

# Designing Technology: An exploration of the relationship between technological literacy and design capability

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## Abstract

The aim of this article is to contribute to the debate on the nature of technology education. This is especially pertinent at times of curriculum change and uncertainty, such as currently exist in relation to the Primary school curriculum in England and Wales. Two phrases ('technological literacy' and 'design capability') have been used by previous theorists and curriculum writers to encapsulate core understandings of what our subject is about. Are these helpful in the present context? Or do we need to move into a new way of seeing, more fitted, perhaps, to the world order of the 21st century?

The following issues are converted into 'core questions' within this article:

- The words 'literacy' and 'being literate' are usually interpreted as the ability to read and write. Widening the application of these terms to other fields (such as technology) implies understanding and communication of abstract but culturally determined symbolism (analogous to interpreting graphemes, phonemes and so on). If the term 'literacy' is applied to the processes of 'doing technology'; what is being 'read' and what is being communicated?
- The distinction between 'technicity' and 'technology'. 'Technicity' is taken to mean the ability to carry out a range of actions that result in a product whereas 'technology' implies a higher level of functioning, including an understanding of systems, with implications for learning technology and for developing design capability.
- What balance should exist between teaching 'about technology' (which might be analogous to 'reading') or 'through' designing technology (which might be analogous to 'writing') as a personal or creative endeavour? Examples within the text are taken from the Primary phase of education, although application to Secondary and Tertiary phases may be extrapolated.

## Key words

technological literacy, design capability

## Introduction

The role of technology in shaping the human destiny, past and future, has become increasingly apparent in recent decades, as archaeologists continue to unearth evidence of our deep past and environmentalists model worrying futures. Educating the young about technology seems, therefore, to be ever more urgent, rather than to be abandoned; it is intricately entwined in who we were, who we are and who we might become.

Starting from a consideration of the role of technology within the development of humanity and our relationship with the world of objects of our own creation, this article attempts to examine the role of technology within human culture, focussing on the use of the phrase 'technological literacy' to ascertain whether, linked to design capability, this might be usefully employed within the debate concerning the aims and direction of the technology curriculum within Primary education.

The term 'literacy' traditionally referred to the dual processes of reading and writing. The extension of the term to cover other systematic symbolic forms of communication (mathematical literacy, graphical literacy) is relatively recent. Employing the term 'technological literacy' might seem a way forward; the word 'literacy' might provide higher status to activities, with strong appeal to researchers, theorists and practitioners (Todd (1991); Waetjen (1993)). However, no phrase should be adopted for its persuasive value alone, especially if it appears at first sight to have real potential.

The reading and writing of text involves the recognition, decoding and creation of a culturally agreed symbolic system of recording language, itself a symbolic system. Thus, to apply the term 'literacy' to technological activity requires a systems view of technology that might be seen as parallel to the systems view of language. Gineste (2012), for instance, makes a quite specific link between the construction of grammar and the relationship between persons and things (Subject > relationship > Object). Like colleagues within the field of literature, he is concerned that focusing on the rationality of procedural ways of thinking may lead to the neglect of a more holistic approach that also considers values and ethics, so that technology education may 'lose the construction of meanings by reinforcing the acquisition of formalized procedures in the technical languages to the detriment of the development of semiotic thought' (p.198).

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Three core questions aim to unpick the phrase 'technological literacy' and consider how this terminology might move forward the discussion of the aims and principles underlying technology curricula:

1. *Widening the application of the terms 'literacy' and 'being literate' beyond the realm of language implies understanding and communication of abstract but culturally determined symbolism (analogous to interpreting graphemes, phonemes and so on). How does 'literacy' relate to the processes of 'doing technology'? What is being 'read' and what is being communicated?*
2. *A distinction needs to be made between 'technicity' and 'technology' 'Technicity' implies the ability to carry out a range of actions that result in a product. Much of this may be learnt behaviour, taught routines or enculturation. What implications does this have for learning technology and for developing design capability?*
3. *Finally, in relation to technology education, what balance should exist between teaching 'about technology' (which might be analogous to 'reading') or 'through' designing technology (which might be analogous to 'writing' as a personal or creative endeavour? What is the knock-on effect on curriculum development?*

