Beyond Knowing How to Make it Work: The conceptual foundations of designing

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Abstract
Gilbert Ryle (1949) divided knowledge into "know that" and "know how", which is neatly appealing to many design and technology educators, and like many writers on developing the curriculum, Kahney (1993) made a distinction between declarative knowledge:

> *verbal knowledge, that is, the kind you get from books, instructions and being told what to do.*

and procedural knowledge:

> *In order to achieve skilled performance you need to be able to translate declarative knowledge into actions. A new form of representation, known as procedural knowledge must be established. (p.91)*

However, a curriculum that consists simply of information and techniques not only fails to reflect the original intentions of the creators of the UK National Curriculum for design and technology but also misses the mark in terms of developing creative and inventive minds.

Evidence from such fields as cognitive archaeology (e.g. Renfrew, 1994) suggest that the symbiotic relationship between mind and hand that typifies technological action and innovation was a primary driver within human evolution. Thus designing technology is one of the defining characteristics of our species. Technology education, therefore, should not be seen simply from an instrumentalist viewpoint as a preparation for the world of work but as a preparation for full functionality in human society.

A tentative taxonomy of the features of conceptual learning within technological action should, therefore, include those features that define our humanity and our distinctiveness from other species. These are identified as the ability to be self-reflective, to play with ideas, to make analogical connections between apparently disparate features and to indulge in leaps of the imagination. The contention is that if we fill up our curriculum with declarative and procedural knowledge, without acknowledging and encouraging the unique response or the innovative idea, then we will have designed a curriculum that, however hard we try, will never really succeed in "making it work" for many of our most creative pupils.

Key words design, cognition, symbolism, evolution

Introduction

This article is a snapshot of a moving target, which is in the early stages of its trajectory. It documents a process of personal boundary crossing that began during my doctoral research into young children's use of drawing for designing and is currently developing into an exploration into human cognition as revealed through our design capability. This has included the literature on metaphor, analogy, humour and other areas related to the way the human brain functions but, currently, into human evolution and the pre-history of the human mind in order to unpick the characteristics and capabilities that underpin what it means to be a creative, design-capable human being.

From looking at research beyond the normal boundaries of design and technology into the field of cognitive archaeology and at the evolution of our species from tool-making primates into designers of technology, conclusions have been drawn on the kind of technological education we should be providing. A curriculum that consists simply of information and techniques about making things misses the mark in terms of developing creative and inventive minds. Technology education should not be seen simply from an instrumentalist viewpoint as a preparation for the world of work but as a preparation for full functionality in human society.

Thinking about Knowing and Doing

Archer (1986) asserted that the three "R's" of education were "reading, reckoning and wroughting" which represent three modes of knowledge: narrative, paradigm and "doing"; the Greek *techne*. The duality of mind and body in Western thought, with its insistence that mind was more important, has constantly devalued practical activity. Gilbert Ryle (1949) divided knowledge into "know that" and "know how", which is neatly appealing to many design and technology educators since the dualism of *know how/know that* can be extended and applied to designing and making processes. There is more happening within designing, however, that this simple dualism. The strategy chosen to move the design forward depends on seeing potential within a parallel, analogical system for modelling a design solution (which may be a drawing, a mock-up or a maquette) all of which stand in an analogical relationship to the final, real, product (Figure. 1).

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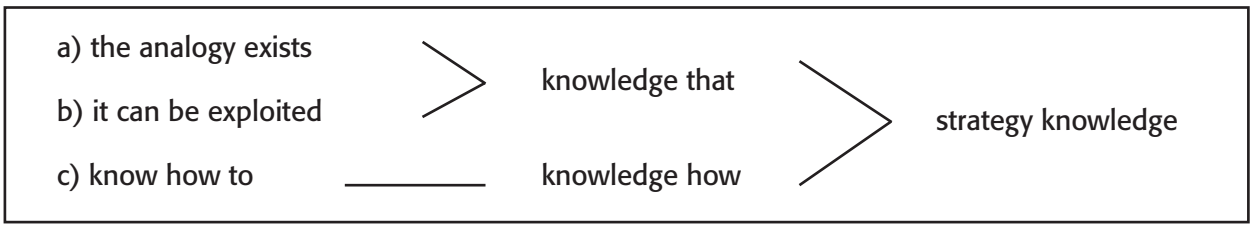


Figure 1. Strategy Knowledge (Hope, 2000)

The *knowing that* includes the recognition of both the relationship and the relevance of a modelling technique as well as the *knowing how* to do so.

