

# ED309049 1988-00-00 Teaching Problem Solving--Secondary School Science. ERIC/SMEAC Science Education Digest No. 2, 1988.

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This digest is focused on problem solving in secondary school science classes, as illustrated by research studies found in the literature for 1982-88.

## PROBLEM SOLVING: WHY IS IT IMPORTANT?

Helping students develop problem solving skills is a frequently cited goal of science educators. The National Science Teachers Association (NSTA), in its 1980 position statement, advocated that science teachers help students learn and think logically, specifying that "...high school laboratory and field activities should emphasize not only the acquisition of knowledge, but also problem solving and decision making" (1985:48). Problem solving means many things to many people. For some, it includes an attitude or predisposition toward inquiry as well as the actual processes by which individuals attempt to gain knowledge. Usually, when teachers discuss problem solving on the part of pupils, they anticipate pupils will become involved with the thinking operations of analysis, synthesis, and evaluation (considered as higher-level thinking skills). The American College Testing program has redesigned its college admissions test with a new emphasis on assessing higher-order thinking skills (EdLine, 1989).

## WHAT CHARACTERIZES PROBLEM SOLVING RESEARCH IN SCIENCE EDUCATION?

Good and Smith (1987:31-36) provided a summary of problem solving research in science education. In the 1960's, research on problem solving was focused on how people solve puzzles and games. In the early 1970's, science education researchers tape recorded "think aloud" interviews to gather data. Current research on problem solving in science education involves information processing theory - the idea that solving a problem requires two processes: retrieval from memory of the pertinent information and proper application of the information to the problem. Research studies now published are frequently comparisons of expert and novice problem solvers in physics, biology, and chemistry.

The focus of problem solving research in science varies with the discipline. The following studies are some representative examples, grouped by biology, chemistry, and physics:

Problem solving research in biology. Most of the problem solving research in high school biology involves teaching genetics. In a recent article on teaching genetics, Stewart discussed ways different problem types may contribute differentially to learning outcomes (1988:237). Stewart contends there are two main types of thinking involved in solving genetics problems: (1) reasoning from causes to effects, and (2) reasoning from effects to causes. Most high school or introductory college textbook genetics problems

are cause to effect, with the difficulty of the problem varying with genetics content and wording. Such problems require content-specific algorithms. Cause to effect problems do not provide students with insights into the nature of science. However, effect to cause problems can be developed if computer-generated information is provided. The most important insight that students may gain from solving effect to cause problems may be the outcome of understanding science as an intellectual activity (1988:243-251).

Problem solving research in chemistry. Chemistry courses and textbooks appear to focus on quantitative problems. There is interest in how chemistry students solve quantitative problems and also in the effects of different instructional strategies on students' success in problem solving. Many research reports are focused on the use of algorithms, "...rules that can be followed more or less automatically by reasonably intelligent systems..." (Bodner, 1987:513).

Nurrenbern and Pickering (1987:508-510) worked with five different general chemistry classes, at two different institutions, in which students were given examinations with "traditional questions" (could be answered using algorithmic strategies) and multiple-choice questions with no mathematics content but which required conceptual understanding of chemistry content for correct solution. Students had far greater success in answering "traditional" questions than in answering the concept questions.

Problem solving research in physics. Research in physics has gone in two directions: information processing research concerned with observable and measurable steps in problem solving and research in constructing solutions in which investigators are concerned with the internal cognitive processes that result in these steps (Omasta and Lunetta, 1988:625). Much of the research on concepts and conceptual change in physics had been conducted against a background of problem solving in which pupils worked on problems found in the back of the textbook (Watts, 1988:74-79).

## WHAT ARE SOME IMPLICATIONS OF PROBLEM SOLVING RESEARCH IN

SCIENCE? Problem solving is identified as a top priority in many curricula in science. Teachers are not trained to teach problem solving. In addition, problem solving strategies involve formal operational skills such as proportional reasoning, logical-deductive thinking. Science education researchers report that 50 percent of college chemistry students are not formal operational, so it seems logical to conclude that most high school students do not operate at this level (Powers, 1984:63).

McDermott and the Physics Education Group at the University of Washington have investigated how students learn physics. They report that many students emerge from their study of physics or physical science without a functional understanding of some elementary but fundamental concepts. The problem exists at all levels of education and

is particularly distressing because it means that precollege teacher have not developed sound conceptual understanding of the material they are expected to teach (McDermott, 1984:31).

While students' naive ideas or preconceptions may interfere with their understanding of science concepts and thus influence their problem solving, math anxiety may also handicap students. Gabel and Sherwood investigated the effectiveness of four instructional strategies for teaching problem solving to students of various proportional reasoning abilities, visual and verbal preferences, and levels of math anxiety. They suggested that teachers need to incorporate teaching strategies into lessons to reduce the level of students' mathematics anxiety. Students with high levels of anxiety and the absence of another aptitude (visual preference or proportional reasoning ability) profit by methods containing supportive material that is not mathematical in nature. Teachers should use supplemental materials, less mathematics, and more visual approaches with high math-anxious students also deficient in proportional reasoning ability or with low visual preference (1983:175).

Staver, after studying the effects of problem format and number of independent variables on the responses of students to a control of variables reasoning task, found that more independent variables, more pieces of information, more steps necessary to solve the problem resulted in a decline of student success rate. Staver suggested that teachers need to use methods of instruction and evaluation that reduce the overload on working memory as such ideas are introduced and evaluated (1986:535-541).

Ronning, McCurdy, and Ballinger point out that teachers need to consider more than problem solving methods and the degree of knowledge acquisition involved in problem solving. They also need to consider individual differences among problem solvers. Field independent students, in the Ronning et al study, solved more problems than did field dependent students. It is possible that field dependent students might benefit from carefully structured instruction with clearly defined objectives because the students seemed unable to bring past experience (knowledge) to bear on tasks, as well as being unable to analyze the tasks (1984:80).

Nurrenbern and Pickering discussing conceptual learning in chemistry, stated, "Most educators see solving chemistry problems to be the major behavioral objective for freshman chemistry. Textbooks are written from this point of view, and this may be what establishes the supreme importance of numerical problems in student minds..." Chemistry teachers need to keep in mind that solving problems is not equivalent to teaching pupils about the nature of matter (1987:509).

Technology is being used to teach problem solving. Powers (1984:13-19) described a computer-assisted problem solving method for use with beginning chemistry students. Krajcik et al. (1988:147-155) described several preliminary studies involving students interacting with genetics and with the molecular structure of gases. Group and individual

patterns of how students learned concepts and applied problem solving strategies were compared. Such research should provide guidance to classroom teachers about the use of technology and the design of curriculum and instruction.

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