
UNIT 2 STAGES OF PROBLEM SOLVING

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2.0 INTRODUCTION

In this unit, we will examine the basic steps and strategies involved in problem solving – the ways to reach to solutions of the problems, and the various methods to solve different kinds of problems. For this, in particular, the following topics are discussed in detail. We will deal with Stages of Problem Solving, Techniques of problem solving, Creativity and Problem solving and the role of Artificial Intelligence in Problem Solving

2.1 OBJECTIVES

After completing this unit, you will be able to:

- Define problem solving and problems;
- Describe the various stages in problem solving;
- Analyse the various solutions; and
- Explain the steps to reach the best solution.

2.2 NATURE OF THE PROBLEM

The first step to solve the problem is to understand its different aspects and nature i.e. to figure out just what issues, obstacles and goals are involved. According to Greeno (1977), Understanding involves constructing an internal representation. For e.g. If you understand a sentence, you create an internal

representation or pattern in your head so that concepts are related to each other in the same way that they are related to each other in the original sentence.

In order to create this pattern in your head you must use background knowledge, such as the meaning of the various words in the sentence. In order to understand a problem you must pay attention to the important information in a problem. Furthermore, you must ignore the information that is irrelevant. As soon as the problem solver has decided which information is essential and which can be disregarded the next step is to find a good way to represent the problem. The representation can be done by using symbols, lists, matrices, graphs and visual images.

2.3 GENERATING SOLUTIONS

The next stage is finding variety of potential solutions for the problem. For this one can use one's past experiences and/or present resources and thinking critically about the problem. Several strategies can be used to solve the problems. Some methods are very time consuming but they will yield an answer. Other methods are less wasteful of time, but they may not produce a solution. These strategies are discussed in another section of the unit.

2.3.1 Judging the Best Among the Likely Solutions

At this stage we must evaluate each alternatives and outcomes of the problem. The objective of this step is to move closer to goal and learn about major obstacles and hidden costs of the particular solution and choose the best solution.

Carrying out the best solution

This stage involves actually working out the best solution. Various strategies can be adopted in reaching the solution. Algorithms and heuristics are the strategies which can be used depending upon the requirements of the problem. These are being dealt in the next section.

Evaluation of solution

In this the problem solver compares the solution with the representation of the problem. The path taken from the initial state to the goal state is checked as to whether it is specified as legal or not. Sometimes the evaluation stage leads to the conclusion that the problem has not been solved adequately, and thus one starts from an earlier stage, depending upon the source of the inadequacy.

2.3.2 Strategies for Problem Solving

An individual uses various kinds of methods or strategies to solve problems. Some strategies when used take a long time but definitely give an answer. On the other hand, there are some other strategies which take lesser time but do not always guarantee success. These strategies can be mainly classified under two categories, viz., (i) algorithm and (ii) heuristics. These two are discussed in the following section.

Algorithm

An algorithm is a specific procedure for solving a type of problem. An algorithm invariably leads to the solution if it is used properly, that is. It is a procedure of

steps that does guarantee a solution if one follows the steps correctly. The rules of multiplication constitute an algorithm because a correct answer is guaranteed if one follows the rules.

Consider anagram problems in which we try to reorganise groups of letters into words. Examples of algorithms are systematic and unsystematic random search techniques. Unsystematic random search means that we try out all kinds of possible answers but make no attempt to be orderly in our search and keep no record of our previous attempts. As a consequence we may repeat a response that has already proved to be wrong. In systematic random search we try out all possible answers using a specified system. This method is somewhat more efficient than unsystematic random search, but it is highly time consuming when there are many alternative answers. If you are given a 3 letter anagram, YBO, with instructions to unscramble it, proceed with a systematic random search: YOB, BYO, BOY, ! However, notice how time consuming it would be to use a systematic random search to solve a longer anagram, such as LSSTNEUIAMYLOU.

