Technology Education: Providing Strategies for Creative Learning or: Doing More than Making, Shaking and Breaking

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TECHNOLOGY EDUCATION: PROVIDING STRATEGIES FOR CREATIVE LEARNING OR: DOING MORE THAN MAKING, SHAKING AND BREAKING

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This paper describes a research project concerned with the development, trialing and evaluation of heuristic strategies to use in technology education classrooms. The research is based in cognitive psychology and draws on information processing theory. A central premise of the project is that the move to creative design-based approaches over the last 25 years in Australia (Curriculum Corporation, 1994, ACARA, 2013), 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 is 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 creative 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 and Engineering Teacher Education (CTETE, an affiliate organisation of the International Technology & Engineering Education Association, ITEEA), 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 in its selection 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 (ACARA, 2013). One feature of this change has been a growing emphasis on the development of students' technological problem-solving abilities with an emphasis on creativity and invention.

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, ACARA, 2013), 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 one 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).

Solving Problems

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.

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 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 judgement 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.

The Research Question

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 involved 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 were developed, trialed and sent to trial schools. The expectation was that teachers would trial the heuristics during Term One. It is important to note that while the researchers 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 Acrilonitrilebutadenestyrene 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 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, 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) found that visualisation can be used to generate new ideas when subjects mentally manipulated images of objects until new and useful shapes emerged.

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 that 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 join 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)

Case Studies

The format for reporting the case studies was developed in conjunction with the teachers involved in the project. Teachers in the trial felt that before teachers would use the heuristics they would want to know the geographical, social, economic and cultural contexts of the setting for each case study report. Their view was that this information would be important in helping them make the decision about the use of any heuristic in terms of similarities between trial schools and their own schools. The format for the case study reports includes a description of the context, project brief, heuristic/s used, including variations, and reflections on the trial by teachers. These reflections include student work, the teaching process and use of the heuristics. The trials have been documented as case studies and that is reported in depth elsewhere. Details of the case study groups are provided in Table 1 below.

Table 1: Summary details of case study groups

School type	Grade	Class size	Gender F:M	Subject	Heuristic/s
Rural	8	24	12:12	Technology	Major adjustment
Suburban	8	23	11:12	Technology	Functional Analysis
Rural	10	24	3:21	Industrial technology	New function & functional analysis
Suburban	9	25	3: 22	Industrial Design	Joining approach
Suburban	10	24	2:22	Industrial Design	Functional analysis
Suburban	10	25	5:20	Graphics	New function, functional analysis, visualization & conceptual exploration
Suburban	8	30	14: 16	Graphics	New function, functional analysis, visualization, conceptual exploration, resolving contradictions & attribute analysis
Suburban	8	24	12:12	Industrial Design	Joining approach & new function.

Discussion

During this study, ten heuristics were developed prior to trialing. Teachers who trialed the heuristics with their classes were given complete freedom in terms of which heuristic or combination of heuristics they used with their class. During the study eight of the ten heuristics were trialed.

For seven of the groups the heuristics were seen as being useful in providing a starting point for the generation of ideas. For six groups the heuristics were useful for teachers to suggest to students as ways of resolving mental blocks during the process of developing their designs.

One process to emerge in the study was the use of a two-stage process where students were initially presented with a brief and an heuristic for generating ideas. As the students proceeded to create their designs, they came up against problems. Teachers reported that other heuristics were then useful for resolving these blocks.

There were a number of unforeseen difficulties encountered during the project. The first and most general one was in convincing teachers to become involved. The resistance appeared to be based on conceptions like "I'm involved in practical education and that has nothing to do with research". Others were unconvinced that the results of research would be of any use to their teaching. Others appeared to be reluctant to be involved in something that might expose their teaching to scrutiny.

A second difficulty was inherent in an unavoidable aspect of the research design. It was necessary to recruit teachers who understood, were sympathetic to, and to some extent at least, were engaged in what is often described as problem-based learning. The reason for this is that teachers will only engage successfully in activities they feel comfortable with. However, these same teacher, having an understanding of problem-based learning, were, by virtue of their experience, likely to gain less from the research experience than a teacher who had no experience with this kind of teaching/learning. However, to recruit teachers who were still using completely directed teaching strategies, was likely to result in no gain due to an inability to utilize the heuristics. The problem was generally resolved through discussion, however, it did result in a number of teachers who were involved in the focus groups not being involved in the trials.

Conclusion

The research project was small, being a pilot study, and hence limited in its generalisability. However, the feedback from teachers did suggest that the heuristics were useful as strategies they could employ both as general problem-solving strategies given to students at the outset of a project, and as strategies that could be suggested to students when they were encountering difficulties in coming up with ideas. The fact that teachers were sufficiently comfortable with the heuristics to customise them to suit their particular circumstances is also seen as positive in terms of the future use of the heuristics. Hopefully, then with appropriate strategies technology teachers can move beyond "making, shaking and breaking".

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