. ...Design knowledge resides in processes, the strategies designers use to move from problem state to solution state. ...Design knowledge resides in products themselves: in the forms and materials and finishes which embody design attributes. (p.101)

From this analysis, Cross (2006) developed the following taxonomy for fields of research:

1. Design epistemology – the study of designerly ways of knowing.
2. Design praxiology – the study of the practices and processes of design.
3. Design phenomenology – the study of the form and configuration of artifacts.

Lawson (2004) suggests five research tools that could be used to begin to find out about 'designerly ways of knowing' and about learning to design:

1. Simply sit back and think. There is a need for theoretical deliberation and reflection on the nature of designing.
2. Design empirical studies in which the designer is placed in a highly controlled situation and observed. It is clearly problematic in that the lack of realism may produce data that does not reflect what designers actually do.
3. Observe designers as they go about designing in the 'natural' setting of the studio. While this increases the realism of the activity, the researcher is faced with the problem that much of what the designer does is hidden inside his or her head.

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A great deal of this research will involve the investigation of modelling, which numerous authors have referred to as 'the language of design' (Archer, 1979; Davies, 1996; Evans & Wormald, 1993).

4. Ask the designer to tell the researcher what he or she knows.
5. Collaborate with cognitive scientists, who are beginning to develop software that simulates designing.

Some questions about design research with pupils

- In what ways could Cross's taxonomy inform design research with pupils?
- In what ways are Lawson's five research tools appropriate for use with students?
- What are the most appropriate methodologies for investigating how pupils go about designing?
- What are the most appropriate methodologies for investigating how pupils learn to design?
- What could the study of the form and configuration of products designed by pupils tell us about learning to design?

Conclusion

Hannah Arendt (1958), the social philosopher, wrote that our environment could be divided into two parts: the 'planet,' which is shaped by natural forces, and the 'world,' which is built up by human effort. Designing is a central and critical element of that human effort. Design activity encompasses some of the highest cognitive abilities of humans, including creativity, synthesis and problem solving. But design is about more than simple considerations of form and function. Products need to become 'objects of desire.' To achieve this, products must make pleasurable emotional connections with their end-users through the joy of their use and the beauty of their form. How do we enable pupils to design products that will bring them and others joy?

I have talked about how learning is now conceived of as a process of becoming a member of a particular community, which entails, above all, the ability to communicate in the language of this community and act according to its particular norms. In Sfard's (1998) terms, a participation metaphor has replaced talk about private possessions with discourse about shared activities.

I do not pretend to have addressed the complexities of both theoretical and empirical issues surrounding the idea of transfer. What I have tried to do is suggest that the 'transportation metaphor', to use Lobato's (2006) term, underlying much of the discussion of transfer is ill-founded. I think that our conversations about the supposed benefits of 'Linking Learning' must be cautioned by the questions surrounding transfer of learning. Given the current rhetoric surrounding cross-curricula links, it is imperative that we conduct research to investigate the nature of links between what pupils learns in other subject domains and how this might be used in design and technology, and vice versa.

In thinking further about linking learning, we could consider Hargreaves' (2001) words: 'design and technology is...a bridge linking the arts to science and mathematics in the interest of curriculum coherence' (p25). One responsibility of the design & technology research community is to investigate the nature of this bridge, bearing in mind what we know (or don't know) about transfer of learning.

One task for an educational research community such as ours is to develop empirically-grounded knowledge that will improve educational practice. As a community we should be quite good at research, for it requires intuition, imagination and creativity – intangible elements also essential to designing, in which many of us have expertise. A second task is for members of the community to make explicit the epistemological, theoretical, and methodological basis of their work. I want to suggest that there is a need for us to begin to link our work to overarching theories or conceptual frameworks from the wider corpus of educational research. When this linking happens, our community will build its own corpus of theoretical and empirical work that not only supports ongoing research and classroom practice, but also establishes itself in the wider educational and research community. I want to suggest there is an increasingly urgent need for us to do this.

One of the difficulties I think we face is that much of what we know about the answers to the questions I have posed about designing and learning to design has been derived by empirical studies of expert designers. It is not clear to this author the extent to

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which this knowledge correlates with pupils' in their position as 'fledgling designers' (Trell, 2007).

I would like to see us establishing, once and for all, that 'design intelligence' is a critical part of the education of all pupils. But I would like us to engage pupils in not just learning to think in a designerly way, but what Bell Hooks (1994) has described as 'learning as a place where paradise can be created' (p207).

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