Heuristics

In this strategy an individual does not go for all the alternatives to solve problems but choose some most relevant alternatives. This is kind of short cut rule which takes lesser time but does not guarantee success. Heuristics are rules of thumb that help us simplify and solve problems.

Heuristics do not guarantee a correct solution to a problem but when they work, they permit more rapid solutions. A heuristic device for solving the anagram problem would be to look for familiar letter combinations. For e.g. how many words can you make from the pool of letters DWARG? In this anagram we can find the familiar combinations *dr* and *gr*. We may then quickly find draw, drag, and grad. The drawback to this method, however, is that we might miss some words.

Psychologists have paid more attention to how humans use heuristics than how they use algorithms. Let us look at some of the heuristics as strategies in solving problems. Problem solvers can use one or more of these heuristics as they attack a problem.

Self Assessment Questions

- 1) Define problem and problem solving.

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- 2) Discuss the nature of the problem.

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3) How do we generate solutions to the problem?

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4) Discuss strategies for problem solving.

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5) What is algorithm?

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6) What is heuristics?

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2.3.3 Some Specific Techniques of Problem Solving

The way to solve a problem depends to a great extent on the nature of the problem itself. For example, if you want to go from New Delhi to Chennai you will call various travel agents for information regarding the various available options for traveling and staying. However, if you want to know your bank balance you will not call a travel agent for assistance but go to your bank or nearest ATM or use net-banking. This is called domain specific problem solving approaches, that is the solution that work only for a limited class of problems. In the following section, a certain class of general, domain independent techniques of problem solving is discussed.

2.3.3.1 Generate and Test Techniques

To understand this let us begin with a simple problem:

“Think of ten words beginning with letter c that you eat or drink.”

The process that most of us use to arrive at the solution to such a problem generally involves what is called generate and test technique. It consists of generating possible solutions and then testing them. For example, for the above problem of generating a list of things to eat or drink beginning with letter c, some of the names that often come to our mind that sound as if beginning with c but which actually do not (like ketchup) and some that start with c but are not names of eatables/drinks (like cable, can) might have come to your mind as a solution but on thinking you would have discarded these words. This explains the process of thinking of possible solutions (generating) and then seeing if those possibilities met all the criteria (testing).

Generate and test is a technique that loses its effectiveness very rapidly when there are many possibilities and when there is no particular guidance over the generation process. For example, if you forget your ATM pin, the technique might eventually work but your frustration level by that time might exceed beyond your willingness to work on the task. Moreover, if we do not have a way to keep track of the possibilities that we have already tried, along with the ones that we still have to try, we might be further frustrated.

Generate and test can be useful when there aren't a lot of possibilities to keep track of. If you have lost your keys somewhere between your classroom and college cafeteria the technique can be easily used to help search the keys.

2.3.3.2 Means-ends Analysis

It is a strategy in which the problem solver divides the problem into a number of sub problems, or smaller problems. Each of these sub problems is solved by detecting the difference between the original state and the goal state and then reducing the difference between these two states. The name means ends analysis fits the process, because it involves figuring out the “ends” you want and then figuring out what “means” you will use to reach those ends. Every day we all solve problems by using means ends analysis. Means ends analysis involves subgoals to eliminate the difference between the current state and the condition for applying desired operator.

Our original state at one point is an equation

$$2s - 10 + 5 = s + 5 + 8$$

and our goal state is an equation with a single s alone one side. We reduced the difference between the two states by adding +5 to each side of the equation and subtracting s from each side of the equation.

This strategy repeatedly compares states and seeks operators, establishing subgoals and finding ways to reach the sub goals, all on the way to finding a path to the final goal.

2.3.3.3 Backward Search

With the backward search heuristic, the problem solver starts at the goal state. Sometimes it is useful to start at the goal state of a problem and attempt to work backward to the initial state. In solving a paper-pencil maze, it may be easier to see the correct path by starting at the end. Working backwards can be a very useful heuristic, particularly for problems that contain a uniquely specified goal state. For example, a backward search would be ideal for a maze with many paths out of the beginning point yet only one path leading from the goal.