### Technology systems and technological literacy

Technology, the capability to design artefacts, to envisage new systems and to significantly change the global environment, highlights humankind as a different sort of animal from even our closest relatives (Parkinson & Hope, 2009). Although other creatures (e.g. nest-building birds) make products, use tools, and depend on these for survival and adaptation to the environment, a distinguishing feature among humans is the constant refinement, adaptation and change of tools and artefacts at an ever-increasing rate. This is compounded by their reuse to create systems to develop further tools, artefacts and environments in a spiralling feedback loop (Leroi-Gourhan, 1945).

The University of Edinburgh reported (in Science Daily, November 14, 2012) the isolation of a gene (miR-941), which appeared after 6 million years ago (the separation of hominids from the apes) and is considered responsible for humans' abilities in tool use as well as language capability, suggesting that both are inherent within the human species. The ability to name relationships as well as objects enables humans to overtly evaluate the

effectiveness of tools, artefacts, systems and environments (both natural and humanly created) and facilitates the conscious construction of new forms at every level. Furthermore, we are able to do this predictively, involving internalized language through high-level analysis of the interactions between systems. Such purposeful design activity and its resulting products can be called 'technological' in a way that the activities of thousands of generations of nest-building birds or even the activities of our tool-using primate cousins cannot.

Defining design as 'the planning and patterning of any act towards a desired end', Papanak (2003 p. 3) claimed that the capacity to design is basic to all human activity and that the separation of designing from other human activities 'to make it a thing-by-itself, works counter to the inherent value of design as the primary, underlying matrix of life.' By this view, design, as a purposeful creative action in response to an opportunity or problem, not only underlies human activity in creating technological artefacts and systems but is embedded in their planning and production and cannot be separated from them. Not only is design inherent in the made world but our technologically constructed world has design at its heart.

Thus Doyle (2004) was careful to apply the word 'technicity' rather than 'technology' to the capacity to use tools for cutting, shaping and joining materials, components and/or ingredients in creating artefacts to satisfy human needs or wants. His term 'technicity' includes human activity in the pre-historic past, the routine use of tools by experts in the fabrication of artefacts, as well as the activities of children in response to direct teaching of skills and techniques. The term 'technological', on the other hand, implies systems thinking. For instance, an architect needs an understanding of physics in order to take account of tension and stress in reinforced concrete girders. The application of systems knowledge to complex socio-technical problems enables the construction of environments and even 'mega-systems', requiring an appreciation of 'fuzzy logic' in order to solve what Rittel and Weber (1974) called 'wicked problems': those that lack clear-cut solutions because of their complexity (including social implications), only succeeding as 'best fit' resolutions requiring re-assessment in the light of the demands of clients and desires of users.

This holistic thinking underlies the difference between design capability and simply the having of bright ideas. Young children have many bright ideas but these rarely work in the real world. Design capability implies an ability to see to the core of a problem or perceive an unrecognized opportunity and to devise an innovative way

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towards its resolution. To do this successfully requires understanding the nature of the beast, the physical and social systems that make up the whole environment in which the product is to be embedded.

The production of 'technology' requires the application both of design capability and systems thinking. Technology is more than a purposefully created system for solving human problems. It can itself be applied creatively to its own problems, thus forming feedback loops which generate more technological solutions that may or may not be deemed more successful or appropriate to human needs and wants. The human ability to build on the ideas of others, to see connections made by analogy and metaphor has enabled the exponential escalation of technological capability across the millennia. The ability to produce new and innovative ideas, to re-apply solutions from one area of human activity to another is the process by which technology has been created. Thus to employ the term 'technological literacy' must include full recognition of the role of design within the construction of artefacts and systems that support human life, whether this be the complexity of modern health care in a hospital or the apparent simplicity of a ring pull on a drinks can.

