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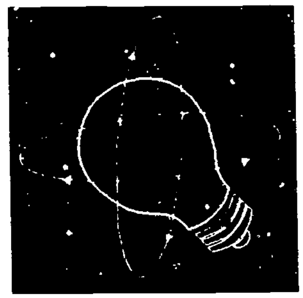
ABSTRACT

Top-down problem solving is a methodical approach to obtaining real solutions for open-ended problems common in the realms of engineering and science. The technique provides a means for logically understanding a problem prior to attempting a solution. Steps in the top-down problem-solving method include the following: (1) identifying a need; (2) defining the problem; (3) developing ideas; (4) analyzing alternatives; and (5) evaluating a solution, leading either to development of additional ideas or solving the problem. Problem solving is a thinking skill that must be learned. Teaching it requires demonstration and practice. An effective way for students to improve their problem-solving skills is to work together (brainstorm), think aloud, learn from each other, and learn how others approach the same problems. Top-down problem solving lends itself well to almost any type of life's problems and, if taught at an early age, can provide children with a very useful tool for their entire education. (KC)

Teaching Top-Down Problem Solving



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Abstract: The average person commonly uses a bottom-up approach in all but a few of life's problem solving situations. Solution attempts are quickly made before fully recognizing and defining the problem. This results in solutions which address mostly symptoms rather than the true problem. The bottom-up method is very common for K-12 and college students. Top-down problem solving is a methodical approach to obtaining real solutions for open-ended problems common in the realms of engineering and science. The technique provides a means for logically understanding a problem prior to attempting a solution. It lends itself well to almost any type of life's problems and, if taught at an early age, can provide children with a very useful tool for their entire education.

Introduction

Problem solving is a learned skill. At the initial stages of a person's life, the problem-solving technique most frequently used trial and error. Attempts are made at problem solutions with no consideration of how a particular solution was chosen or why it worked. This technique, as illustrated in Figure 1, is termed bottom-up problem solving and, at a very young age, is effective on simple problems. However, as more complex problems are encountered, a more sophisticated solution approach is needed. Otherwise, the person continues to utilize methods which are both inefficient and frustrating, resulting in a lack of confidence in one's problem solving skills.

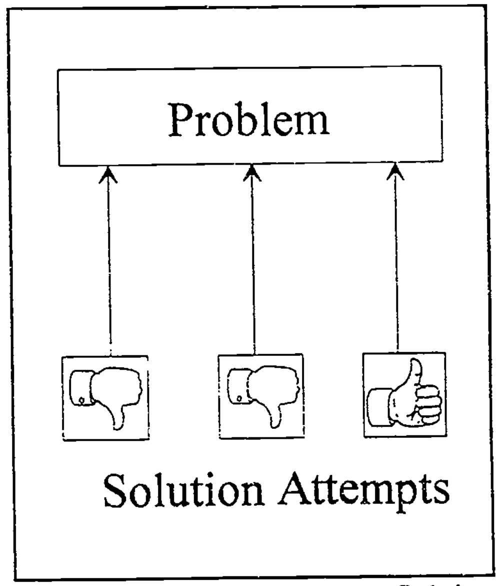

Fig. 1 Bottom-Up Problem Solving

Top-down problem solving describes an approach, commonly used in engineering and science, which can be applied to most types of problems (Pond, 1990). It provides a method to logically identify the problem, stepping through it by developing alternatives, identifying pertinent data, and arriving at a satisfactory solution. The intent of this paper is to present a cognitive approach to effectively teach top-down problem solving in technology education.

Problem Types

The recognition of an answer type is the first step at identifying alternatives for solving a problem. Problems can be classified according to the type of answer that is required. These classifications are convergent, divergent, and a convergent-divergent combination (Krulik and Rudnick, 1993).

The convergent problem, such as "2 + 2 = 4," proceeds inward toward a single answer. This objective type of problem is very common in technology education since much of the material to be taught is based on math, science, and/or logic principles.

