Design and technology: what is the problem?

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Howard Middleton PhD

Abstract

This paper examines designing from a cognitive perspective. A long-standing model that attempts to explain how people solve problems is examined. Also examined is recent work suggesting design problems have a number of features that distinguish then from other kinds of problems. A revised model and theory are presented and discussed.   The revised model accounts for the characteristics of design problems in that it acknowledges that design problems have an ill-defined starting point, there are many ways to solve them and there are, in theory at least, an infinite number of solutions for each design problem. The implications of this work for current understanding of problem-solving and designing are discussed, as are the implications for teaching and learning in design and technology classes.

Keywords

Design, technology, cognitive processes, problem-solving

Background

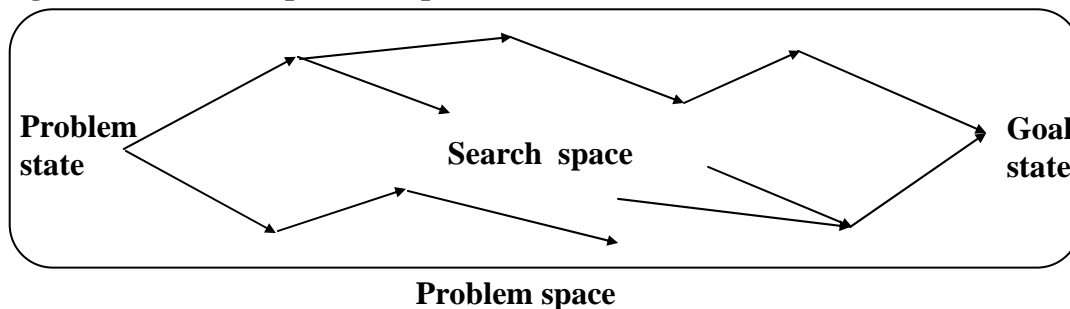Understanding how human beings solve problems has been the subject of considerable research since the 50's. A model to explain the cognition of human problem-solving was developed in 1972 by Newell and Simon. The model has been able to characterise many forms of problem-solving and is the basis of much current cognitive theory. However, the model is unable to explain the cognitive processes involved in designing.

Problem Space Model

In Newell and Simon's (1972) model problems are said to reside within a problem space. People solve problems by finding procedures (strategies, actions) that will help them move through the search space from the problem state, to reach the goal state (Figure 1).

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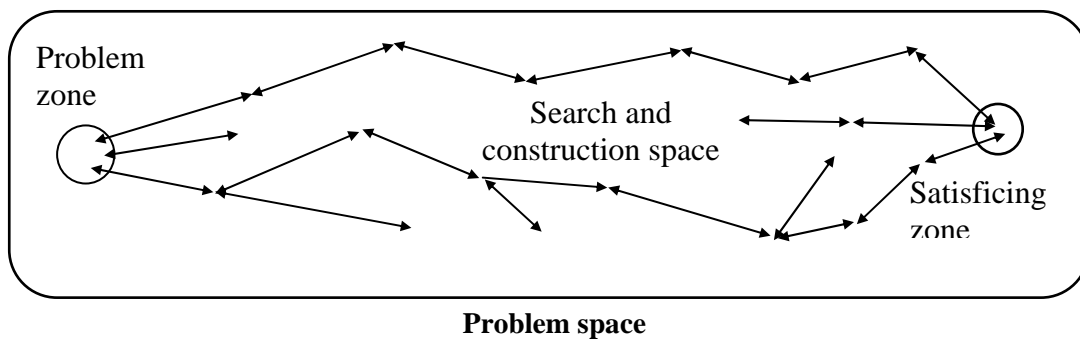

Problem space

In the Newell and Simon model, the problem state is taken to be the clear descriptor from which problem-solving commences and is represented 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 that need to be taken to reach the goal state, will be found. Finally, the goal state is represented by a single point, indicating that for problems, there is a single, correct answer.

The remainder of this paper is devoted to establishing that this model has inadequacies for design problem-solving because of the special characteristics of design problems; and to synthesising a revised model which overcomes these inadequacies.