The reason working backward helps lies in the subgoals that one begins to see by starting with the final goal. Once the problem solver can envision a string of subgoals projecting backward from the goal state, then going about solving the subgoals in a forward direction can be readily accomplished. Working backward is only viable when the goal state is uniquely well defined (Wickelgren, 1974).

2.3.3.4 Planning Strategy

In this heuristic, the problem is divided into two simple aspects and complex aspect. First, the simple aspect of the problem is solved leaving behind the complex one, and thereafter the complex aspect is taken and is solved. It is particularly useful if the aspects that are ignored can easily be worked into the solutions to the complicated problems.

One common kind of planning strategy is analogy. In analogy, a solution to an earlier problem is used in order to help with an original problem. The current problem is solved on the basis of past experience of solving similar problems. This heuristic looks for similarities between a current problem and one solved in the past. Try to solve the anagram BODUT. By thinking of words D, O, U will simplify the problem information. The usefulness of the planning strategy depends on the extent to which the solution to the simple problem will be helpful when the complex problem is considered.

2.3.3.5 Thinking Aloud

Ericsson and Simon referred to the method of thinking aloud as a Method for Studying Human Problem Solving is referred too as concurrent verbalisation, that is verbalisation of information at the time the subject is attending to it. This is to be distinguished from *retrospective verbalisation*, in which the subject is asked about cognitive processes that occurred at an earlier point in time.

Concurrent verbalisation relies on short-term memory whereas retrospective verbalisation relies on long-term memory.

When subjects think aloud, they put into words a process that normally takes place nonverbally. This provides a description of the subject's solution process. A verbal description so obtained is called a *protocol*. Although there may be omissions in these protocols, they still contain a great deal of useful information.

Newell (1977) recommended a series of steps in order to clarify the protocol.

1st Step: First, the protocol needs to be divided into phrases, which are descriptions of single acts.

2nd Step: Second, the experimenter constructs a *problem behaviour graph*, a concrete description of the way in which the subject moves around in the problem space. This description can be used as the basis for a production system designed to model the subject's behaviour.

Although concurrent verbalisation is widely used, there is evidence suggesting that it may interfere with some aspects of the problem-solving process. For example, Schooler, Ohlsson, and Brooks (1993) did a study in which subjects were interrupted while trying to solve an insight problem.

One group was then asked to describe their problem-solving strategies, while another group engaged in an activity irrelevant to the problem. Subjects then resumed attempting to solve the problem.

The group that had verbalised their strategies were less likely to solve the problem than the group engaged in an irrelevant activity. Schooler, Ohlsson, and Brooks concluded that there are “non reportable or unconscious processes” that lead to insightful solutions, and these are interfered with by verbalisation.

These non reportable processes may be memory searches that lead to the recovery of the items needed for the solution. These processes may be disrupted by the attempt to verbalise the solution process. Therefore, researches using think-aloud techniques should also consider including silent control groups to determine whether verbalisation influencing performance.

2.3.3.6 Other Strategies

Some other strategies that people often employ in problem solving include:

Abstraction: This technique involves solving the problem in a model of the system before applying it to the real system.

Divide and conquer: While using this approach to problem solving, people break down a large, complex problem into smaller, solvable problems.

Hypothesis testing: This involves assuming a possible explanation to the problem and trying to prove (or, in some contexts, disprove) the assumption.

Lateral thinking: Many problems involve approaching solutions indirectly and creatively and this involves the use of lateral thinking.

Method of focal objects: This approach involves synthesizing seemingly non-matching characteristics of different objects into something new and reaching to a solution.

Reduction: Problem solving may also be done by transforming the problem into another problem for which solutions exist and this is called reduction.

Research: This involves employing existing ideas or adapting existing solutions to similar problems.

Root cause analysis: involves eliminating the cause of the problem.

Trial-and-error: This is one of the most widely studied methods in psychology and involves testing possible solutions until the right one is found.

