Assessing Technology Education: Some Theoretical Issues

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Abstract

This paper explores the basis of assessment within contemporary technology education programs. The examination is cognitive in nature and raises the question of what is to be assessed when students engage in design-based learning activities. The paper explores the kinds of problem-solving that have become central to technology education and the implications these might have on decisions about what should be assessed and how assessment might be accomplished. The paper argues that design problems are inherently ill-defined and complex, and students engagement in solving them is valuable in terms of student learning, because of these characteristics. The implications of design, problem-solving for current assessment practices which are moving toward outcomes-based or competency-based approaches are also examined.

INTRODUCTION

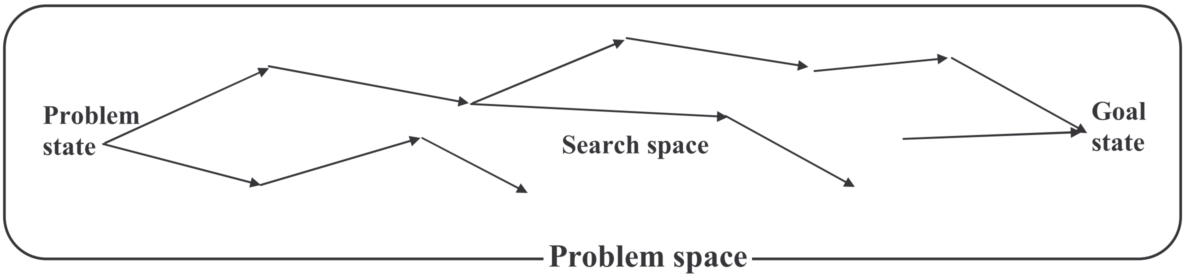
Problem solving has been an enduring emphasis of technology education programs throughout the 1990's. Moreover, the emphasis has shifted from problem solving per se to problem solving with an explicit emphasis on creative thinking. This is sometimes referred to in terms of design (Curriculum Corporation, 1994a,199b), or innovation (TFAAP, 2000). The most significant cognitive difference between contemporary technology education programs and earlier, more directed approaches is the explicit emphasis on problem-solving. More specifically, on problem-solving that produces something new or different and involves a creative process. However, over the same period that design-based problem-solving has been introduced, education authorities have moved to make assessment practices more prescriptive as part of moves to make teaching more 'accountable'. These more prescriptive assessment practices have gained popularity with educational authorities in many countries and are described variously as outcomes-based or competency-based.

This paper reviews initially, cognitive literature concerned with the nature of problems, and concludes that design problems are complex because they are ill-defined, there are many ways to solve them and they require a creative response to achieve resolution; and that the complexity is conceptually different from ideas of complexity expressed in existing problem-solving literature (Kotovsky & Fallside, 1989; Kotovsky, Hayes & Simon, 1985; Anderson, 1987; Gott, 1989, 1994). Then, the nature of the learning that occurs when students engage in design, problem-solving is discussed. Finally, the assessment issues that arise as a result of students' engagement with design, problem-solving are examined.

The Psychology of Problem Solving

The way in which humans think and solve problems has been the subject of research in cognitive psychology for many years (Newell & Simon, 1972). Using the results of a wide range of research projects, Newell and Simon developed a model to characterise the nature of problems, and of how people solve them. Newell and Simon argued that their model was capable of being used to characterise all problems human encounter and attempt to solve. Despite its age, the Newell and Simon Model is still regarded as the starting point for research in problem-solving. The Newell and Simon model is illustrated in Figure 1 below.

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



In the Newell and Simon model above, all problems are regarded as occurring within what is described in psychological terms as a problem space, indicated by the area enclosed by the border. The problem space contains three problem elements: The problem state; the search space; and the goal state. The problem state is taken to be the clear descriptor from which problem-solving commences and is represented in the model by a single, defined point, indicating that the starting point of problems can be characterised by one clear descriptor. The search space is described as the information space from which all procedures (actions or strategies) that need to be taken to reach the goal state, will be found and is represented by an area with arrowed lines going through it from problem state to goal state. Finally, the goal state is the end point of problem-solving and is represented by a single point, indicating that for problems, there is a single, correct answer.