Factual knowledge will not impact on a child's (or adult's) approach to a practical design task unless they see its relevance to the task. Children as young as five years old, for instance, can draw what they want to make but some of my research subjects asked "Why are we drawing this twice?" (i.e. once on the paper and again on the card) when they were making puppets. Egan (1999) also noted that children did not understand the function of drawing in the design process. Knowing the parameters of the task and knowing how to draw their ideas was not enough.

A key to the success of my own research in the classroom was explaining to the children the purpose of design drawing in a way that they could understand. This explanation (extrapolated from Lakoff and Johnson, 1980) was that design drawing is simultaneously a Container For Ideas and a Journey Of Ideas across the page and off the page into the prototype and/or product (Figure. 2, Hope, 2003).

Enhancing children's ability to model design solutions through equipping them with the techniques to do so would only be possible if they saw analogies between their ideas, the model and the final product, and also perceived the potential of making those analogies explicit.

The model (whether drawn, made or described) stands for the image in the mind and the product that will exist in the real world and can be discussed, examined and evaluated as if it were the real thing.

However, despite the success of the metaphor, I was acutely aware that I had neatly side-stepped the central issue of whether or not design drawing was a metaphor by finding a metaphor for design drawing that produced success in a classroom. I believed, but could not imagine how it might be proven, that the human ability to see analogies across domains and to see and reason "as if" (Craft, 1997), "seeing as" (Wittgenstein, 1969), is close to the heart of design capability. The ability to gain new insights and build new concepts as metaphors or analogies to the ones we already possess is parallel to the capabilities that enable us to be designers.

The Contribution of Cognitive Archaeology

Paralleling the philosophy of Ryle, but with no reference to him (and probably quite unaware of his contribution to English-speaking epistemology) the French cognitive archaeologist Pélégrin (1991) identified *connaissance* ("knowledge with understanding") and *savoire-faire* ("know-how") as the two main characteristics of stone knapping hominid's cognitive capabilities. Producing a stone chopping tool, says Pélégrin (1991), required an inner mental model of the final shape, an understanding of the properties of stone and the know-how with which to combine the two. Handling examples of such tools from half a million years ago inspires a sense of

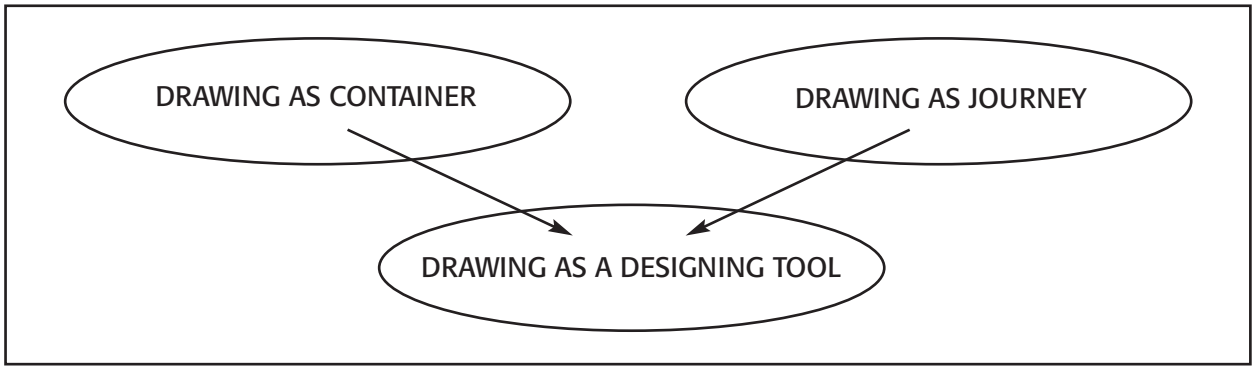


Figure 2. Container and Journey Metaphor of Design Drawing (Hope, 2003b)

connectedness with the tool-makers who created these beautiful tear-shaped symmetrical artefacts. Yet these tool-makers were not us, *homo sapiens*, but pre-human hominids, *homo habilis*. In fact, the first stone tools were not created by hominid species at all but by *pre-homo* primates, *australopithecus*, the younger cousins to 'Lucy' discovered by archaeologists in Ethiopia on which Coppens comments:

> *This is the first appearance in our history of "one tool made by another" for a clearly determined purpose..... The crafted tool, modest as it may be, implies a form for an idea, an organised and transferable project, an elaborative communication.*
>
> Coppens (1985)

Thus, whatever it is to be fully *human* does not reside within the technical competences of making things. *Know-that* and *know-how* are not enough to define our technological capabilities. Among the distinguishing characteristics that separate modern humans (*homo sapiens*) from our closest living relatives the common and pygmy chimpanzees (*pan troglodytes* and *pan paniscus*), design capability comes high on the list. Evidence from cognitive archaeology (e.g. Renfrew, 1994) suggests that the symbiotic relationship between mind and hand that typifies technological action was a primary driver within human evolution, such that it divided those who became us from the Rest, even within the hominid species. Thus designing technology is one of the defining characteristics of our species.

The joined-up analogical thinking of which *homo sapiens* are capable, transforms *know-that/know-how* into the most powerful thinking strategy on the planet. It enabled us to design technology. No other creature on earth does this. Other creatures have technical fixes that enable them to survive but no other creature actively and purposefully designs the technology that they use in the way that humans do. However much training various researchers have devoted to pygmy chimpanzees, they do not make metaphorical leaps between domains of knowledge (Mitchell, 1997).

Mithen (1996) claimed that a cognitive re-shuffle happened at the birth of *homo sapiens*. Whereas other previous and contemporaneous *homo species* (including the Neanderthals) were knowledgeable about their environment, had well-developed social skills and tool-making capacities, there were limited connections between their separate spheres of thought. When the Great Leap Forward of metaphorical thinking occurred (somewhere between 100,000 and 40,000 years ago), then creativity is evident in the sudden flowering of tool types, decoration, statuary and art.

Remains of Neolithic culture in Britain and Europe, illustrates the contrast between the thinking and acting of homo sapiens and earlier *homo species.* Stonehenge is one of the best known of the megalithic monuments created in the more recent pre-historic past. Pitt (2001) claimed that its construction combined the stone-working techniques in which these people were undoubtedly expert with the structural form of earlier wooden circular monuments such as Woodhenge. Pitt goes as far as to claim that the underground parts of the sarsen stones (the massive outer circle that support lintels to make the horse shoe shape of Stonehenge) give evidence of having been worked as if they were giant flints, by flaking off large shards, as would come naturally to expert Neolithic stone-workers. The tops of the sarsens, meanwhile, show mortise and tenon joints associated with woodworking techniques. Further, he claims that each pair of lintel-supporting sarsens consists of one well worked, smooth stone (representing timber?) and one rough, more natural stone, as if the builders were consciously playing with the wood/stone relationship.

Even if Pitt is wrong, the plausibility of his argument connects us to the thinking of these people. The way in which Medieval master masons incorporated religious messages in the design and layout of cathedrals and churches across Europe gives us a feel for the way in which Stonehenge's constructors might have played with the meanings and metaphors in the construction of their great religious monument. It matters not that we cannot know what these were, we can put ourselves into their mind frame. Incorporating religious, social and cultural symbolism into products and structures is a uniquely human affair. Our Neolithic ancestors had technology, in all its social, cultural and economic dimensions, not just techniques (Hope, 2008).

Design and Cognition

The following list, a sort of tentative taxonomy, of generic human capacities that underlie design capability is not exhaustive and is certainly not in any particular order. These are areas that need to be explored and examined in greater depth, suggesting other boundaries to cross in order to understand the nature of human design capability. The evidence from cognitive archaeology cited above seems to indicate that the ability to design is close to the core of what it is to be human. The examples from children designing that are used to illustrate some of these capacities come from my research into children's design drawing, simply because they were readily to hand. Other

forms of modelling (discussion, mock-ups, maquettes, and so on) satisfy the criteria equally well.

