UNIT 3 THEORETICAL APPROACHES TO PROBLEM SOLVING

Structure

3.0 INTRODUCTION

The different forms of thinking behaviour including problem solving vary along a number of dimensions. The degree to which we are conscious of our thought processes can vary considerably. We tend to be conscious of the products of problem solving rather than the processes themselves. Furthermore, even these conscious products may not be recalled accurately in retrospect by people. Problem solving tasks can also be more or less directed. Some problem solving tasks are directed towards specific, well-defined goals, whereas other forms are rambling and goal-less. Thinking episodes directed at problem solving also differ in terms of the amount of knowledge that comes into play to achieve .a goal and these may be knowledge-lean or knowledge-rich. Most of the early research on problem solving has examined directed thinking in knowledge-lean situations that have specific goals (i.e. puzzles). Later research considers more knowledge-rich situations (e.g. expert problem solving). In the present unit we focus on the various theoretical approaches to understanding the process and nature of problem solving.

3.1 OBJECTIVES

On completing this unit, you will be able to:

- Explain the theoretical aspects of problem solving;
- Give a historical account of problem solving; and
- Describe the various theories related to problem solving.

3.2 APPROACHES TO PROBLEM SOLVING

In this unit, we will examine the theoretical understandings of nature and process of problem solving from the traditional to the most recent viewpoints. The theoretical models that are discussed in detail include the traditional models of problem solving, Gestaltists Theories, Information processing and computer simulation, The General Problem Solver (GPS), Wickelgren's general problem solving strategies and Newell's approach to understanding Problem Solving.

3.2.1 Traditional Approaches

Traditional approaches explain problem solving in terms of principles of associative learning derived from the studies of classical and instrumental conditioning. According to some theorists an individual enters a problem situation with an existing complex of stimulus response associations as a result of prior experience. The problem is more likely to elicit some of these associations than others, with a clear implication that problem difficulty will depend on the strength of the correct association relative to the strength of other incorrect associations. In the course of problem solving, the associative complex gets rearranged as some tendencies are weakened through extinction (failure) and other strengthened through reinforcement (success). This viewpoint stresses the transfer of prior learning to the problem situation and to the learning which takes place during problem solving.

3.2.2 Gestalt Approaches

A different view of problem solving was proposed by the gestalt psychologists. These theorists emphasised the importance of the structure of the problem situations and the formation of new combinations of old ideas. They were particularly interested in how people solve problems by rearrangement of objects. A well known example is the problem described by Kohler (1925) in his book, The Mentality of Apes. Kohler hung some fruits from the top of a cage to reach it. The cage contained several sticks and crates. The solution depended on finding a correct way to rearrange the objects. According to the Gestalt analysis, solving the problem required the reorganisation of the objects into a new structure. Gestaltists argued that discovering the correct organisation usually occurred as a flash of insight. Insight is the sudden discovery of the correct solution following a period of incorrect attempts based primarily on trial and error. Insightful solutions seem to occur in a flash.

Gestalt psychologists distinguished between reproductive and productive thinking (Wertheimer, 1959). Reproductive thinking entails the application of tried and true paths to solution. The thinker reproduces a series of steps that are known to yield a workable answer by using rote memory. Productive thinking on the other hand, requires insight and creativity. According to gestalts view the thinker must see a new way of organising the problem, a new way of structuring the elements of thought and perception. A classic problem calling for productive insightful thinking is the nine dot problem shown below:

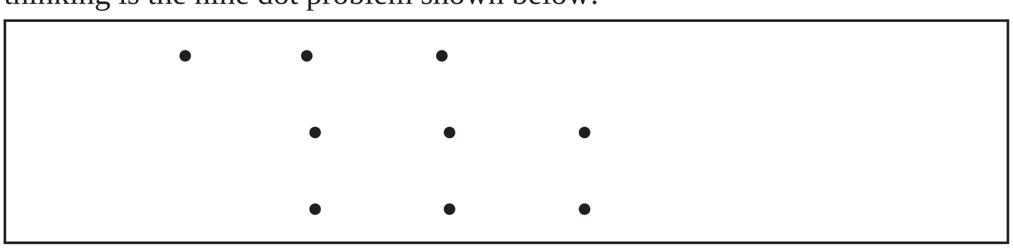

Fig. 1: The Nine dot problem

The task (problem) is to connect the nine dots with just four straight lines, without lifting your pencil from the paper in drawing the lines. To think productively in this problem situation one must restructure the problem, to throw off the unnecessary assumption that the lines must lie within the visual boundaries.

Self Assessment Questions

1) Describe traditional approaches to problem solving.

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2) Describe Gestalt approaches to problem solving.

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3) Compare and contrast the traditional and Gestalt approaches.