Brainstorming: This approach is especially used among groups of people wherein a large number of solutions or ideas are suggested by various members of the groups and later these ideas are combined and developed until an optimum solution is found.

Self Assessment Questions

1) What are some of the specific techniques of problem solving?

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2) What is involved in “generate and test” technique?

3) What do you understand by the term “Means Ends “ analysis?

4) What is backward search in problem solving?

5) Discuss “thinking aloud” as a method for studying human problem solving.

2.4 CREATIVITY AND PROBLEM SOLVING

As discussed in Unit1, many of the problems are called insight problems, and are believed to have a solution that comes from insight. The process by which insight comes is not well understood. However it is strongly believed that creativity plays a vital role in insight and vice versa.

Although the term is difficult to define precisely, many psychologists believe that creativity has to do with appropriate novelty, that is, originality that suits some purpose (Hennessey & Amabile, 1988).

Appropriate ideas that lack novelty are mundane; conversely original ideas that do not address some problem in a useful way are bizarre. Cognitive scientists refer to creativity as a combination, or recombination, of knowledge, information or mental representations. In other words the person who has created it knows about it, and also has depicted it. (Dartnall, 2002). Creative problem solving forms the essence of insight problem solutions. Insight seems to involve at least three separate problem-solving skills (Davidson, 1986; Davidson & Sternberg, 1984) and these are (i) selective encoding (ii) selective combination (iii) selective comparison. These are discussed below.

- 1) *Selective Encoding.* When we try to solve a new problem, we are often overwhelmed by large amounts of useless information. An insight arises when we determine which information is relevant for further consideration. Sir Alexander Fleming discovered penicillin through selective encoding. Fleming's attempts to grow bacteria had been disrupted by the appearance of a mold in his culture. Rather than dismissing this mold as irrelevant to his original experiments, he realised that the mold's bacteria has a killing ability that was relevant to a greater medical concern, that is the need for antibiotics to kill disease-causing organisms.
- 2) *Selective Combination:* When we have a problem to solve, we often have all the pieces of the solution, but we do not know how to put them together. An insight arises when we discover a novel way of combining the elements of the solution.

For example, Darwin's construction of the theory of evolution involved selective combination. The various facts about natural history had been available to him for a long time. What Darwin did was to combine this information into an innovative and coherent theory.

- 3) *Selective Comparison.* When we solve a problem, we often use a model solution that we encountered in the past. Insight occurs when we discover that a more novel comparison leads to unforeseen consequences.

To give an example, Kekule's discovery of the structure of the benzene ring involved selective comparison.

In a dream Kekule saw a snake curl back on itself and catch its own tail. Upon waking, he realised that this was the structure he had been seeking. His insight was to discern the underlying similarity between his dream image and the benzene ring.

As the above examples suggest, insight is an important aspect of the creative process. Even though the laboratory puzzles and problems that we have been discussing in this Unit as examples bear little resemblance to the kinds of problems that Fleming, Darwin, and Kekule worked on, they all involve insight in that a solution suddenly comes to mind. They also share another property, that is, the person begins in the dark, not knowing what to do. What factors promote creative solutions to important problems?

2.4.1 Stages Involved in Creative Discoveries

Many creative discoveries seem to occur in these four stages:

- 1) Preparation
- 2) Incubation

- 3) Insight
- 4) Verification.

As discussed, Creativity is the ability to see something new in something quite ordinary.

Preparation: First a goal is set. Then potentially relevant information is gathered, sometimes deliberately, sometimes by accident.

Incubation: This preparation done, a period of apparent inactivity, that is incubation can set in. Incubation may involve unconscious mental activity, or it may simply be a period of waiting for some important missing link to fall into place.

Insight: The moment of insight (also called illumination) often involves familiar elements coming together in new ways. The mathematician Henri Poincare wrote, “To create consists of making new combinations of associative elements that are useful” (1929).