The application of top-down problem solving is highly effective in this realm, providing a methodical approach to problem understanding. The subjective divergent problem, such as "list the possible uses of a brick," proceeds outward from the problem statement in many possible directions. While this open-ended type of problem has many answers, the development of feasible and logical answers is still greatly aided by the top-down technique.

The combination of convergent and divergent problem types are often found in more complex problems, such as "Which college will I choose?" The ability to finance a college education is convergent, with a single answer for the level of available funding. The choice of curriculum or major is divergent, being greatly effected by more subjective factors involving personal interests, attitudes, and backgrounds.

Top-Down Methodology

Arriving at solutions of problems through the top-down approach follows a general pattern of logic. This logical pattern is commonly used to solve problems in the realms of science and engineering (Pond, 1990). After a need is identified and stated in general terms, the first task is to formulate a clear statement of the problem. Next, various ideas for solution of the problem are developed. These ideas are analyzed for feasibility and, finally, evaluated to determine the idea that best solves the problem. In some cases, it is necessary to return to the idea development stage if no satisfactory solution is obtained by the original effort. This sequence of events is illustrated in Figure 2.

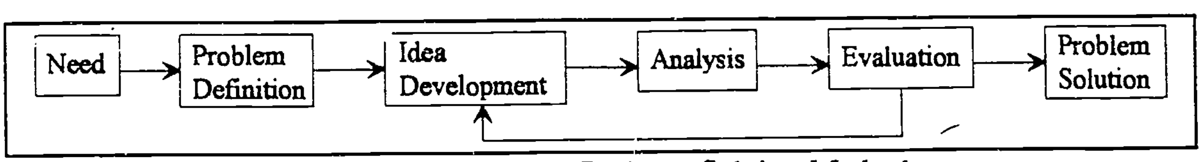

Figure 2 Top-Down Problem Solving Method

Need Recognition

Everything that was not created naturally is a result of a need. These needs are commonly human based, either personal, societal, or health related, or some combination. Other times the needs are environmental, e.g. pollution, deforestation, or wildlife oriented, e.g. endangered species, habitat. Need complexity varies infinitely, thereby complicating problem definition and solution alternatives.

In education, problems are defined for students while the need to solve the problem is typically given less emphasis or completely ignored. Recognition of the need or purpose of the problem is an integral factor in motivating the desire of a student to solve the problem.

Problem Definition

Generally, problems are represented as a vague and disjointed collection of statements describing the problem situation. Before a solution attempt can be made, a clear statement that identifies the most perplexing part of a problem must be developed. The problem statement effectively lays down the objectives for the problem solution and sets the criteria by which solutions will be judged. It must provide data on conditions of the problem situation, as well as any constraints on the problem solution.

Before a solution attempt can be made, a clear statement that identifies the most perplexing part of a problem must be developed.

Too often, the problem is overstated, thus limiting the scope of possible solutions. The U.S. space shuttle orbital re-entry is presented as an example. During atmospheric re-entry, space vehicles are exposed to temperatures as high as 14,000° F (7,760° C) on the forward surfaces. The problem statement was formulated as: Find a material that can withstand the high temperature of re-entry. However, this statement was too confining and led nowhere because no such material could be found. A more definitive problem statement was: Find a means of protecting the astronauts during re-entry. This allowed for other approaches to the problem and led to development of the

oblative heat shield. This material is destroyed during re-entry in a controlled manner, such that heat is dissipated from the shield into space rather than carried into the space shuttle. Thus, when the truly perplexing part of the problem - protection of the astronauts - was stated, the possible avenues of approach broadened.

Idea Development

In this stage, it is necessary to explore all possible approaches to solution of the problem. Reasoning, logic, creativity, and experience are called upon to devise one or more solution alternatives. Brainstorming and thinking aloud are effective techniques for this purpose. For complex problems or in cases where the problem solver is confused, each alternative should be described in general terms in written or sketch form for later analysis and evaluation.

Brainstorming and thinking aloud are effective techniques for developing alternative solution approaches to a problem.