Newell and Simon's model has been useful in characterising many kinds of problems, including some technological problems. However, other researchers (Schon, 1990) have questioned the Newell and Simon model. In a recent study, Middleton (1998) argued that most research into problem-solving, and research from which the Newell and Simon model was developed, has involved simple and well-defined problems such as mathematical sums, games and puzzles. It is argued here that technological problems that require creativity, such as design, are complex and contain features that are different to those found in problems that have generally been the subject of research. Design problems are complex because:

1. They contain a large search space (of knowledge and potential strategies, materials, processes etc) where the problem-solving strategies are often linked in complex relations (that is, if you chose to design an object in metal, the manufacturing processes open to you are linked to your choice of material);

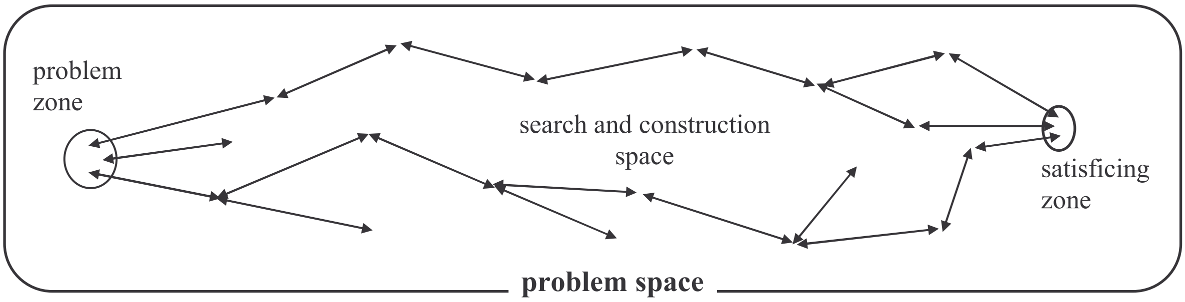
2. They are ill-defined (it is not possible to specify how you design a house with a certain ambience or a car with a particular appeal);

3. They require creative approaches to achieve a solution (commercial and patent law requires this) and cannot be solved using algorithms;

4. They often contain potentially contradictory goal criteria (designing a chair that is strong but lightweight).

A new model of a problem space that incorporates the demands of design and invention problems has been synthesised (Middleton, 1998). The new model replaces the problem state with a problem zone, the search space with a search and construction space and the goal state with a satisficing zone. The synthesised model is illustrated in Figure 2 below.

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



The revised model acknowledges that there can be multiple starting points for design problems and it may be difficult to determine which starting point to take. For example, the problem of having a population on one side of a river and the industries they work in on the other might be conceptualised as a problem of providing a bridge, or a ferry or a tunnel, or of moving the people to the same side of the river as the industry. This suggests the problem is ill-defined and it may be difficult to even determine some aspects of the problem, which means it may also be described as opaque. For these reasons, the term problem state is replaced with *problem zone*. The model also indicates that the process of reaching the goal involves creation as well as search, involves strategies that emerge during problem-solving, and that there will be many possible solutions to a design problem. For example, in designing the A380 Airbus, The Airbus Industries Corporation are using existing solutions for some aspects of the craft, such as the landing gear (thus involving a process of search), but is developing new materials for wings and fuselage to gain greater fuel efficiencies (thus involving the process of construction), thus the use of the descriptor *search and construction space*. The solutions to design problems will not be right or wrong, but will solve the problems to a greater or lesser extent, and the criteria for establishing that a solution is satisfactory may emerge during problem-solving, thus the use of the term *satisficing zone* rather than goal state.

The Newell and Simon (1972) model and the modified model (Middleton, 1998) are based on information processing explanations of the nature of human thinking. In information processing approaches, the mind is regarded as an information processor analogous to a computer. The approach is based on the proposition that if it is possible to produce a computer program that performs problem-solving or other thinking activities in a human-like way, then this performance is taken as evidence that the mind may also perform the activity in a similar way. The characteristics of design problems in terms of the three parts of the problem space are shown in Table 1, below.

Table 1. Summary of characteristics of the problem space of design problems

Problem zone	**Search and construction zone**	**Satisficing zone**
Ill-defined Opaque	Numerous procedures Figurally complex Opaque Emergent procedures Constructed procedures	Ill-defined Figurally complex Contradictory criteria Emergent criteria Creative

Learning through Design-based problem solving

The basic premise in contemporary technology education programs is that students will engage in solving problems, and in doing so learn important content and processes (QSCC, 2000). Most programs provide details of content to be covered and a suggested process, at some level of specificity, often described as a design process. The design process will generally include the following stages:

- Identify a problem
- Conduct research into the problem
- Generate ideas
- Refine the ideas
- Construct the solution
- Evaluate the solution

The process is often seen to be unproblematic. That is, it is often assumed that students will not have difficulty in identifying a problem or in generating ideas for solutions. Teacher experience and some research (Middleton, 2001a, 2001b) suggest that the characteristics of design problems identified in the research literature manifest themselves in the kinds of problems students encounter in technology classrooms. That is, they encounter problems that are ill-defined and complex. The important point to note is that despite these characteristics, students do solve these complex, ill-defined design problems. Moreover, there is evidence that they do so with solutions that are often beyond those that teachers considered them to be capable of. What then are the implications of this for assessment in technology education?

Assessment in Technology Education

The major conclusion that one can draw from the section on design problem-solving is that design problems are, or can be, problematic in each of the three parts of the problem space. The previous section indicated, albeit briefly, that these problematic characteristics are also encountered by students in contemporary technology education classrooms. In addition, the design problems that students encounter determine that different learning occurs from that which occurs in traditional workshop classes. They also determine that the task of assessment is different within these two learning approaches.