'Technological literacy' must include the development of pupils' own ability to design technology *through* direct hands-on action and problem-solving, not just by learning *about* the solutions of the past or the engineering of the present; in other words, considerably more than just a course on 'how things work'. Otherwise it would be as if children were to learn to read and copy without being encouraged to create texts that communicated their own ideas or demonstrated their understanding of the views and ideas of others.

In his discussion of the neural basis for language readiness Arbib (2003) lists skills that have parallels in pre-requisites for design capability: symbolization, intentionality, temporal ordering and 'beyond the here and now'. He also lists parity (the 'mirror property' p. 184): 'what counts for the speaker must count much the same way for the listener'. At first sight this is less obvious as a design skill until considering the focussed turn-taking of construction / manufacture that may happen without verbal communication or even eye contact.

Communities of enquiry and practice evolve systems of communication to enable 'inter-thinking' (Mercer, 2000), whereby systems such as drawing or constructing may be seen as possessing language-like characteristics, lending weight to the nomination of the term 'literacy' to the overall communicative process, regardless of medium.

For instance, Mercer asserts:

'Almost always, significant achievement depends on communication between creative people. Creative explosions of literature, art, science and technology, which occur in particular places at particular times, represent more than coincident collections of individual talent: they represent the building of communities of enquiry and practice which enable their members to achieve something greater than any of them ever could alone. '(Mercer, 2000 p.3)

Such formalization of communication creates a culturally agreed means of:

- Receiving and recording information,
- Understanding perceptions, ways of thinking and seeing the world,
- Framing thoughts and ideas,
- Communicating these to others who share their thoughts through a similar communication system.

To what extent does this insight from the field of linguistics enable us to think profitably about the nature of technology and apply this within a school setting? To consider the possibilities, three core questions (see introduction, above) have been formulated and are used to structure the arguments within the remainder of this article.

## Core Question 1:

*How does 'literacy' relate to the processes of 'doing technology'? What is being 'read' and what is being communicated?*

Widening the application of the terms 'literacy' and 'being literate' beyond the realm of language implies considering the understanding and communication of abstract but culturally determined symbolism to being analogous to decoding graphemes and encoding phonemes within written texts. The term 'computer literacy' is widely accepted as meaning the ability to use computers to communicate through this medium. Communication of technological design sophistication depends on social understanding as well as the functionality of materials and tools. From beads to iPads, markers of social identity and cultural status are interwoven with the exploitation of the physical characteristics of the materials and the means of production.

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Possible contexts of technological design might be summarized as:

- Socio-physical surroundings, resources, materials and techniques;
- Past shared experience and relationships between designer and user of technological products;
- Shared tasks or goals among community members and / or the ability to envisage these;
- Extrapolation / metaphorical leap from previous experience of similar kinds of tools, artifacts, systems and environments.

Viewing products created within other social contexts and cultures allows for cross-pollination of ideas and design solutions, which can become incorporated into the personal or local repertoire, through perceiving shared frames of reference within the products or systems. In school, teachers plan lessons based on an assumption that children understand the social and personal needs of others and will be able to design appropriate products, building on the children's ability to appreciate the perspective of others, including those they will never meet (Hope, 2004). For instance, children may be asked to design and make a mask to wear in a carnival procession, to find a solution to transporting water to a drought-ravaged village, or to design a throne for a sixteenth century queen. In all these activities, children are being asked to 'read' the social markers and cultural environments in which a specific technology is embedded, becoming aware that created objects bear socio-cultural knowledge (Baird, 2004).

This communication may be highly abstract and symbolic, more complex, multi-layered and socially nuanced than the reading and writing involved in decoding / encoding words on a page or screen. Design contexts may involve both 'modelling of' a solution and 'modelling for' its development and production, which, as Janich (2009) observes, require the forms 'X ist Model von / fuer Y bezueglich Kriterium K' (X is a model of / to Y pertains criterium K). To manipulate such cognitive complexity demands high level linguistic-like capability, which require the language-like structures of tacit knowledge (Polanyi, 1958).