In the development of solution alternatives, breadth of background is more useful than depth. While students need specialization (e.g. math, communications, science) to solve problems, such specialization does not open up a wide variety of approaches to a problem. A broad, open-minded approach in the development of solution alternatives is more effective at this stage.

Analysis

Each alternative must be carefully analyzed since subsequent evaluation is based on the results of the analysis. A sound background knowledge of the problem subject is important for determining the feasibility of any alternative. A solution may be conceived, but be physically impossible. Imagine the use of falling water on a paddle wheel to turn an electrical generator which supplies power to drive a pump that returns the water to a reservoir for reuse on the paddle wheel. Once started, this system would seemingly go on forever giving us free electricity. In reality, of course, such a system

would not work because it violates a physical law, which essentially states that "you don't get something for nothing."

Of all alternatives, the feasible solutions are identified according to the objectives and constraints of the problem. These constraints may be weight, height, color, cost, size, appearance, or any other factor as specified by the problem definition.

Evaluation

From the problem definition, conditions and specifications that will satisfactorily solve the problem were established. From all successful solutions techniques, further evaluations are made to determine the "best" solution. Best can be defined in terms of minimum or optimum elements or a simple convergent answer is determined.

The evaluation may find none of the original feasible solution satisfactory, making it necessary to devise new alternatives. Often, these new approaches are suggested from what was learned from analysis of the original set of solution techniques.

Teaching Problem Solving

Problem solving is a thinking skill which must be learned, yet is difficult to teach. The difficulty lies in the methods used to teach a thinking skill. Two phases are required - demonstration and practice. Typically, students are shown problem solving techniques through repetitive examples and gain experience through practice. However, examples do not adequately demonstrate the thinking skills needed for effective problem solving. Students are left to learn the skill, through trial and error, on their own.

The top-down technique provides the building blocks to develop good problem-solving skills. However, this technique is not simply taught to students. Demonstration and practice are still essential steps in skill development. An effective way for students to gain this experience is to work together and learn from each other. Several methods are available which provide the cooperative learning experience.

An effective way for students to improve their problem-solving skills is to work together (brainstorm), think aloud, learn from each other, and learn how others approach the same problems.

Of these improvements methods, brainstorming and thinking aloud are the most effective. Thinking aloud or vocalizing mental processes forces students to be more careful and thorough in analyzing ideas. More importantly, the process allows the observers, other students, to visualize the thinking process. In other words, the "thinking" process is being visually and verbally demonstrated. A key element in the development of problem-solving skills is to get the student to be mentally aware of the thinking process for each attempted problem.

Thinking aloud encourages the student to decide on the level of complexity of the problem and if the problem must be divided into subproblems. To accomplish this, the student must orally review the problem statement several times. For the method to be productive, the problem solver must always state any thoughts relevant to the problem, especially when confused so as to not miss any facts. The observer continually checks accuracy and demands constant vocalization. Some factors relative to effective problem solving are given in the table below (Elias and Tobias, 1990).

Characteristics of Good Problem Solvers	Common Errors in Problem Solving
• Positive attitude • Concern for accuracy • Breaking problem into parts • Being very careful when guessing • Constant self-questioning	• Inaccuracy in reading • Inaccuracy in thinking (illogical) • Weakness in problem analysis • Lack of perseverance

Conclusions

The worldwide diversity of technology greatly effects the current global market-place. Technology growth and utilization are increasing at amazing rates. While this

phenomenon increases our capabilities, it challenges academia. The technology educator must identify techniques which provide students with ways to solve a wide range of open-ended problems, while maintaining technical constraints.

Metacognition is being mentally aware of the thinking process and is currently referred to as critical thinking. Top-down is being mentally aware of the problem-solving processes or critical thinking about solving problems. Top-down problem solving, common in engineering and science, can be used in most problematic situations. Coupled with demonstrative methods which teach thinking skills, such as thinking aloud, students gain insight into an approach to effectively solve open-ended problems of all types.

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