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Some new ideas on new ideas: Creative, inventive thinking, values and Design and Technology Education

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Abstract

The development of Design and Technology curricula has always been premised on the importance of the act of designing and of the value of the contingent activity of creative thinking. Despite this, there has been a great deal of uncertainty about methods for developing creative thinking abilities in design and technology students. However, the results of research from cognitive psychology, engineering and invention suggest some promising strategies for application in design and technology classes. Moreover, these strategies are emerging during a time when issues concerning ethics and values are also being raised. This paper presents a brief summary of the research into creative thinking strategies, and of possible applications, and then goes on to argue that the strategies and settings that promote creative thinking in design and technology make the area not only one that is suitable for addressing ethics and values, but that it may be one of the major reasons for including design and technology programs in school curricula.

Keywords:

creativity, psychology, engineering, invention, design and technology, values, research

Introduction

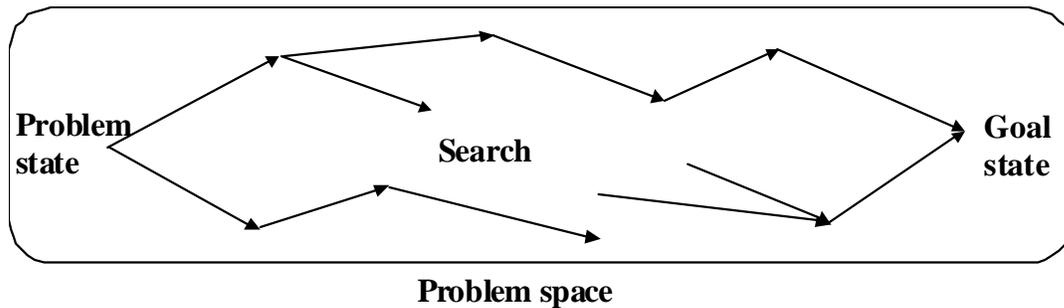
Design and technology programs have been seen by practitioners to perform various roles in school programs. On the one hand the area has been regarded as requiring low-level intellectual skills and as a suitable vehicle for developing physical skills in manipulating concrete materials. On the other hand, claims have been made that because students regard design and technology learning activities as challenging, and 'real', that the activities that take place in these settings involves more profound learning. However, until recently, there was little evidence to support either proposition. In this paper I will draw initially on research into designing to make the point that this is a complex intellectual activity. Then I will draw on material from the literature on mental imagery, engineering and invention to suggest that we now have sufficient research to draw some conclusions about learning in design and technology. Finally, I will draw on recent research on values to suggest an important purpose for design and technology education.

Designing

Designing, or technological problem-solving, has, until comparatively recently, been seen as a largely unproblematic process within the psychological literature (Simon, 1981). The process is often represented in a diagram that generally includes the steps of: identifying a problem, undertaking research, generating solution/s, producing solutions, and evaluating the solutions. The implication contained in the diagram is that each of these steps can be accomplished in the same way that a mathematical problem might be solved if you know the steps. This view has been supported implicitly from cognitive psychology (Greeno & Simon, 1988; Anderson 1993), with information processing theory arguing for a similar process for solving simple or complex problems. Indeed, the same model, illustrated in Figure 1 below, has been used to characterise the nature of all problem types.

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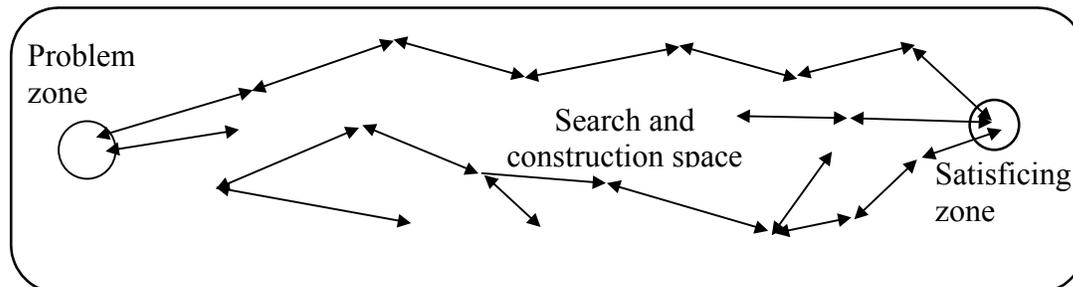
Figure 1. Model of a problem space (Newell & Simon, 1972)