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3.2.3 Information Processing and Computer Simulation

A number of researchers have tried to program computer to perform tasks that human beings do. Such computer simulation research has had a profound influence on psychology of human cognitive processes. The method consists of programming a computer to work in a specified manner and comparing its performance to that of human subjects given the same tasks. Researchers employing computer simulation have made major contributions to the development of information processing view of problem solving.

A problem requires a person not only to register information from the environment but also to operate on, modify, or transform that information in some way in order to reach a solution.

Solving problem also requires the retrieval of both factual and procedural knowledge from long term memory. Especially for longer problems, reaching a solution might involve repeated storage and retrieval of information generated early in the problem for use in later stages. Even this brief listing clearly indicates that problem solving is not a single cognitive process but rather involves a number of activities which need to be properly executed and organised to be successful.

The most promising kind of theory in the early 1980s involves computer simulation. In the last couple of decades a number of computer simulation theories of problem solving have emerged. The general problem solver (GPS) developed by Newell, Shaw and Simon (1958). It introduced a way of looking at problem solving which has influenced virtually all problem solving theories.

3.2.3.1 The General Problem Solver (GPS)

The program was equipped with the equivalent of:

A limited capacity working memory characterised by rapid storage and retrieval

A large capacity long term memory characterised by relatively low storage and retrieval

A serial processor that performs one operation at a time

A reliance upon heuristics, rather than algorithms that would require a large number of high speed calculations.

Newell and his colleagues collected verbal protocols that were used and kept as a record of people talking aloud as they solved problems. Then they transcribed these lengthy records carefully to see if they could find general heuristics that emerged. It introduced a way of conceptualising problem that is adopted in most contemporary theories of problem solving.

The General Problem Solver (GPS) assumes that the problem solver represents a problem as a problem space which consists of a set of nodes, each node corresponding to a state of knowledge about the problem. The problem solver begins at the initial state of knowledge and seeks to convert it into the goal state by applying operators, which are actions that are permitted in order to move from one state of another. Problem solving, then, requires a constructive search during which the solver builds up a problem space, which leads from the initial to goal state using a set of allowed operators.

3.2.3.2 Means End Analysis

This was recognised as a general problem solving heuristic which involves a search for operations that will reduce the difference between present state of knowledge and the goal state. In particular, means-end analysis involves the following steps:

Set up a goal

Look for a difference between the current problem state and the goal state.

Look for a method to decrease or eliminate the difference between the two stages.

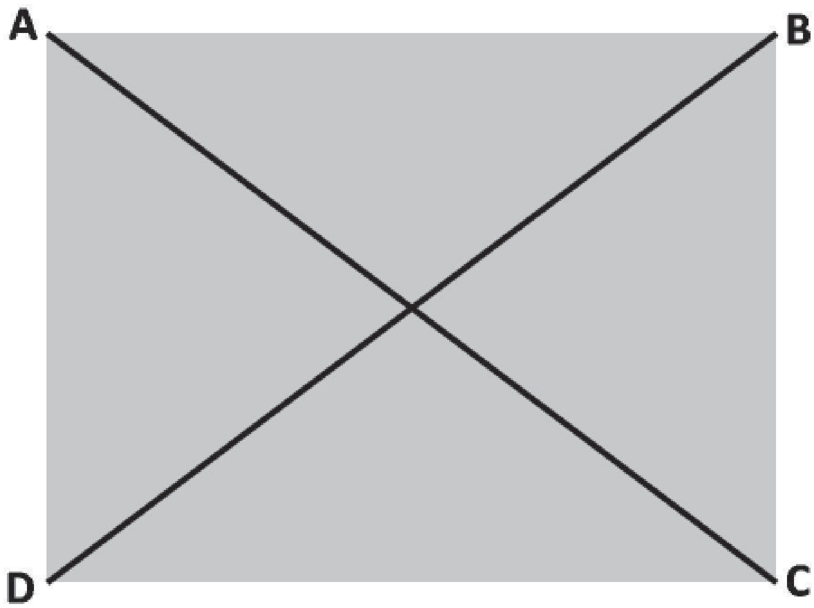
Set as a sub goal which is the application of that method.

If necessary apply means- ends analysis to apply to the sub goal.

Thus, the main heuristic used in GPS involves setting up goals and sub goals. In fact, this strategy can be expressed very precisely as a production system, that is, as a set of if – then pairs stored in the computers memory as production.

An illustrative geometric problem:

The problem is that ABCD is a rectangle; prove that AD and BC are same length.



Steps in problem solving:

Represent the problem as a proposition or in visual form

Determine the goal.

Break down the goal into sub goals.

Select a problem solving technique

Solution is:

It can thus be proven that triangles ACD and BDC are congruent if one could prove that two sides included angles are equal. (We reason from goal to sub goal, proving the triangles congruent, from the sub goal to another sub goal improving the sides and angle equal), and so on, until we reach a sub goal that we have a ready means of obtaining).