Revised model and theory

The revised model and the theory that underpins it have been tested with a number of case studies (Middleton, 1998). However, apart from indicating that the studies appear to support the model and theory, reporting of those studies is outside of the scope of this paper.

Figure 2 Revised concept of a problem space (Middleton, 1996)

Problem space

Problem zone

In design problems, the <u>problem zone</u> is defined as that portion of the problem space from which a representation of the problem is derived and is comprised of the information that exists prior to the problem-solving process commencing. The need to provide permanent shelter is an example of information indicating the existence of the problem zone.

The problem zone of design problems is complex because it is ill-defined and opaque. It is <u>ill-defined</u> because the existence of some information of the problem zone is not known, or can not be articulated by the person who defines the problem (Perkins, 1990). For example, in architecture, the client will usually indicate some of the desired features of a building to be designed, but the architect will be required to supply additional details for the problem to be solved (Middleton, 1994).

The problem zone in design problems is opaque when the problem-solver is unable to perceive all elements of the problem zone and is thus unable to form an accurate representation of the problem zone. For example, in the design of a house, the client may have requirements that they were unaware of until the violation of those requirements was apparent in a proposed solution.

The ill-defined and opaque nature of the problem zone in design problems means that the term problem state, and the representation of the problem state in Newell and Simon's (1972) model (Figure 1) is limited in its ability to characterise design problems. In the alternative model (Figure 2), the problem state is described as a problem zone and is indicated by an area enclosed by a circle. The problem-solving process can start from a variety of points within the circle, because, given the ill-defined and opaque nature of the problem zone, a variety of representations of the problem may be possible

Search and construction space

The search and construction space of design problems is regarded as the portion of the problem space (Newell & Simon, 1972) where the problem-solver navigates to reach the solution. It is argued below that the search and construction space of design problems is complex because: (i) it may contain numerous potentially useable procedures; (ii) many procedures may be opaque; (iii) there can be complex relations between procedures; (iv) some procedures may emerge only during the process of problem-solving; and (v) some procedures may have to be constructed during problem-solving.

The search space in design problems is complex, firstly, because design problems always contain a large number of possible procedures, and thus have a large search space (Goel &

Pirolli, 1992; Simon, 1981). Secondly, the search space of design problems is complex also because elements of the search space are often <u>opaque</u>. The design of a chair, for example, is opaque because the appropriate materials to use in the construction of the chair and the tasks to construct the chair may not be obvious from the presentation of the design brief or the designer's initial representation of the problem.

The problem of opacity in the search space is also a function of the interaction between procedures and potential goal states which are also opaque. The goal states or goal criteria are opaque because the criteria for a successful solution may emerge only as the problem-solving process proceeds (Schon, 1990). Designing, using new materials or processes, involves trial and error, with goal criteria emerging from the interaction of what is possible with what is desirable.   Thus, the precise dimensions of the search space are a function of the interaction between search, as represented by, say, the trial and error testing of new materials, and the goal state, in terms of what is possible and what is desirable.

Moreover, it is argued that many procedures in the search space of design problems are opaque because, being new, the logic of a particular path through a search space may not be apparent until the goal state has been achieved. In addition, the path traversed through the search space by the particular procedures employed in any design problem represents only one of many paths through the search space. For example, a four cylinder, front wheel drive car, as the chosen path between the problem state of needing personal transport, to the goal state of a car, represents only one of many combinations of operators in a large search space.

The term search space, as the name implies, is the area where the problem-solver searches for procedures to find a path through the search space to reach the goal (Newell & Simon,

1972). Such a definition pre-supposes that all the procedures are contained within the space and are in a form that requires only that they be recognised. The characterisation of problem-solving as a search through a problem space may be a useful characterisation of such creative problem-solving activities as the discovery of scientific principles. The principles may be 'out there', within a search space, and the task for the problem-solver may only be to apply ingenious ways to locate and recognise the characteristics of the principles.

