SOME DIFFICULTIES ASSOCIATED WITH THE TEACHING AND LEARNING OF PROBLEM SOLVING IN SCIENCE*

Review by
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Problem solving has an important place in children's learning of science in schools. However, problem solving is still a continuing area of difficulty as far as classroom instruction for effective learning is concerned. Common teaching methods used by instructors or textbooks to teach scientific problem solving skills, rely predominantly on presenting information, showing prototypical examples of worked-out problems, and providing students with practice in solving similar kinds of problems. Less emphasis has been placed on the more important aspects such as the systematic organisation of the thinking process required for problem solving. Students should be specifically taught how to start, where to start, how to analyze and how to proceed with the solution. The purpose of this article is to identify some common difficulties in the teaching and learning of problem solving in science. Some implications of effective teaching of problem solving will also be discussed.

COMMON DIFFICULTIES OF TEACHING AND LEARNING PROBLEM SOLVING

Problem solving in this article is defined as a form of discovery learning that bridges the gap between the learner's existing knowledge and the solution to the problem. The term "problem" refers to a question to which a given individual cannot give an immediate answer. Otherwise the question would be called "an exercise" instead of "a problem".

Reif (1983) reports on the observations of the naturally occurring problem solving behaviour of novice students and experts. The information of problem solving behaviour was collected in the form of protocols. A protocol is a think-aloud exercise while writing out the solutions for the problems. Such protocols provide much more useful and detailed information than those would be obtained by test results, questionnaires or other similar gross measures. His observations indicate that novice students possess conceptual structures derived from prior experience and from informal cultural transmission. Unfortunately, these conceptual structures are often ambiguous, vague, inconsistent, and not accurately predictive. In contrast, experts possess knowledge which is remarkably large and well-organised. Much of this knowledge is tacit, i.e. used automatically without any conscious awareness. Yet this tacit knowledge is essential to good problem solving performance and sometimes quite subtle.

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According to Reif (1983), novice students usually try to assemble problem solutions by proceeding, in linear sequential fashion, to piece together various mathematical formulas. By contrast, experts often approach problems by using qualitative arguments and seemingly vague language. These plans are later refined into more mathematical language. The observations show that the experts' superior performance is not merely due to their large store of accumulated knowledge, but also to problem solving procedures more effective than those used by students. Reif (1983) suggests that problem solving involves some general problem solving procedures used in conjunction with a knowledge base containing particular knowledge about a specific domain. The problem solving procedures include three stages:

(a) Initial problem description
(b) Synthesis of a solution
(c) Assessment and improvement of solution.

Two steps of initial problem description are described. The first step aims to generate a "basic description" of a problem into a form where it is readily understandable to the problem solver. The basic description summarizes the information specified and to be found, introduces useful symbols, and expresses available information in various useful symbolic forms, e.g. the use of diagrams. The next step of the problem description is more complex. It aims to redescribe the problem in terms of the special concepts provided by the knowledge base for the relevant knowledge domain. The resulting problem description greatly facilitates the subsequent search for a problem solution since all principles in the knowledge base are expressed in terms of these special concepts and thus become readily accessible.

Once a problem has been translated, one can turn to the task of constructing its solution. The task is difficult because the search for a solution requires decisions among many possible alternatives, only a few of which lead to the desired goal. Once a problem solution has been obtained, it is important to assess whether it is correct so that suitable improvement can be made.

The comparative studies of successful and unsuccessful problem solvers in their problem solving were also reviewed by Woods (1988/89). He finds that unsuccessful problem solvers fail to know where to apply general theory and when to apply specific subsets of the general theory that seem to apply. Unsuccessful problem solvers place more emphasis on collecting sample solutions and working examples than on understanding the fundamentals. They do not memorize experience or tacit knowledge. Successful problem solvers can rapidly and accurately identify knowledge useful in solving a problem. He considers three components that contribute to successful problem solving. These are:

(a) possession of problem solving skills,
(b) a knowledge structure of the laws, concepts and "textbook" knowledge in a subject discipline;
(c) embedded components of tacit(or experience) knowledge - the discipline-specific knowledge that is implied but rarely stated in textbooks.

A study of teachers' teaching of problem solving in classes was carried out by Lee (1986). Case studies were undertaken to examine teachers' behaviour in teaching problem solving and to infer from classroom observations the students' experiences of learning about solving chemistry problems. Four teachers from four different schools (1 boys', 1 girls' and 2 co-ed schools) in Melbourne were involved. The case studies involved classroom observations and recordings of these teachers while they were teaching problem solving in electrochemistry at the HSC level. Among the four cases, the number of visits ranged from three to five lessons. For each lesson, the researcher sat at the back of the classroom to observe the activities occurring during the teaching. The blackboard and/or overhead projector presentations and the teachers' verbal instructions including their dialogues with the students were written down by the researcher. The teachers' oral presentations were taped during the lessons with the permission of the teachers. These data were qualitatively explored and analyzed. Some important results that relate to classroom learning and teaching of problem solving emerge from these case studies.