In that model, problems are regarded as occurring in a *problem space* that contains three elements. The first element is what is described as the *problem state*. This consists of all that is known of the problem at the start of problem-solving. The second element is the *goal state*. The goal state is intended to represent the solution to the problem. The third element is the *search space*. The search space is taken to be all of the information the problem-solver has in their memory or can access that will help them solve the problem.

This conceptualisation works for simple problems and problems where it is possible to specify all aspects of the problem space. Indeed, the model assumes that there is a specific and singular starting point and that there is one precise and correct solution. It also assumes that all strategies required to solve the problem will be present in the search space and need only be found by a process of search. However, design problems tend not to have precise starting or finishing points (Schon, 1990; Goel, 1988; Goel & Pirolli, 1992) and they are generally solved by a combination of strategies that come from memory and strategies that have to be created. Over the last few years I have been doing some work developing and examining a modified version of Newell and Simon's problem space model. The model is illustrated in Figure 2, below.

Figure 2. Revised concept of a problem space (Middleton, 1998)



The modifications were made to account for the particular characteristics of design problems. The modified model does make the point that design problems are complex and ill-defined. As a consequence of this, students in design and technology who engage in designing are also involved in a complex intellectual activity.

Representations of knowledge

One reason for the complexity of design is that the act of designing involves the use of at least three representations of knowledge. The three representations are visual, verbal and tacit. That is, designing involves: producing and using mental images that are in some way isomorphic to objects in reality; producing and using abstract propositions of knowledge that can be likened (broadly) to verbal renditions of knowledge; and using tacit knowledge, which may be derived from either of the two previous representations or from perception of physical action.

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Designing involves the devising of solutions to problems where there is the requirement, additional to solving the problem, that the solution be creative. That is, that the solution be original and purposeful (Torrance, 1964). Work by Finke (1989), Finke and Slayton (1988) and Finke Ward and Smith (1995) have provided some important findings that suggest that the use of visual mental images provides a powerful representation for generating creative solutions to design problems. In one large research project Finke and Slayton (1988) demonstrated that with suitable instructions, students could use visual mental images to respond to design-like problems. In doing so, they generating solutions that were judged to be noticeably creative.

Engineering and invention

Webber Moder and Solie (1990) examined the way contemporary inventors in engineering produce new solutions to problems. Weber et al found that inventors routinely use visual mental images to both represent possible inventions, and to vary parameters and to test the effects of the variations. Thus Weber et al found that inventors used both static and dynamic visual mental images in the generation and testing of new solutions to engineering problems.

Carlson and Gorman (1992) examined the invention processes of a range of famous inventors such as Bell and Edison. Carlson and Gorman found that in addition to visual mental images, inventors worked from existing objects to create new ones. By working from, Carlson and Gorman meant that they had the physical items available to view, handle and use as idea starting points. Thus, viewing and manipulating objects that had some meaningful relationship to the to-be-invented object was seen as important to the process of invention.

In summary, designing, inventing, and the related activity of design and technology learning are: complex activities requiring higher-order thinking; where that higher-order thinking is facilitated not primarily by abstract thought but by visual mental imagery and the manipulation of concrete materials; in situations and contexts that are meaningful to students.

So what?

I would now like to refer back to one of the themes for this conference - What purposes do we value for Design and Technology Education? In June last year I attended the Thinking Conference in Harrogate, somewhere south of Hadrian's Wall. The Keynote speakers included David Perkins, Bob Sternberg and Howard Gardner - three of the leading researchers in thinking, creativity and intelligence. However, Perkins presentation departed from his previous themes of inventive thinking and was concerned with morality, Sternberg's paper went beyond his previous work on intelligence to explore the issue of wisdom, while Gardner concluded that performing what he called "good works" which he describes as "when excellence and ethics meet" is important. In other words, all three presenters had come to the not particularly surprising conclusion that intelligence and creativity were not of themselves enough, and that human thought and action, even very clever thought and action, needed to be mediated by what is variously referred to as ethics or values or something connoting "goodness".