In traditional workshop practice, the problem state was clearly specified by the teacher. Similarly, the search space was specified in terms of a set of specific construction steps. Likewise the solution was embodied in a set of plans, often accompanied by a model of the finished article. Assessment was generally based on the degree to which the student's product was an accurate copy of the model produced by the teacher.

In terms of educational objectives, assessment in traditional approaches was concerned with what Bloom (1956) defined as recall, comprehension and application. That is, students were required to demonstrate that they understood the verbal instructions, physical demonstrations and instructional material, could remember them, and apply them in the production of the nominated article. Generally speaking, the finished article was regarded as a suitable measure of the degree to which each student had met these objectives.

The model of the design problem-space illustrated in Figure 2, makes clear that a different problem-solving process is involved when people design and it is argued here that in terms of Bloom's taxonomy, when students learn through designing, different learning objectives may be achieved. If the design problem-solving that students engage in conforms to the problem characteristics outlined above, students would need to engage in the cognitive processes of analysis, synthesis and evaluation, in addition to the recall, comprehension and application noted above for traditional workshop activities. Given these differences in the learning activity, what are the implications for assessment of student learning?

What to assess in technology Education

Research by Walmsley (2001) provides interesting insights into what is being learnt in design-based technology education classrooms. Walmsley used the *Cognitive Holding Power Questionnaire* (CHPQ) (Stevenson & Ryan, 1999) to investigate various technology education learning environments. These included classes where the teaching was described as traditional and classes where the teaching was described as design-based. The CHPQ measures the degree to which a learning environment 'presses' learners to engage in particular kinds of thinking. Learning environments high in what is described as cognitive holding power tend to press learners to engage in the higher-order thinking processes of analysis, synthesis and evaluation, which are described as being high in 2nd order cognitive holding power. Learning environments low in cognitive holding power tend to press learners into engaging in the lower-order thinking associated with recall, comprehension and application, called 1st order cognitive holding power. Walmsley found that design-based technology learning environments pressed learners to engage in 2nd order thinking while traditional workshop learning environments pressed learners to engage in 1st order thinking.

The Walmsley study is interesting as it indicated that design-based learning environments were perceived by students as pressing them to engage in higher order thinking. However, it is not clear that this perception of their learning environment, by students, is reflected in the assessment of their work within the technology classroom. Moreover, it is also not clear what teachers should use as measures to indicate learning. That is, if Walmsley is right and students in design-based classes are engaging in analysis, synthesis and evaluation, how do we establish that this is happening.

Teachers have attempted to assess more that the finished product by including design folios in the assessment process, to supplement student designed artifacts. However, as McCormick (2003) observed, these were often undertaken after the designing was complete and were not a part of the design process, but rather a separate task, completed to satisfy the demands of the teacher for a folio. The explicit or implicit requirement for these folios was for a well-presented document, rather than a record of the thinking about and development of design ideas. The assessment of folios might then, not be a useful way of assessing design thinking. It may be that teachers will have to move from the requirement for neat and pretty folios to documentation that more accurately reflects the more idiosyncratic and iterative process by which students generate and develop ideas for design solutions. One characteristic of this possible assessment process will be the need to consider all aspects of the student's design problem space.

Adopting assessment practices that acknowledge a more authentic, if messier account of designing on the part of students, requires some thought if issues such as fairness and coherence are to be addressed. However, the issue of what is to be assessed becomes more problematic in an outcomes-based assessment regime. That is, in a regime where it is a requirement to be able to specify what students will know and be able to do as a result of engaging is a course of study. The most obvious approach is to establish criteria for assessment that take into account the various aspects of the process of designing. However, there are two potential problems with such an approach. The first is the tendency, to encounter a phenomena called regression to the mean, where increases in number of criteria cause a grouping of assessment marks around the mean. The effect of this is that it disadvantages high achieving students and advantages low achieving students, thus, distorting the assessment outcomes. The second is that criteria inevitably attempt to unpack a design process in order to assess individual components. The problem with this approach is that it generally omits the links between the various aspects of the design performance, giving a false indication of the worth of the work. In addition, as Kimbell (1997) found, that teachers who provided an overall assessment of student design work were more reliable than teachers who assessed based on a range of criteria. Kimbell argued that, in effect, the overall assessment method was more reliable because designing was a case of the whole being more than the sum of its parts.

Conclusions

What then can one conclude? The first conclusion is that designing is a complex and educationally valuable activity for students to engage in. Students in design engage in higher order thinking processes but we have some difficulty in providing authentic ways to assess their learning. This problem is made worse by the current enthusiasm by educational authorities to mandate assessment practices that require highly prescriptive outcomes. Reconciling the need for assessment in contemporary technology education programs that is authentic with demands for prescriptive assessment practices is an important challenge for technology educators.

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