- **Agency and conation**

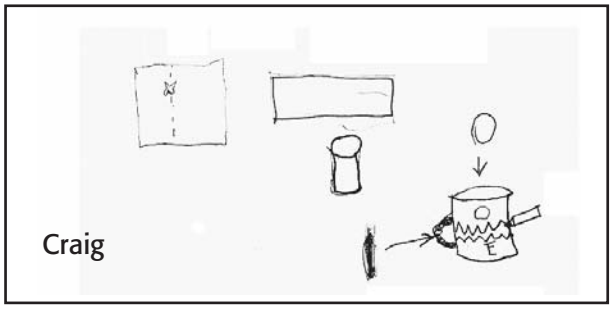
  Subsumed under the term 'agency' are concepts such as sentience, self-awareness and evaluative capabilities and all the other relatives of meta-cognition. The ability to classify and reflect on the success of one's own and other peoples' thoughts, ideas and designs depends on the awareness of one's self as an agent who can plan, decide and effect changes in the environment, whether physical, social or cognitive. This is unique to humans and has led, among other things, to the ability to take the perspective of another and design something that will be useful for someone else, even if we have no need of the artefact. It enables us to evaluate existing products or possible design solutions which we will never use ourselves.

  Atman (1992) used the word 'conation' to imply an "I can do", empowerment and action, for which a sense of agency is primary. 'Enaction' is a similarly related term, utilised by Khatchatourov et al.:

  … all technical artefacts, from stone tools to cars to computers, are "enactive interfaces" that mediate the structural coupling between human beings and the world they live in, and hence bring forth a particular world of lived experience

  (Khatchatourov et al. 2008)

  In Example 1, Craig, aged seven years, has drawn a pencil alongside his design idea. "That's me drawing" he explained, in assertion of agency and self-reference.



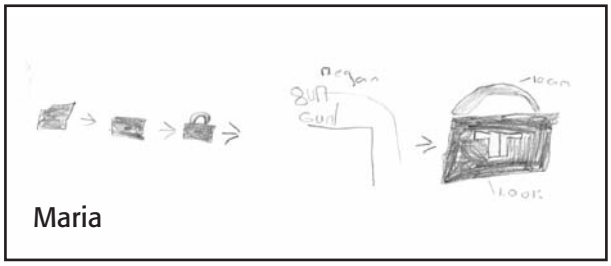
Example 1."That's me drawing!"

Tomasello (1999) claimed that awareness of one's own agency leads to a theory of mind that perceives others as having similar minds. Deliberate teaching and attentive learning spring from the assumption of intentionality: that what is be demonstrated is intended to be imitated. Not only are both teacher and learner agents within the transmission of knowledge from teacher to learner, but the assumption of the learner's agency by the teacher means that the teacher relies on the learner's ability internalise the learning and to apply it across a range of new situations. Young chimps copy older chimps cracking nuts with stones but they do not take that knowledge and apply it to new and novel situations nor do they seek out or create new opportunities for applying that knowledge. We live in hope that our learners will take what we teach them into new and innovative areas of exploration and discovery.

- **Symbolism**

  Part of the limitation on chimps' cognitive development is, of course, linguistic. Language, both spoken and written is the uniquely human symbolic reference system that enables us to think, imagine and design: "Man is a symbolic animal" (Fèvre, 2004). This symbolic capability enables us to make sense of the world through the creation of narrative and to communicate our ideas to others.

  Drawings, prototypes and models also serve a symbolic function. Example 2 not only shows seven year old Maria's use of numerical standardised measuring units, but also her ability to use a diagram that records just the relevant part of the drawing for her purpose. She does not need to re-draw the whole travel bag that she is designing for a toy teddy, just the two sides to remind herself of the dimensions.