This new information might be interesting and indeed compelling in its apparent logic and contemporary relevance, given current and recent past world events. However, it still begs the question of how this relates to design and technology education, and indeed how it relates to what I have said in the earlier part of this paper. I will make this connection by drawing on research concerning knowledge representation and its role in problem-solving and thinking, two reasonably important processes in learning.

Until quite recently, ideas were only seen to have importance if and when they could be expressed in words. Indeed, some commentators have expressed the view that ideas do not exist until they have been rendered in words. Ideas expressed in images or concrete representations were seen as not so important, and ideas expressed in ways that are neither verbal nor visual, such as tacit knowledge, were seen as least important. Thus there was seen to be a hierarchy of representations of knowledge with abstractness seen as most cognitively demanding and most important. This is played out in education where universities, which are seen to deal with abstract, verbally mediated ideas are seen to be more important than technical colleges, which deal more with visual and concrete ideas, and these are seen as more important than

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settings where tacit knowledge is gained through practice of a skill, such as a workshop setting. (Fortunately, this generalisation is becoming less general).

It also used to be thought that only abstract representations of knowledge were used in complex thinking. However, we now know that humans use mental imagery to solve complex problems (Kaufmann, 1990), and moreover, that images can provide the most efficient representations for solving complex problems. Larkin and Simon (1987) have provided some useful evidence to suggest why this is so. Larkin and Simon argue that images provide more efficient representations for problem-solving because the material in an image is organised according to the relations of the problem content rather than being organised according to the rules that apply to the abstract code.

We now know that inventors routinely work from concrete representations of past inventions to generate new inventions (Weber, 1992; Weber, et al, 1990; Carlson & Gorman, 1992), and that idea generation fits within Bloom's category of synthesis, and is thus a higher-order thinking process.

Work in cognitive psychology (eg Anderson, 1982) suggests that when the mind processes procedural knowledge, or the knowledge of how to do something, it uses the same mechanisms to processes thoughts as it does to process actions. That is, there is no higher-order mechanism for processing abstract thoughts that is separate from one used for concrete thought, using, for example, imagery, or physical action.

This means that because we work with children where they engage with real materials in concrete settings that have personal meaning, we are also working with children in settings where values, or Gardner's "good works" have the best chance of being taught and more importantly, learnt. This is not a new idea. It was Steiner who said, and I am paraphrasing him "don't worry about what the child does to the wood – be more concerned with what the wood does to the child". Steiner knew that profound learning came from engaging with real materials in solving real problems, but did not have access to research to validate his ideas.

The significance of the research work referred to is not simply that we can insert some 'values' learning into the design and technology curriculum. Rather, the important point I would like to make is that because of its very meaningfulness to students which is related to the ways in which knowledge is represented in design and technology settings, it is best placed to have students explore questions of value. In such a proposition, the object of the design and technology learning experience is not simply to have students learn how to come up with bigger, faster or cheaper gizmos, but to have students design with values as a key component of the designing and the learning that comes from the activity.

Conclusion

In this paper I have used the existing and emerging research literature to argue that designing is a complex intellectual activity that requires higher-order thinking. I have also argued that this thinking is best facilitated by non-abstract representations of knowledge such as visual mental images and concrete representations, rather than the abstract representations previously thought of as those used exclusively for complex thinking. I have then argued that because of the kind of learning environment that occurs in good design and technology settings, which use the representations of knowledge referred to earlier, these settings are both appropriate for exploring questions of value and are settings where such ideas are meaningful for students. In drawing this conclusion I will draw on Herbert Simon's 1969 book *The Science of the Artificial*, where he argued that all human activity could be divided into two categories. The first he called the natural sciences, and defined them as being concerned with understanding 'the way things are'. The second he regarded as design and called it the science of the artificial, and defined it as being concerned with understanding 'how things might be' thus Simon saw the normative aspect of design as a fundamental and defining characteristic.

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