

# **Technology Education: More than Making, Shaking and Breaking**

Howard Middleton

*Griffith University*

## **Abstract**

This paper describes a research project concerned with the development, trialing and evaluation of heuristic strategies applicable to technology education programs. The research is based in cognitive psychology and draws on information processing theory. A central premise of the project is that the move to a design, make, appraise approach (Curriculum Corporation, 1994), or in the case of the USA of Technology Education as Innovation in Action (ITEA, 2000) creates the need for technology teachers to develop new teaching strategies. One important feature of these new strategies will be the know-how to assist technology students to develop practical, creative abilities. The development of heuristics is regarded as one important contribution to these new teaching strategies.

## **Introduction**

Schulman (1987) has argued that all good teachers need three kinds of knowledge: content knowledge; pedagogical knowledge and pedagogical content knowledge. Content knowledge is seen by Schulman as knowledge of the domain, or what is generally described as subject content. Pedagogical knowledge is described as the general abilities all teachers possess. These include the ability to motivate a class, the ability to plan lessons and the ability to establish and maintain an appropriate level of discipline within any class. Pedagogical content knowledge is described by Schulman as the knowledge of teaching skills and strategies that are specific to a domain or to particular topics within a domain. For example, knowledge of the best way to teach differential equations or computer numerical control (CNC) programming.

Banks (1999) has argued that Schulman's (1987) arguments are based on an essentially teacher-centered pedagogy that is inappropriate in a discipline where there are no correct answers to the problems students attempt to solve. While not taking issue with Banks, this study has worked on a somewhat broader assumption of what constitutes teaching strategies, or pedagogical content knowledge. That is, while technology has features that are quite different from other subjects, it still involves an interaction between teacher and student. That being the case, there may be better or

worse ways in which the teacher manages their side of those interactions. Thus, the heuristics described later can be seen as ideas that inform the teacher's interactions with students.

The rationale for the research project was that, as a consequence of the move to technology education, technology teachers do not yet have sufficient appropriate pedagogical content knowledge to develop innovative thinking in students and that there is a need to develop further, pedagogical content knowledge in technology education. The basis for this assertion does not come from detailed research as there are few relevant studies conducted within technology education. However, anecdotal evidence from technology teachers who report difficulty in providing students with strategies for generating new ideas, and the fact that the issue has been identified as an important research issue by the Committee on Technology Teacher Education (CTTE)<sup>1</sup>, suggest that the assertion has face validity. On that basis it is argued that the identification, development and trialing of heuristic strategies is one important way to develop the required pedagogical content knowledge.

Finally, before addressing the issues of the paper, a comment on the title of the paper. A certain amount of poetic licence has been taken as the term "making, shaking and breaking" was originally coined to describe technology, by an unknown author (as opposed to technology education). However, the implication seemed to be that technological activity was not necessarily preceded by a thoughtful planning process. In addition, the order of the terms seemed to suggest a process that was devoid of social and environmental considerations. That is, you make them, shake them (use them) and break them (discard them). Thus, if technology education was analogous to the technology process in the title, we needed something better. However, being a catchy phrase probably counted for as much as any other consideration.

### **Background to the project**

It is almost axiomatic to suggest that technology education is in a state of change. Significant change has been occurring since at least the mid nineteen eighties. The change has been in part a response to rapid technological change within industrialised societies. The change in technology education has largely manifested itself in terms of changes in subject content, with such things as the introduction of computer-aided

drafting and design, digital electronics and robotics. In more recent times the emphasis on content change has shifted to include changes in the way teaching and learning occurs. One feature of this change has been a growing emphasis on the development of students' technological problem-solving abilities.

However, problem-solving has always been a feature of technology education. Indeed, others (Perkins, 1990; Anderson, 1993) have argued that most tasks that humans perform can be conceptualised as being problematic because all tasks contain a challenge. For example, the task of planing a piece of timber flat is problematic because the challenge is to perform the task with accuracy. Technology education has also involved more complex problem-solving in areas like automotive and electronic troubleshooting, where it is often the case that malfunctions will need to be diagnosed without the symptoms being able to be viewed directly, and where some interpretation is required.

In more recent initiatives in technology education (ITEA,2000), however, there has been an explicit emphasis on certain kinds of problem-solving. The emphasis has been directed towards teaching and learning activities that develop creative problem-solving abilities. The Technology for All Americans project, with its underlying theme of "Technology Education - Innovation in Action" is the most recent and significant manifestation of this emphasis. Two examples of technological problems that explicitly involve creative problem-solving are invention and design. Designing and inventing are problem-solving activities that involve the higher order cognitive processes of analysis, synthesis and evaluation (Bloom, 1956).