Mock-ups or drawings may act as metaphors between ideas and products, as intermediaries between inner and outer realities (Winnicott, 1971), to convey ideas and communicate with others. Designing depends on shared meanings and understandings through symbolic systems whose terms have been agreed or are assumed by the community of practice and established usage. Eibl (2009) employs the useful term 'Zwischenwelt' (between-world)

to describe the role of human culture in structuring human interactions as well as symbolically interpreting the constructed world. This seems to encapsulate the way in which drawing, language, mock-ups and even gestures support the development of design ideas and the sharing of them within a community of practice.

Within the context of language development, Jackendorf (2002, p.242) identifies a 'metasymbolic capability' that can be observed in small children as well as adults. The 'open vocabulary' of human semiotics and semantics has its parallel in a design context, allowing for the development and flow of ideas, using and adapting existing conceptual frameworks in constantly changing and innovative new ways. This implies that 'design literacy' (a sub-set of technological literacy?) should include the novel application of symbolic systems to support the development of design ideas.

### Core question 2:

*What implications does a distinction made between 'technicity' and 'technology' have for learning technology and for developing design capability?*

Doyle (2004) employed the term 'technicity' to describe human interaction with tools and artefacts, based on an assertion that this activity has two basic characteristics: a symbolic system (such as drawing) and the manual competence to create artefacts. However, a distinction needs to be made between 'technicity' and 'technology' 'Technicity' implies the ability to carry out a range of actions that result in a product, which may include learnt behaviour, taught routines or enculturation. In line with Norman's (2007) wider application of Doyle's insights, this article asserts that the development of a symbol system is a marker for *technological* activity, a stage beyond Doyle's 'technicity'.

The knowledge required for the development of sophisticated techniques of manufacture may have had language as a significant by-product (as suggested by the discovery of miR-941) and deeply affected the way in which humans were able to manage their environment through created systems (for instance, through agriculture). Newborn babies are soon able to mirror the actions of others and to model possible solutions to their needs and wants (Pinker, 2002). The cognitive advantages of human neonatal helplessness include brain growth in response to outside influences rather than being mostly formed before birth as with other species. Making sense of the constantly changing and complex social world in which tools and artefacts are used within humanly created systems and environments, mediated through language,

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requires adaptable, flexible brains, especially where a new generation may be born into a very different technological environment to that of their parents.

The concept of 'inter-thinking', (Mercer, 2000) implies although the knowledge of science and technology exists in artefacts and their production, the driver of technological progress is hearing what others have done with them and/or what works in practice: 'In normal human life, communicative activity and individual thinking have a continuous, dynamic influence on each other.' (p.9). In other words, sharing knowledge, primarily through language or language-like activity, is foundational to the creation of technological systems. In evolutionary terms, therefore, once human language was sufficiently complex to describe and account for the needs and wants of others, to tell narratives that put those needs within the social context, to articulate the evaluation of the effectiveness of the technological solution and make comments about improvements and refinements, and to take on board these assessments in the production of the next artefact, then Doyle's 'technicity' was developing into 'technology' and technological literacy might be said to have emerged.

If this be so, then technological literacy was embedded in the enculturation of human infants from an early stage in the emergence of fully modern humans. The technicity of showing a child how to use a knife safely is essentially the same, whether the knife is made of flint or steel. However, enculturation into a system of technological literacy enables the imagination of a future by building on knowledge of the past and present through communicating shared knowledge and understanding within a social context.

The question remains, however, whether this is sufficient to encompass designing, which involves more than invoking the collective memory of cultural knowledge to ensure the continuity of established routines and technical practices, even ones that have proved successful over generations. The Neanderthals, that 'other humanity', appear to have perfected their stone-knapping techniques so well that although their bi-face axes became increasingly symmetrical over time, they remained essentially the same for millennia. Despite evidence of more complex use of bone, wood, birch gum, sinew and other materials to make simple tools with separate parts, in contrast to the explosion of range and variety tool forms of *homo sapiens*, conservatism and reliance on established practice characterized their technical world (de Beaune, 2008).