In terms of the students' potential learning experiences of problem solving, it was found that the students were mainly witnessing their teachers' demonstrations of using rules or algorithms for solutions to problems. The repeated practice of solving the sorts of problems that occur in examinations was also included as part of the learning experience. The students were not exposed to a range of strategies that could possibly be used to solve the same problems. There was no explicit teaching of important problem solving skills such as translation skills (comprehending, analysing, interpreting, and defining a given problem) and linkage skills (concept relatedness between two concepts or using cues from the problem statements to associate ideas, concepts, diagrams, etc. from memory). When teachers solve problems, they use, in general, several strategies to solve the same class of problems and they are very careful and explicit about translating problem statements, making relevant linkages and checking. (This finding is derived from the protocols (think-aloud) of these four teachers in solving four problems given by the researcher outside the classroom.) These absences in the teachers' teaching of problem solving and hence in the students' range of learning experiences are particularly interesting because they are part of the teachers' own repertoire of skills. In the light of the above reviews, some common difficulties in teaching and learning solving problems are identified and summarised as follows:

1. Students lack knowledge pertaining to the problems.
2. Students lack an organized, hierarchical knowledge structure which can be easily remembered and appropriately retrieved in complex contexts.
3. Students lack problem solving skills such as translation and linkage skills. They have difficulties in translating the problems into meanings and in setting goals or subgoals for the problems, especially for the unfamiliar ones. They also have difficulty in linking the appropriate knowledge from their minds to the novel problem situations.
4. Students do not seem to know any problem solving strategy or procedure with which they can apply to their problem solving. It is not a surprise to see some problems unattempted by many students when the problems are the unfamiliar ones.
5. Students lack experience and confidence in problem solving.

Teachers do not explicitly teach the processes of problem solving but emphasize the strategy which directly uses rules or algorithms for solving the problems. Their sense of strategy in fact was more than a strategy of using rules or algorithms for a typical type of problems. The evidence for this can be drawn from the way they perceive the problems, the way they pull the information together, also from the way they check their solution.

IMPLICATIONS

Based on the preceding literature reviews, students' failure in problem solving could possibly be attributed to the fact that they do not receive a wide range of learning experiences in the problem solving lessons. It is necessary to improve the methods of teaching problem solving if we want to strengthen our students' problem solving ability and skills. Some suggestions stated below may be useful for this purpose.

1. Develop the structure of the knowledge

It is important not only to teach the concepts, principles and rules as individual knowledge or facts but also to teach deliberately the possible organization of this knowledge. Information can be easily linked and retrieved in complex contexts (such as solving problems) only when it is effectively organized. The technique of concept mapping (Cliburn, 1990) can be used as a tool to enhance the development of an organized and hierarchical cognitive structure.

2. Develop students' problem solving skills

Two important problem solving skills - linkage and translation skills - are most likely to be neglected in the teaching of problem solving. The learning of linkage skills can be enhanced through word association (Gunstone, 1980), idea association (Lee, 1993) and concept mapping. Teachers can arrange activities for students to practise word association by responding to the same word with various single words which come to their minds. Idea association is quite similar to word association. Key words from the problem statements are given to students who in turn are required to respond to these key words with words, phrases, equations, diagrams, or anything that comes to their minds. The teacher can then discuss with the students which idea responses are correct and relevant to solving a particular problem.

The learning of translation skills could be considerably emphasized by teachers dwelling on the significance of the problem statements and their component parts. For instance, what important information can be selected from the problem statements, what are the possible meanings of the statements and what are the goals that can be pursued. The practice of problem translation through class activities or home exercises can be organized as part of teaching strategies.

3. Teach overall problem solving strategy

Students should have a sense of an overall strategy that will solve science problems. Teachers could incorporate problem solving strategies such as Reif's problem solving procedures in their teaching of problem solving in science by emphasizing the important stages or processes involved.

4. Teach think-aloud strategy

The protocol approach mentioned earlier is a good technique for tapping the thinking in people's minds. Accordingly it may be useful in classrooms, if teachers and students attempt to solve aloud unfamiliar problems. Through this kind of exercise in the overall teaching approach, strengths and weaknesses of students' problem solving strategies could be revealed and hence the necessary steps for rectifying errors or undesired behaviour in problem solving can be followed.

SOURCES

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