PROMOTING HIGHER COGNITIVE LEARNING IN SCIENCE THROUGH A PROBLEM-SOLVING APPROACH

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INTRODUCTION

There has been an increasing emphasis on the use of problem solving in science instruction. Instead of dispensing content information as a body of facts, teachers are encouraged to employ teaching strategies that foster critical thinking and problem-solving skills. These skills, which focus on the student's ability to hypothesize, analyze, synthesize and evaluate, are important for students to interact effectively with the real world environment of day-to-day problem solving. However, the use of problem solving in teaching science implies the use of approaches that have been associated with the development of higher-order thinking skills. What then, are these approaches? To answer this, the concept of problem solving is first discussed. This is then followed by an analysis of the teaching and learning tasks associated with a problem-solving approach in science instruction.

WHAT IS PROBLEM SOLVING?

Problem solving involves higher-order thinking skills beyond that required of questions answerable at the knowledge and comprehension level. If the question posed can be recognized as of a certain type, and the method for solving it can be recalled by merely applying a standard known procedure consisting of a series of sequential steps to obtain the solution, then it is not a problem but only an exercise.

Gagné (1977) regards problem solving as a process whereby learners discover a combination of previously learned rules that they can apply to achieve a solution for a novel problem situation. This implies an unfamiliar situation as being an important prerequisite for problem solving. Garrett (1987, 1989) considers open-endedness to be an essential component of genuine problems, with a variety of answers possibly being acceptable and arrived at by routes requiring the discovery of new information, or the realignment and manipulation of previously known concepts into new configurations.

PROMOTING PROBLEM-SOLVING SKILLS THROUGH INVESTIGATION

Teaching students to provide, as fast as possible, the one correct answer to a problem, does not contribute towards fostering students' problem-solving abilities. If the emphasis is on the correct solution, then the students' originality and creativity can be stifled. Many authors (e.g. Pérez & Torregrosa, 1983, Lock, 1990) view problem-solving as an investigative task. This is often seen as an experimental study requiring first-hand student participation and gathering evidence that permits a question posed to be answered. There is the need for students to put forward hypotheses, point out ways of solving the problem, and carry out a careful analysis of the results.

If the purpose of the work is to develop inquiry skills, then it is important to ensure that opportunities are provided for students to have more control over these aspects. Where the activity involves giving students the problem, detailed procedure and the solution, little if any problem solving is present. Where the student is provided with only the problem, and the ways and means and solution are withheld, this may be termed guided-discovery problem solving.

In problem-solving by open enquiry the student has to identify the problem, formulate hypotheses, initiate the design of the experiment and identify the resources required, as well as consolidate, interpret and evaluate the results.

Lock (1990) categorizes the nature of investigative practical work by describing it in relation to where it lies along a continuum between close-ended and open-ended work, and a second continuum between a student-directed and teacher-directed approach.

The open-ended nature of practical work refers to whether more than one design, solution or answer is possible. At one end of the continuum is the close-ended type of work where the outcome is known before the work is undertaken. For example, students carry out an activity to prove a theory, verify previously taught concepts, or demonstrate a phenomenon. Despite being convergent in nature, this type of work could still be considered as problem solving if students are not told how to carry out the activity.

Lock (1990) identifies five key questions in relation to enhancing the open-endedness of practical work, all of which ask whether it is the student or the teacher who has control over specific aspects of the work. He questions who is responsible for:

(1) Defining the area of interest.

(2) Stating the problem.

(3) Planning.

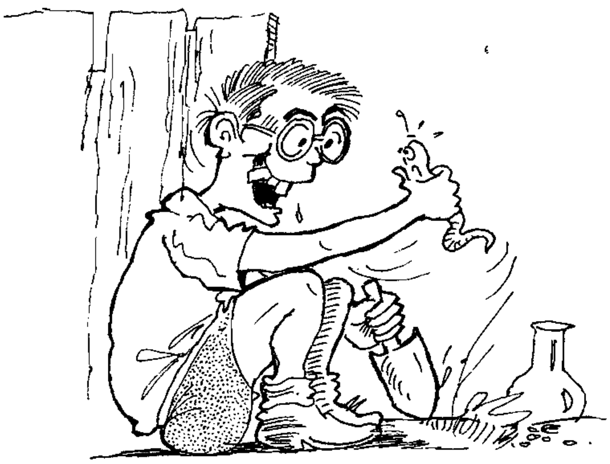
(4) Deciding on the strategy used.

(5) Interpreting the results.

Another essential problem-solving skill is student questioning. Zoller (1987) advocates the strategy of fostering students' question-asking capability by teaching via asking questions rather than using statements, encouraging students to ask questions, using open-ended questions extensively, and emphasizing the use of questions at the application-analysis-synthesis-evaluation levels. The problem-solving approach also values first-hand student interaction with materials so as to ensure active processing of ideas (Martens, 1992). The use of cooperative group work is also considered to be effective for problem-solving investigative tasks.