In contrast to *homo neanderthalensis*, we *homo sapiens* seem to relish surprise, humour and novelty. We are fun-loving innovation-junkies – especially when young and our brains are developing most rapidly. Karmiloff-Smith (1993, p. 63) quotes Marler (1991): 'It is less illogical than it first appears to speak of instincts for inventiveness'. The human mind, says Karmiloff-Smith, re-represents implicit knowledge explicitly. 'Do chimpanzees, like children, play with *knowledge*, just as they play with physical objects and conspecifics?' she asks (ibid.). Successful designing requires the ability to juggle and think creatively about all three: abstract knowledge, real objects and the needs of other people.

The desire for novelty drives technological design beyond the need to find solutions to problems of survival and comfort. Styling, decoration and customization relate to cultural and social semiotics, to reading and transmitting the literacy of community cohesion and belonging, which mediate between the individual and the group through artefacts within the social setting. In modern youth culture this might involve having the 'right' boots or the latest mobile phone. In early human culture, it may have been having a really life-like carving of a mammoth on your spear-thrower. The semiotics seem to be the same: 'I have the right stuff; I belong to the in-group; I am (or I am trying to be) socially successful.' The use of artefacts to support communication between individuals within and between communities and social groups enhances collective thinking through the development of design genres and communities of discourse. Evidence for this exists in Blombos Cave, South Africa as far back as 80,000 years ago where archaeologists found shells carefully pierced with a tool to make beads (Balter, 2009).

Such routines and repertoires, carrying over from one task to another, can become the means of orientation to the minds of others. The development of a community of practice can be observed among young children in school as they build a repertoire of shared solutions to practical problems. For instance, a teacher might be heard saying to a child something like: 'You could use that criss-cross folded mechanism so-and-so used the other day.'

This might also occur, for instance, through:

- A 'conversation' with a drawing: making ideas explicit, viewed, evaluated, modified and communicated;
- Working in collaboration: creating together, perhaps with a construction kit, in a conversation-like form, each child adding or modifying the evolving product.

Complex systems of design conversation are operating here; enhanced by language, especially for evaluation, but

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both activities can be continued without recourse to words as the symbolic systems support the development and progress of design thinking. The drawing, perhaps, is more likely to be an individual activity, although knowledge of shared systems such as employing a certain kind of shading or the use of a legend to enhance readability. In collaborative construction, reading body language and facial cues may be as important for turn-taking as seeing a potential next step in the design development. In the author's research into young children's design capabilities, some children were seen to observe each other's contribution and then add a next or alternative step without making a verbal comment (Hope, 2007), sometimes whilst talking about something entirely unrelated.

### Core question 3:

*What is the knock-on effect on curriculum development in maintaining a balance between teaching 'about technology' and 'through' designing technology?*

This article has argued that the application of the term 'literacy' to technological capability requires systems understanding. The individual needs to know and understand the conventions of the system in order to be able to comprehend and communicate meaning. Familiarity may have made this automatic and highly efficient (e.g., scanning text) whereas originality may demand days or weeks of deep thought (writing a poem). Many years of schooling is required to learn the skills to interpret graphemes and phonemes, use connectives, choose a good metaphor, become aware of bias, be able to write in a range of appropriate registers, and so on; likewise with the development of technological literacy.

Learning about technology, as a form of technological reading, knowing what others have said and wish to communicate is only part of what is required. Teaching children about already existing technologies may give them a deep understanding of mechanisms or electronics or food production, but, as in language literacy teaching, the aim is not just to enable children to read the words of others, but also to create their own texts in a range of genres – and to know which is appropriate genre to use in specific situations. In the National Curriculum for England and Wales, the emphasis within teaching technology has tended to be on design capability rather than on technical competence (Barlex, 2011).

Further, concerns about the ethical and moral assumptions that lie at the heart of a consumerist society and its demands upon designers, technology and the finite resources of the planet, have led to calls for such issues to also be included within technology education (Baynes

(2005), Keirl (2007)). As Martin (2012) rightly argues, as the gap between consumers and producers widens (literally, the width of the globe, as well as in experience) so this increases the need for young people to understand and experience the means of technology production for themselves. The consumer society of the 'developed' countries, built on the backs of the 'less developed' world, is a non-sustainable technological system that needs examination with and by the young people who will inhabit the global future. The ethical dimension of technological literacy, so strongly advocated by Keirl (2009), needs to draw on a critique of the history of technological development in the Western world.