It is argued here, however, that in design problems, the task is different from that in scientific discovery. In design, some aspects of the process of solving a problem can be characterised as search to discover a solution path. For example, in the design of a car, one may choose from a range of already existing engine configurations. Other aspects, however, can more accurately be described as <u>construction</u> of a solution path (Schon, 1990; Gick & Lockhart, 1995).

The diagrammatical representation of the search and construction space in Figure 2 indicates various starting points from the problem zone and various finishing points in the "satisficing" zone. The existence of more than one solution path, each of which starts from a different point of the problem zone and ends at a different point of the satisficing zone is important in characterising design problems. Problem-solving literature has always acknowledged the existence of a variety of solution paths. The variety of paths, however, is taken to represent different arrangements of the knowable procedures for any given problems. The search space of design problems, on the other hand, contains a potentially unknowable number of procedures.

Finally, complexity in the search and construction space of design problems can be a function of the relationships between various elements including the problem-solving procedures. According to Schon (1990) design problems are <u>figurally</u> complex. Figural complexity is a term used to describe complex problems where a contingent relationship exists between variables. The variables may include the procedures in the search space and elements of the goal criteria. The consequence of this relationship is that if one variable is altered, those variables related to it will also be altered. The design of a car provides an example of figural complexity. Changes to the requirement for a particular level of comfort in the design brief for a car may mean that the variables of cost, weight, size, materials and construction methods, among others, will be affected.

Thus, the search and construction space of design problems is figuratively complex because it contains numerous possible procedures, many of which are linked and often opaque. In addition, procedures may have to be constructed and involve the problem-solver in the process of idea generation, thus suggesting the need to change terminology from a search space to a search and construction space. In addition, some procedures may only be found through an interaction between possible procedures and possible goal states.

Satisficing zone

In this paper the term <u>satisficing zone</u> is used to refer to the stage of a design problem when it is possible to make the judgement that a solution has been achieved. In design problems, this satisficing zone contains aspects that are ill-defined and often opaque (Simon, 1981), with goal criteria that may be linked and contradictory (Schon, 1990) and which may emerge during problem-solving (Schon, 1990). Design solutions also have the requirement to be creative (Perkins, 1990). The term <u>satisficing</u> was coined by Simon (1981) to describe design solutions. Simon argued that it is not possible to conclude that a design solution is

correct, only that a solution satisfies known goal criteria at a particularly time. Thus, in Figure 2 the satisficing zone is represented as an area bounded by a line, indicating an area in which various solutions may reside, rather than as a point indicating a single, correct solution (Simon, 1981).

The satisficing zone of design problems is complex because it is ill-defined (because the precise nature of goal criteria is not known (Simon, 1981). For example, the requirement to design a house that has a particular ambience or a car that will appeal to a particular market, is complex because, often, the criteria that determine that a new design is successful can be determined only by analysing market reaction after the product has been successful. Thus, as all designed products contain new and different aspects, it is not possible to define criteria for successful design solutions with any precision.

The satisficing zone of design problems is also complex because goal criteria for design problems can be linked and contradictory (Helfman, 1992). The problem of designing and constructing a comfortable yet inexpensive car or a strong but lightweight chair, are two examples of design problems with linked and potentially contradictory criteria.

A summary of the characteristics of design problems is provided in Table 1.

Table 1   Summary of characteristics of the problem space of design problems (Middleton, 1998)

Problem Zone	Search & Construction Zone	Satisficing Zone
Ill-defined	Numerous procedures	Ill-defined
Opaque	Figurally complex	Figurally complex
	Opaque	Contradictory criteria
	Emergent procedures	Emergent criteria
	Constructed procedures	

Discussion

Implications of the model in terms of our understanding of problem-solving is that it challenges the idea that all problems can be characterised as instrumental and amenable to resolution through a process akin to formal logic. This finding is important as it challenges the dominant theory which argues that algorithms provide strong procedures for solving problems wheras heuristics are weak.

The full implications of the model and theory for teaching and learning in design and technology will come from future research. However, there would seem to be two immediate implications. Firstly, the need for students to critically analyse design problems in order to establish a representation that will assist them to solve the problem and secondly, the need to develop strategies or "heuristics" that students can use to navigate the "construction" aspects of the search and construction space.

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