Verification: The final step, verification, tells whether a new combination is, in fact, useful. Two characteristics stand out in the creative person:

The first is a clear sense of purpose: An invention, a painting, a musical composition, or any other creative product is a solution to a problem. Without a clear goal, a clear problem to solve, nothing would be created. The second outstanding characteristic of creative people is their store of knowledge and techniques. Inventors have to know both the content and the techniques of their field, composers have to know music and the craft of composition, and scientists must know the facts and theories of their field and master the mathematical and technical tools of the trade. Because “creativity” has an almost mystical connotation, it is easy to forget how basic and indispensable purpose and knowledge are.

Self Assessment Questions

- 1) How are creativity and problem solving related?

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- 2) What are the 3 problem solving skills that insight involves? Give examples

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3) What are the various stages in creative discoveries?

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2.5 ARTIFICIAL INTELLIGENCE IN PROBLEM SOLVING

Researchers studying problem solving propose problem space hypothesis which states that “every possible state of affairs within a problem corresponds to a particular mental node and the entire set of nodes occupy some mental area and this area together with the mental graph is a problem space”.

This problem space hypothesis has been used to create expert systems called computer programmes designed to model the judgments of one or more human experts in a particular field.

Expert systems contain a knowledge base that store facts relevant within that field. They typically also contain a set of inference rules, a search engine that the programme uses to search knowledge base using inference base and some interface or means of interacting with a human user who has a question or problem for which he/ she is consulting the expert system.

These are computer programmes that solve problems in ways that are similar to the intelligent way in which humans solve problems are called artificial intelligence approaches and have been found to be extremely influential.

2.5.1 Criticisms of the Computer Simulation Approach

Not all researchers agree that computer simulation can capture the way that people think when they solve problems. Some people argue that thinking is just too complex to be mimicked by a machine. However, as we know, computer programs can produce some solutions to very complicated problems. Current experience and researches suggest that there appear to be no reason, in principle, why computer program should not-approach (or surpass) the complexity of human thought.

Other criticisms derive from the belief that whatever it is that computer programs do it does not really count as thinking and problem solving. People who express this belief often ally themselves with the German philosopher Heidegger (1968).

The properties of computer programs that they can represent the chain of inferences leading from one state to another are not the essence of thinking for Heidegger who strongly propound that ‘Computer programmes are good stimulators of such processes as reasoning and calculating. However, the essence of thinking lies behind such processes as reasoning and calculating and computer programmes are not reducible to them. It is the subjective origin of thinking-the

concern with the fundamental problem of being alive in the world which the computer programmes do not capture. Despite these arguments, in the current times artificial intelligence is widely used for problem solving and appears to have promising future.

Self Assessment Questions

- 1) How does artificial intelligence function in problem solving?
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- 2) What is meant by computer simulation approach in problem solving?
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- 3) What are the criticisms against computer simulation? Discuss
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2.6 LET US SUM UP

Problem solving involves both domain specific and general strategies that people may use. General strategies (like generate and test, means-ends analysis, reasoning by analogy) are believed to be general strategies of problem solving that people use in wide variety of situations. In contrast there are domain specific strategies that are suitable in one particular situation and problem but not for others.

Many expert systems that represent artificial intelligence are specially designed computer programmes that mimic a human expert in a specific field. However, there are many unanswered questions pertaining to the utility of artificial intelligence in problem solving. Insight problem solving has been found to be related to creativity. In summary, problem solving is a multi step process and may be facilitated by individual characteristics such as creativity.

2.7 UNIT END QUESTIONS

- 1) What are the stages in problem solving? Highlight the stages with a problem from your day to day life.
- 2) Compare and contrast the generate- test, the means ends and the backward search method of problem solving.
- 3) Discuss “thinking aloud as a method of studying human problem solving
- 4) Discuss “other strategies” in problem solving. For example, abstraction, divide and conquer etc.
- 5) Critically evaluate the utility of artificial intelligence in problem solving?
- 6) Compare and contrast the general stages of problem solving with the stages of creative problem solving.
- 7) Discuss the concept of thinking aloud approach of problem solving.

2.8 SUGGESTED READINGS

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