The 3 strategies that we can use to solve this problem are difference reduction, means-end-analysis, and working backwards and these three strategies are extremely general and can be applied to virtually any problem.

3.2.3.3 Wickelgren's General Problem Solving Strategies

Wickelgren's view of problem solving is based on information processing theories such as GPS. According to this view, a formal problem contains three types of information:

A statement of the initial state.

Description of the goal state.

Description of set of operation or transformations.

A solution can be defined as a sequence of state or actions which helps to represent in a diagram called the State Action Tree. The nodes or branch points on the tree represent all the possibly different problem states that could result from all the different action sequences.

The branches on the tree represent the possible actions that could be made at the particular state of knowledge. The given state is represented by the single node at the top level of the state action tree, and the goal state is represented by the indicated node in the lowest level of the tree.

For this schematic tree, we assume that from the goal state there are only two possible actions that the person can take. One of which starts the person on the path toward the goal, the other of which does not.

Having chosen one of these (thereby leading the person to state level 1), the person is then faced with a new set of possible actions. Here, we arbitrarily assume that there are three possible actions that could be taken at either of the state level 1 nodes.

This successive making of choices goes on and on until the person either reaches the goal state or finds himself at a dead end. Thinking about state action trees is the fact that as you get further into a problem (i.e. lower and lower levels in the tree) the number of possible action sequences increases rapidly. Wickelgren argues that there are seven general problem solving techniques for searching the state action tree.

i) *Inference:* Deducing from the explicitly stated goals givens, and operations stated in the problem

ii) *Classification of action sequences:* organising possible sequences of actions (or operations) that are equivalent as far as the problem is concerned. These are called equivalence classes.

iii) *State evaluation and hill climbing:* state evaluation involves defining a quantitative evaluation function that can be calculated for all possible problem states and hill climbing involves choosing the action to be taken next that will have an evaluation that is closest to the goal.

iv) *Subgoals:* This stage involves searching for sub goals involve breaking down the problem into sub goals to make it simpler.

v) *Contradiction:* deriving some inference from the givens that is inconsistent with the goal state to narrow down the state action tree in a systematic fashion by eliminating possibilities that could possibly not work.

vi) *Working backward:* It involves beginning with the goal state and working backward from it.

vii) *Finding relations between problems:* finding relations between the new problems and problems solved previously.

Self Assessment Questions

1) Describe and delineate the characteristic features of information and computer simulation approach to problem solving.

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2) What do you understand by the term General Problem Solver.?

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3) Describe the Menan end analysis with examples

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4) Put forward in detail the general problem solving strategies of Wickelgren.

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3.3 NEWELL'S APPROACH

It is very natural to think of problems as being solved through the exploration of different paths to a solution. Taker maze for example. In this, you start from a point outside the maze and then progress through it to the centre. On your way, you reach junctions where you have to choose between going straight on, turning to the left or right, or turning back. Each of these alternative paths may branch again and again so that, in the maze as a whole, there are hundreds of alternative paths (only some of which will lead to the centre). Different strategies can be used to find one's way through a labyrinth.

The strategies provide you with a systematic method for searching the maze and help you to select one from among the many alternative paths.

Newell and Simon used parallels to these basic ideas to characterise human problem solving behaviour.

They suggested that the objective structure of a problem can be characterised as:

i) a set of states, beginning from an initial state (e.g. standing outside the maze),

ii) involving many intermediate states (e.g. moving through the maze), and

iii) ending with a goal state (e.g. being at the centre of the maze).

The application of these operators (turn left, go straight etc.) results in a move from one state to another. In any given state there may be several different operators that apply (e.g. turn left, turn right, go back) and each of these will generate numerous alternative states. Thus, there is a whole space of possible states and paths through this space , and only some of these will lead to the goal state. *This problem space describes the abstract structure of a problem.*

3.3.1 Summary of The Problem Space Hypothesis

For any given problem there are a large number of alternative paths from an initial state to a goal state; the total set of such states, as generated by the legal operators, is called the basic problem space.

People's problem solving behaviour can be viewed as the production of knowledge states by the application of mental operators, moving from an initial knowledge state to a goal, knowledge state.

Mental operators encode legal moves that can be made. There are also restrictions which disallow a move if certain conditions hold.

People use their knowledge and various heuristic methods (like means-end analysis) to search through the problem space and to find a path from the initial state to the goal state.

All of these processes occur within the limits of a particular cognitive system. That is, there may be working memory limitations and limitations on the speed with which information can be stored and retrieved from long-term memory.

Newell's approach, which is based on this problem space hypothesis, propounds that the knowledge level rationalises behaviour in terms of the reasons that an agent has to believe that certain actions will lead to achieving certain goals. In this sense knowledge is a means to an end, a resource for behaviour.