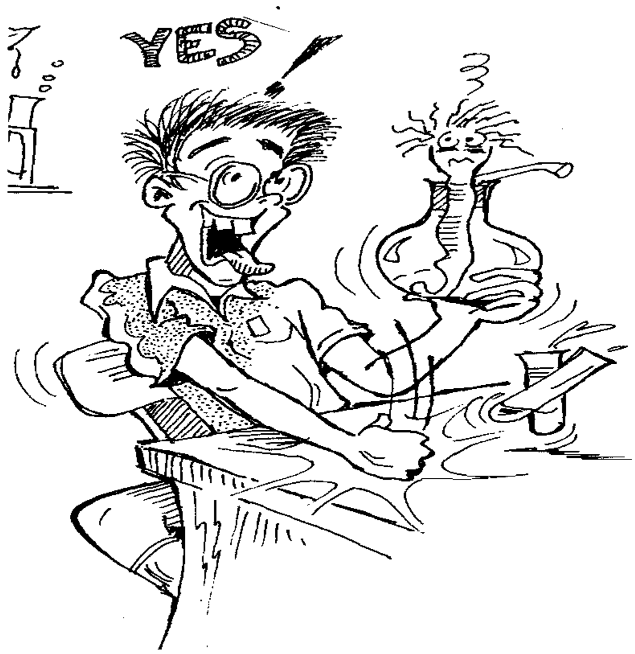
THE SEARCH, SOLVE, CREATE AND SHARE APPROACH TO SCIENCE INSTRUCTION

A problem-solving model specifically for science instruction was proposed by Pizzini, Shepardson and Abell (1989) on the premise that for a problem to be meaningful to a student, it needs to be identified and defined by the student, and that students meaningfully learn problem-solving skills and science concepts through concrete experiences in solving problems in science. This model, named the SSCS model consists of four phases: **Search, Solve, Create** and **Share**.

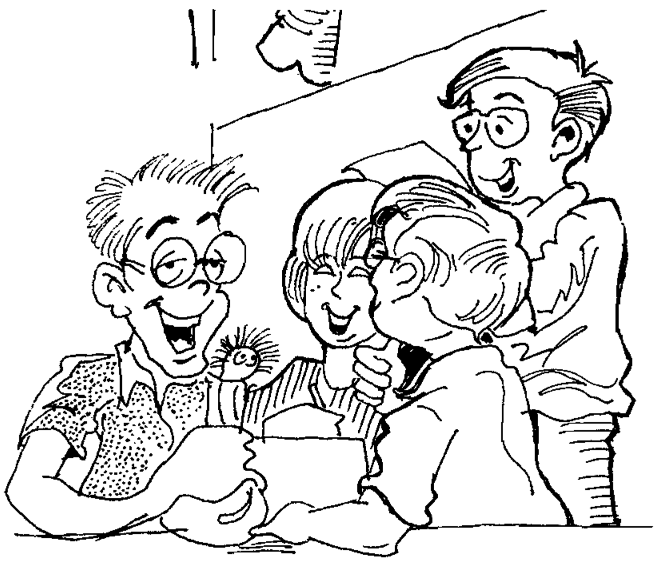


The **Search phase** involves brainstorming to identify and formulate a researchable question or problem in science. Students generate a list of ideas to explore, then select one or two of these and put them in a question format. The chosen question becomes the focus of an investigation in which neither students nor teacher know the answer. Providing students with the opportunity to select and pursue problems of concern and interest to them increases their motivation and persistence to learn. This student ownership of the problem is seen as one of the most essential variables resulting in successful problem solving.

The **Solve phase** requires students to generate and implement their plans for finding a solution to the problem. No detailed 'recipe-following' procedure is given. Students are responsible for designing their own experiment. They develop critical thinking skills such as the ability to decide what to do, how to do it best, what data are important, how accurate measurements must be, and why each step in their process is necessary. They form hypotheses, select the method for solving the problem, predict outcomes, as well as collect data and analyze the results.



In the **Create phase**, the students are required to create a product that relates to the problem or solution, reduce the data to simpler levels of explanation, draw generalizations and make modifications if necessary. Students portray their results and conclusions as creatively as possible. These may include written reports, speech presentations, charts, posters, computer print-outs, videotapes, plays, skits, cartoon, poetry or songs.



In the **Share phase**, students communicate their findings, solutions, and conclusions with teachers and fellow students, articulate their thinking, receive feedback, reflect on and evaluate their solutions. The discussion elicited helps to generate more potential questions for further investigation.

This problem-solving instructional model is less teacher-directed and procedurally structured. It encourages students to become involved in their own learning and undertake the behaviours necessary to solve problems in science. Classrooms are more student-centred, with less teacher expository and procedural talk. The model encourages science students to ask questions and find answers through investigation.

STUDIES OF CLASSROOMS USING A PROBLEM-SOLVING APPROACH

Studies by Abell and Pizzini (1992) and Pizzini and Shepardson (1992) have shown that teaching behaviours such as questioning, problem posing, idea accepting and allowing student planning bring about student outcomes compatible with the SSCS problem-solving model. In classes where the teacher adopted the problem-solving approach (compared to a control group which did not), there was increased use of brainstorming, an increase in time allotted to defining, sharing and presenting the problem, as well as more student-selected research questions and student-designed investigations. The teachers also substantially decreased time spent on expository and procedural talk, fact stating and explaining. The predominant behaviours of the teachers were more of observing and listening to students.

A comparison by Pizzini and Shepardson (1992) of the classroom dynamics of classes using the SSCS problem-solving model and a traditional laboratory model of instruction showed that total student-student (on-task) interactions were greater in the SSCS problem-solving model than the traditional laboratory model. Small group class settings encouraged student-student interactions, whereas large-group class settings encouraged teacher-student interactions. The authors concluded that the students became more involved in their own learning and hence undertook the behaviours necessary to solve problems.

IMPLICATIONS

What implications then, can be made from the above discussion regarding the use of problem solving in science instruction? ***Firstly***, for a task to be considered a genuine problem and not merely an exercise, it should to some extent involve a novel situation, require the use of higher-level thinking skills, and be open-ended in nature. ***Secondly***, students could take on more responsibility in defining a problem, and designing strategies to solve the problem. This shift in control of learning to the students is essential to developing student thinking and problem-solving skills.

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