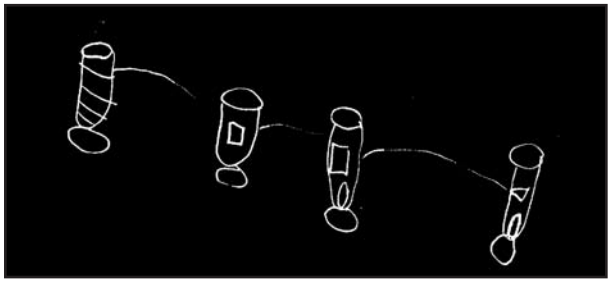
Example 2: Numerical Symbolism

The vital role of language in design was demonstrated in the development of one child, Andy, whose design capability I tracked for five years (Hope, 2007). He was on the Special Educational Needs Register from first entry into school at age four years and identified as having some form of language development delay. When he was six he produced a most impressive drawing of a rocking chair as seen from the back and drew a picture of the house he would like to make for a story character which he followed

quite faithfully in the making. However, despite this apparent early prowess, by age eight he had been overtaken by his peers and by age nine, when they could use drawing quite effectively to generate and develop design ideas, he was producing one simple line drawing without any labelling that communicated little information about what he intended to make. He was not an isolated case. I frequently observed that children with linguistic impairments struggled to design and make a product that was comparable to that of their peers either in terms of creativity of response or in satisfying the design brief. Language, it would seem, is an essential requirement to design.

- **Systems**
  Human technological activity involves awareness of the teleology of the design task and the systematic forethought and planning of the processes and techniques needed to bring it into being, including gathering together all the required materials and, possibly, involving others in the plan. Integral to this are both analysis and synthesis, the ability to mentally take things apart and re-construct something new.

  During one lesson, Maria and I conducted a conversation at cross-purposes because I thought each sketch on her paper represented a different idea. Later, I saw she had added connecting lines and I understood that she wanted me to know that she had been using drawing to think through the process of making the product.



Example 3: Maria's Easter Egg Holder

Being systematic is more than just about being organised or being able to plan what you want to do. It is also inherent in the ability to reflect and evaluate and to compare the evolving product to the idea in the mind's eye. It infers an ability to have in the mind an evolving model of what the product might look like at various stages of production, even when these are spread out across several working sessions that might be a week or more apart. It implies, therefore, the ability to pick up the thread where we left off and know where we were in the process and be able to continue it to the same conclusion that we originally intended.

- **Paracosm**
  A paracosm is a complete, internally logical, fantasy world: those completely imaginary worlds that people create within their heads for their own entertainment, especially when bored or needing some time out from the real world. The ability to create and understand the world as stories and metaphors ("Contes et Metaphores" Fèvre, 2004) underpins the creation of the design narrative, and is first cousin to the dialogue between the inner and outer reality that Winnicott (1971) identified within play. This ability to reason, imagine and think within a complete created system, the author's skill, is also the designer's skill.

  Paracosm as a form of internalised linguistic play has its origins in the role-playing of young children and which, like play, conforms to a consistent internal logic. They may push to the brink the boundaries between the possible and the impossible, but paracosms do not break their own rules. For instance, however crazy the story might seem to others, the idea of an island populated by tiny people, on which a normal sized man is shipwrecked, then falls asleep and wakes up to find himself tied down by hundreds of tiny threads, has its own internal logic. The contradictions were ironed out in Defoe's head as he created the tale, just as the creators of Star Trek struggle to devise solutions to space flight problems that do not contradict the laws of physics, to the extent of even consulting Stephen Hawkings as an advisor.

  In the same way, great breakthroughs in science or technological innovation spring from the human ability to create and reason within a semi-closed logic system, whilst also allowing analogies from completely different, sometimes even contradictory, fields to permeate the boundaries and fuel the on-going creation. This paracosmic capacity is, I believe, fundamental to design, creativity and invention. Designing requires the ability to create paracosms, to think and reason and create possibilities within a narrative context that has its own internal logic and that obeys the laws of the system as created.