Barlex (2011) argues for the need for a greater emphasis on developing systems thinking within technology teaching, whilst acknowledging the difficulty of achieving this in practice. The present article has argued that the term 'technological literacy' involves a systems view and that to design effectively demands the ability to manipulate symbolic and metaphorical systems to develop and communicate ideas. In the same way that children communicate effectively in writing by writing, so too they learn to become effective designers of technology by being directly involved in practical designing. In working in groups with construction kits, for instance, children in Early Years settings develop and exploit a shared language of modelling conventions that facilitate efficient communication and understanding, often developing a storyline that dominates the purpose and form of the model, whilst the shared meanings related directly to physical construction remain tacit and un-stated. The greater the children's shared familiarity with the kit, the more readily and effectively this can take place. This is analogous to the craftsman's ability to create a product without producing formal plans, using internalized knowledge, skills and understanding of tools, materials and techniques.

In classrooms with older children, the teacher may set specific design challenges that require to think beyond the use of tools or joining techniques and to consider the socio-technological environment that is the context for the design challenge. They acquire an understanding of design genres, which are analogous to the genres of language literacy: narrative or persuasive; a nostalgic folk-tale genre or a no-nonsense business genre, and so on. This range is mirrored within the various genres of drawing that might be used within designing: for instance, observational and/or annotated sketches, diagrams, graphs, even maps (Hope, 2008). Design solutions and proposals, like writing and drawing, need to be appropriate for audience and purpose; such design knowledge could, therefore, be itself described as a kind of technological literacy.

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## In Summary

Being literate requires knowledge of the system rules and conventions to be able to apply them effectively and accurately, understanding and employing such means as appropriate genre, register, grammar, syntax and semantics. The development of communities of thought, with shared understandings about symbolic representation, is characteristic of human activity, including technological activity. It can be seen among pre-schoolers playing with wooden building blocks, young designers drawing what they might make and, later, learning to program computers to bring to life their design ideas (Hope, 2006), as well as in the multitude of adult design activity.

In this article it has been argued that human technological capability involves:

- The ability to read and apply metaphorical and symbolic systems to represent and communicate design ideas;
- The ability to perceive and internalise the necessary constraints and possibilities;
- Complex and sophisticated cognitive capabilities in order to imagine and create a product that functions to the satisfaction of a user's requirements.

These capabilities could only be developed through the employment of a symbolic system that enables the manipulation of multiple variables. To further enhance and develop children's technological and design literacy, therefore, requires the development of conscious and explicit understanding with regard to the symbolic nature of design thinking and the nature of technology as a created social system.

In answer to Stables' (2010) question *What do we want learners to 'take home'?* The answer has to be more than just a product that they have made in school.

Technological literacy should combine design capability and ethical awareness with technical competence and know-how. The three core questions of this article have provided the entry points to the discussion.

Black and Harrison's (1986) definition of technology included the core aim as being 'to improve the quality of human life', which seems to be a constant, whether at individual, community or global levels. The centrality of technology within human evolution and civilization, the benefits of its modern developments in terms of prolonging individuals' well-fed lives, adequately clothed and sheltered and in good health are countered by the realization of the downsides, especially in terms of environmental impact, and the question marks over sustainability.

Finally, therefore, what kind of technology education do we, as a design and technology community, envisage will help to 'improve the quality of human life' in the next 20 years and in doing so lay the foundations for our species survival beyond the next 100? Young people are naturally concerned about the future and want to do something to help. What tools can we, as a subject community, provide to them that will be useful, meaningful and worthwhile? The increasingly complexity of the technological systems in and through which we inhabit the planet demand education about that technology. However, being actively involved in designing and creating personal solutions to problems and opportunities stimulates the envisioning of creative possibilities and empowers individual conation. The design and technology community has, rightly, maintained the importance of both sides of technology education and should continue to do so, both in its discussions with governments and in the ongoing support of research and theoretical understanding.

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