The goal of problem solving is to select one of the possible actions.

3.4 PROBLEM SOLVING AS MODELLING

More recently, a different view is being explored, namely the view of problem solving as modeling.

The idea is that problem solving is the construction of situation specific model or case model.

From a knowledge level perspective the person's perception of the world is through knowledge alone. A goal therefore must correspond to the desired state of ones knowledge about the world.

Consequently this knowledge must refer to the specific systems that the goal is about. The case model thus summarises the person's understanding of the problem, and allows it to eventually conclude that the goal has been reached.

The actions are the means by which the person interacts with the world. Since at the knowledge level the person's perception is through knowledge, the interaction must be viewed as a way of obtaining knowledge about the reality. Thus one may say that actions of perception and interactions fit in this scheme.

In the problem solving as modeling, the actions are not the goal of problem solving but are themselves a means to an end. That end is the construction of a model which will help in eventually achieving the goals. Whether it is the domain model or task model the construction of the model should be such that it should lead to the goal.

For instance, in making a domain model, it is not just packaging statements about the domain, but it should involve augmenting statements with a series of assumptions about how the information about the systems is connected.

In regard to task model, it embodies assumptions about the meaning of goals. For example, if a diagnostic task is modeled as a process to generate and test over components of a system, then one implicitly assumes that the fault one is looking for can be localised in a component.

Thus, modeling a task corresponding to a goal is to make more precise what one *assumes* that goal to mean.

The role of the problem solving method is to tie domain and task models together in an argument on what accomplishing the task means in terms of the available models. This is termed as competency theory.

To give an example, a heuristic classification problem solver assumes that the solution to its problem is within the differential and it is what the problem solver believes that it can say about the problem. This actually defines its competence.

In addition the competence theory also talks about what rationality means. A heuristic classification problem solver will use the knowledge and actions pertaining to rationality to reduce the sise of the differential. This is called *specialised principle of rationality*. It contains the basis for all "why" questions about the system's behaviour.

This model is the case model and it is obtained from the competence theory through actions. Specific control regimes (e.g., data-driven or hypothesis-driven heuristic classification) correspond to different ways of operationalising the specialised principle of rationality.

The configuration of models, tasks and methods entails a set of assumptions that together can be interpreted as a model of the problem. The goal of problem solving is to instantiate this model by making it realistic.

This can be done by making derivations from

i) the case-specific knowledge obtained by the person's actions and

ii) the assumptions embodied in the domain and task models.

The form of the case model is determined by the selection of problem solving method.

In this view problem solving is no longer an input-output process (as in KADS-I). It is also not a means to select actions (as in Newell's knowledge level theory). It is also not a model transformation process (as in Components of Expertise). It is in fact a process of organising knowledge by making assumptions (i.e., constructing a model) that allow one to conclude (in effect, only assume) that the task is accomplished.

Successful problem solving is a matter of making the right assumptions and exploring their consequences.

Problem solving is thus viewed as the 'creation' of a suitable case model and the interaction with the world is only a resource for this. It is almost a side-effect in the process of maintaining an internal organisation and identity.

Self Assessment Questions

1) Describe Newell's approach to problem solving.

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2) What do you understand by the term problem space hypothesis?

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3) Summarise the Problem space hypothesis.

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4) What is problem solving as modeling?

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5) Discuss successful problem solving.

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3.5 LET US SUM UP

Like most of the psychological and cognitive constructs problem solving has also been construed in different light by different researchers following different schools of psychology. The more traditional approaches explained problem solving in terms of principles of associative learning derived from the studies of classical and instrumental conditioning.

Gestaltists viewed it differently and emphasised the importance of the structure of the problem situations and the formation of new combinations of old ideas. Since then we have observed many different approaches to understanding problem solving in terms of the Information Processing and Computer Simulation approach, the General Problem Solver (GPS) approach, Wickelgren's general problem solving strategies and Newell's approach which is based on problem space hypothesis.

As knowledge and research progresses it is likely that one may come up with more comprehensive theories of problem solving.

3.6 UNIT END QUESTIONS

1) What are the traditional approaches to understand problem solving? Think of some problems that you can explain based on these approaches.
2) Explain Wickelgren's approach of general problem solving strategies.
3) Compare the Gestallt approach of problem solving with information processing approach to problem solving.
4) Newell's problem solving approach rests on a famous hypothesis in the literature of problem solving. Name and explain this hypothesis.
5) Critically discuss Newell's approach to problem solving.
6) What do you understand by the term "General Problem Solver". Explain with examples.
7) Do you think that a single approach amongst the approaches discussed in this chapter is sufficient to explain all kinds of problems and problem solving that we face.

3.7 SUGGESTED READINGS

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