- **Rationality**
  Our rational faculties enable us to see what will work and what will not, whether by deduction or induction (of which extrapolation is the extension towards analogy and metaphor). We compare what we see to what we know from past experience and can judge whether or not the idea holds an internal logic. This faculty develops with age. For instance, adults see the joke within Heath Robinson's Professor Branestawm inventions whereas

small children just stare at them without perceiving the illogical and impossible.

The age at which children's humour develops to the point where they start to tell linguistic jokes (about age 6-7) is also, interestingly, the age at which they can begin to use drawing effectively for designing. However much Piaget's experimental technique has been maligned for its validity (for example, Donaldson, 1979), he did appear to have come to valid overall conclusions. There is a shift in the way in which children reason about the world around this age. I think this is linked to rise of the rational, the understanding of the rule-bound nature of the external universe. The flip-side, the apparent decrease in creativity, is the evidence of struggling with the rules and learning which rules can be bent and which cannot.

There is a perennial concern that children appear to become less creative in the middle years of childhood and that somehow schooling has robbed them of that essential spark that was so obvious a characteristic of the pre-school years. I would like to suggest an alternative explanation. Young children's ideas are original but they are divergent, which is different from creative. Their ideas rarely work in the real world sense of the word. Their ideas are fluid and they are willing to pretend all the bits that don't fit the rules of the game or task. This creates a dilemma when teacher is setting the task. For instance: when asked to choose which material to use to make a waterproof hat, which aspect of the task do you pretend? That you like black bin liners or that red tissue paper is waterproof? Red tissue paper is the clear winner until you have learnt the right set of game rules.

- **Creativity**
  Koestler (1974) began his book "The Act of Creation" with a consideration of humour. In his view, the ability to see the mis-match between two things as funny is fundamental to creativity. His term "bisociation" includes analogy, metaphors, trophes and other linguistic and poetic devices, as well as design. Paralleling Lakoff and Johnson's "Metaphors We Live By" (1980), Fèvres (2004) in "Contes et Métaphores" (Tales and Metaphors) claims that all social knowledge is built through narrative. However, I would contend these conclusions as much as Bruner's (1962) belief that there was no possibility for dialogue between the paradigmatic (mathematical and scientific) ways of thinking and narrative ways. I think that true creativity comes through the bisociation of the rational and the divergent. It is the application of reason to possibility that turns divergency into creativity, the crazy idea into a plausible design.

Some of the children's work that I examined in my research forced me to question whether a solution is creative if it is beyond the constraints of the design brief (Hope, 2004, 2007). My current thinking is that a successful design solution must also follow from the rational as well as the narrative. One girl, Zara, was so good at narrative that she even constructed "Episode 2" for one of my design tasks (Hope, 2004) rather than satisfy the design brief. It was not, therefore, a creative design solution to the question she was asked to address. Leaps of the imagination are fine, as long as they land somewhere within the zone of possible answers (Middleton's (2000) "satisficing zone"). Playing with ideas only moves on to being a design solution if the answer conforms to the internal logic of the design question; if it lands within the paracosmic space.

In Summary

Engagement with the cognitive archaeology literature has, for me, shed light on the nature of design capability and prompted questions about what kind of design and technology education should be provided for our children. An instrumentalist, vocational view of the subject, simply equipping young people with skills and techniques for the world of work, does not challenge and extend their core human capabilities. Too often, children in schools seem to be doing a series of structured practical tasks in which they learn a series of techniques rather than being given a design assignment in which they can make real choices and make real connections with other things they know and care about. What I have tried to do in this article is to begin to unpick why design and technology education should be going beyond the "how to make it work" approach in which all the real decision-making is done by the teacher.

From my reading of the cognitive archaeology literature, it appears that the now extinct pre-human hominids had *know-that* and *know-how* aplenty. They knew when the herds of antelope or reindeer would pass by their cave and they knew how to make spears and choppers and fire. They passed on this knowledge of facts and techniques from generation to generation and yet they went extinct. It seems that one factor may have been rapid climate change. They could not adapt fast enough or radically enough when huge temperature swings happened within a generation. So, given what might be coming soon, we need to do something in the education of young homo sapiens in the interests of the future of our species' survival on our planet and that equipping children with practical design capabilities is probably one of the most essential components of their education.

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