Two strategies by which problems are solved are through the use of algorithms or heuristics. Algorithms are strategies that guarantee a solution to a problem, with a mathematical formula being a good example of an algorithm. An heuristic is defined as a strategy that increases the chance that a problem will be solved, but does not guarantee success. Algorithms are useful for solving well defined problems but are not able to be used to solve technological problems that require creativity. For example, there is no formula that can be applied to invent devices.

---

<sup>1</sup> The Council on Technology Teacher Education (CTTE) is an affiliate organisation of the International Technology Education Association (ITEA).

People solve problems in new domains by applying heuristics to declarative knowledge ('knowing that') they have about the domain within which the problem resides. New domains are taken to be domains where the problem-solver may have knowledge about the domain in a declarative form but no specific procedural knowledge ('knowing how') about how the problem is to be solved.

Experts in a domain have a large store of procedural knowledge that they can apply to any task within that domain. Novices in a domain, on the other hand, have some declarative knowledge, but a much smaller store of procedural knowledge. A consequence of this is that experts and novices solve problems differently. Experts simply apply their procedural knowledge to the problem and achieve a result. A novice uses trial and error, and in the process, converts declarative knowledge to procedural knowledge (Anderson, 1983, 1987, 1993). For example, a person who has never used a hammer may know that hammering is done by holding the hammer by the handle and striking the object with the head. By attempting and succeeding in hammering, the person will have converted 'knowing that' to 'knowing how'.

The consequence of the above is that when solving problems requiring innovation such as in design and invention, problem-solvers are required to generate new ideas. In addition, school students are by definition, novice problem-solvers. Hence, technology students will need to make use of heuristic strategies that will assist them to generate new ideas to solve technology problems.

Heuristics have been the subject of research but have generally been dismissed as weak problem-solving strategies (Anderson, 1987). A closer look at the kinds of problems that have been the subject of research, and from which these judgements have been made reveals, however, that most problems that have been the subject of research into problem-solving strategies, have been simple and well defined, often to make them more amenable to particular research methodologies. Simple puzzles and mathematical problems are more easily solved by algorithms in the form of formulas than by heuristics.

Technological problems, on the other hand, are often complex and ill-defined and are generally not amenable to resolution by algorithms. There is evidence from research in information processing (Anderson, 1987), physics problem-solving (Clement,

1991), problem representation (Antonietti, 1991) invention (Weber, Moder & Solie, 1990) and creative thinking (Dominowski, 1995) that for ill-defined and complex problems, heuristics provide very useful problem-solving strategies. Furthermore, for some complex problems, heuristics may be the only strategies that provide solutions (Kaufmann, 1990). This being the case, technology teachers need to have a store of problem-solving heuristics and an understanding of when and how they are applicable, as part of their pedagogical content knowledge.

### **Statement of the Problem**

What heuristics can technology teachers use to improve the creative, problem-solving abilities of Technology Education students?

### **Research Design**

The research design includes four major stages. The first stage was the development of those heuristics selected from the literature and deemed to have promise for assisting students to solve technological problems. The second stage consisted of the research team trialing particular heuristics and eliciting feedback from focus groups of technology teachers. The third stage involves trialing the heuristics with technology classes and evaluating the results of the trial, while the final stage involves the development of a framework or set of principles to facilitate the development of further heuristics. For example, Weber and Perkins (1989) analysed existing inventions and proposed a theoretical framework for the generation of new ideas by inventors. The Weber and Perkins framework is based on deconstructing an invention and analysing the functional attributes to establish if new ideas can be generated by varying some of the attributes.

### **Heuristics**

The eleven heuristics described below have been developed, trialed and sent to trial schools. The expectation is that teachers will trial the heuristics during Term One 2000. It is important to note that while the researchers have suggested ways in which the heuristics may be employed, there was an expectation that teachers would vary these. In addition, some heuristics were included despite the researchers being unable to suggest ways in which they might be used. This was done in the belief that teachers may be able to devise ways to utilise those heuristics. The eleven heuristics and related information presented to participating teachers are as follows:

### **1. Major adjustment approach**

*Can we make this product, cheaper, simpler, do more things, do them quicker, better etc?.*

This heuristic comes from research on inventing by Weber, Moder and Solie (1990). For example, they cite the modification of a surface operating herbicide spray, to operate as a sub-soil spreader to reduce the quantity of spray and allow spraying in wind.

An example of use in a school may be

*You have been presented with a set of plans for a children's wheeled toy. Your task is to change the toy so it can do different things .*

It may be useful to change the name used to describe the heuristic. The following were suggested by workshop participants: re-design, unpacking, modification, improving,

### **2. Joining approach**

*Can we join this product with part or all of another to create a new product?*

An example of a possible way of using the heuristic with students may be to provide them with a brief that requires them to either combine two different kinds of objects from a particular type to produce a new object (for example to combine two kinds of toys to produce a new toy) or to combine two objects from different types of objects (for example, combine a toy with a seating device). One example seen at the Tasmanian workshop was of a piece of furniture being constructed by a combination of traditional timber methods and the use of yacht fittings. Another example that students would recognise is the Australian Hills rotary hoist as it combines the original idea of stringing wires between supports, the idea of rotary motion analogous to a merry-go-round, and the use of a bevel gear for raising and lowering the line.

### **3. New material**

To provide students with genuinely new material is probably difficult. However, many materials are new to most students. For example, acrylic is a relatively new material for most school students, and they can gain ideas by working with it and learning its properties. Other materials that may have applications include Polycarbonate (Lexan) or Acrylonitrilebutadienestyrene ABS. These materials will probably need to be used in conjunction with design briefs that will tend to lend themselves to solutions with the nominated materials. Some participants have suggested this heuristic could be used with an industry links project.

#### ***4. New function***

(for existing categories of products). One workshop participant was at a school that had numerous spare science laboratory stools. For this school, the heuristic was to develop a brief based around re-engineering the stools for new functions. This heuristic may be particularly useful for design briefs based around use of recycled materials/objects.

#### ***5. Functional analysis***

If students are to gain most from engaging in designing they need to develop the ability to critically analyse the existing or possible future functions of objects they might design and of the functions of existing objects. (*What precise functions are provided by a desk light or a coffee table?*). Research by Getzels & Csikszentmihalyi (1976) suggested that analysis of problems prior to attempting to solve them was important to success, particularly when new solutions were required.

This may only represent a slight variation on a heuristic that teachers are already using, however, an emphasis on the functional requirements that will need to be incorporated into a new design may be useful in stimulating new ideas (possibly without students being aware that they are generating new ideas).

#### ***6. Visualisation***

*Visualise the problem before attempting to solve it*) Antonietti (1991) has demonstrated that when solving complex problems, visualisation of the problem, prior to attempting to solve the problem, is a heuristic that helps the problem-solver avoid the psychological blocks to creative thinking known as mechanisation bias and functional fixedness. Mechanisation Bias, is the tendency to solve a problem using

routine techniques, when to solve the problem requires the problem-solver to develop unusual ways to solve the problem. Functional Fixedness, is the tendency to see physical features of the problem as having only their usual function, when to solve the problem, the problem-solver needs to think of the features as having new functions. Finke and Slayton, (1988) conducted experiments that suggest that visualisation can be used to generate new ideas by requesting subjects to mentally manipulate images of objects until new and useful shapes emerge.

In a school setting, it may be possible to take a metacognitive approach and explain a little of how the mind works and how we process information and why this heuristic should help they come up with new ideas. It may be that teachers will need extra assistance in using this heuristic.

### ***7. Structural Analogy***

In traditional workshop classes, it has often been regarded as good practice to display well made examples of objects to show students what is required. In using a design approach, this practice can have a detrimental effect in that it can induce pre-conceptualisation. That is, if a particular example of a solution is presented, it can be difficult for people to think up new solutions. However, if students are either given examples of different classes of objects that have similar features, they can be assisted to come up with new ideas. (for example, a chair has similarities to a bridge pylon)

### ***8. Conceptual exploration***

*Activities that explore structural or functional properties of solutions that have characteristics similar to real-world problems.*

This is similar to some of the other strategies. However, it may be more suitable for particular briefs than those related strategies. For example, for briefs that require students to explore a range of required properties such as structural, aesthetic, functional, economic etc.

### ***9. Resolving contradictions***

Some designers argue that one of the important aspects of producing a good design is to locate the inherent contradictions and resolve them (for example, strength versus weight, quality versus cost, complexity versus reliability). Looking for the

contradictions that are inherent in many designed objects. By introducing the concept of contradictions as something that students must address in the design of, for example, a seating device, may highlight the need to find suitable ways to joint the materials to provide sufficient strength.

### ***10. Attribute analysis***

Unless products impact on them directly in a positive or negative way students tend to remain unaware of the particular attributes of many everyday products. However, they are adept at analysing products if given the task. This analysis can be used to develop the student's "ideal solution" (exploring limitations and possibilities of existing products)

### ***11. Metaphor***

The late Donald Schon (1990) argued that the use of metaphors provides a powerful stimulus for the development of new and good ideas. The example Schon gives is to think of the health system in a particular location as if it was a bowl. This then allows one to say what the desirable attributes of a bowl are (not broken) and to transfer these to the objects being designed.

### **Conclusion**

The research project is still in progress and the results will be the subject of another paper. However, in characterising future directions for technology education as encompassing "Design, Make, Appraise" or "Innovation in Action", technology teachers are faced with an important challenge. The challenge is to see if technology classes can become that part of the school where innovation, in thought and action, becomes the norm. However, to fail to achieve this end may place technology education in a difficult position. This project should provide concrete strategies technology teachers can implement to encourage creative and innovative thinking. Furthermore the strategies will have the strength that comes from being grounded in relevant theory and from being trialed with teachers and students. Teachers should not only have useable teaching strategies. They will also need to be able to provide sound arguments to administrators, colleagues and parents concerning the educational value of heuristic strategies and of the learning experiences they provide for students.

In addition, the development of strategies for improving students' problem-solving abilities as an aspect of teachers' pedagogical content knowledge is important for the status of Technology Education. The move to student centred problem-solving has placed Technology Education more firmly in the forefront of subjects that require students to engage in and develop the higher order thinking skills of analysis, synthesis and evaluation. However, for technology teachers to develop these abilities in students they need to use appropriate teaching strategies. Hopefully, with appropriate strategies technology teachers can move beyond "making, shaking and breaking".

## References

- Anderson, J. R. (1982). Acquisition of Cognitive Skills. *Psychological Review*, 89 (4), 369 - 406.
- Anderson, J. R. (1987). Skill Acquisition: Compilation of Weak-Method Problem Solutions. *Psychological Review*, 94 (2), 192-210.
- Anderson, J. R. (1993). Problem solving and learning, *American Psychologist*, 48, (1), 35-44.
- Antonietti, A. (1991). Why does mental visualisation facilitate problem-solving? in R. H. Logie, & M. Denis, (Eds), *Mental Images in Human Cognition*, Amsterdam: North Holland.
- Banks, F., & Barlex, D. (1999). "No one forgets a good teacher!" - What do 'good' technology teachers know? *The Journal of Design and Technology Education*, 4, (3), 223-229.
- Bloom, B. S. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals*. New York: Longman.
- Carlson, W. B., & Gorman, M. E. (1992). A cognitive framework to understand technological creativity: Bell, Edison, and the telephone. In R. J. Weber & D. N. Perkins (Eds.), *Inventive Minds*. New York: Oxford University Press.
- Clement, J. (1991). Nonformal reasoning in experts and in science students: The use of analogies, extreme cases, and physical intuition. In J. F. Voss, D. N. Perkins, & J. W. Segal (Eds), *Informal Reasoning and Education*, Hillsdale, N. J.: Lawrence Erlbaum.
- Dominowski, R. L. (1995). Productive problem solving. In S. M. Smith, T. B. Ward & R. A. Finke (Eds.) *The creative cognition approach*, Cambridge, Mass: Bradford Books. (9-26).

- Finke, R. A., & Slayton, K. (1988). Explorations of creative visual synthesis in mental imagery, *Memory and Cognition*, 16, 252-257.
- Getzels, J., & Csikszentmihalya, M. (1976). *The creative vision: a longitudinal study of problem finding in art*. New York: Wiley.
- International Technology Education Association. (2000). *Technology for all Americans: A rationale and structure for the study of technology*. Reston, VA: International Technology Association.
- Kaufmann, G. (1990). Imagery effects on problem solving. in P.J. Hampson, D.E. Marks, and J.T.E. Richardson (Eds) *Imagery: Current Developments*. London: Routledge.
- Middleton, H. E. (1990). Technology and Science: Making the Link. In M. Dupe (Ed.) *Making the Links, Technology and Science, Industry and Education*. Canberra: Australian Government Publishing Service. pp 5-30.
- Middleton, H. E. (1996) *Complex problem-solving*. Paper presented at the Conference of the Centre for Learning and Work Research, Griffith University, Gold Coast.
- Schon, D. A. (1990). The design process. in V. A. Howard (Ed), *Varieties of thinking: Essays from Harvard's Philosophy of Education Research Centre*, New York: Routledge.
- Schulman, L. S. (1987). Knowledge and teaching: Foundations for the new reform. *Harvard Educational Review*, 57, 1-22.
- Weber, R. J., & Perkins, D. N. (1989). How to invent artefacts and ideas. *New Ideas in Psychology*, 7, 49-72.
- Weber, R. J., Moder, C. L., and Solie, J. B. (1990). Invention Heuristics and mental processes underlying the development of a patent for the application of herbicides. *New Ideas in Psychology*, 3, 321-336.