Research Reviews

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In this last research review for the year we have chosen to review articles that have appeared in the last year's *Journal of Research in Science Teaching* rather than have a theme that all articles fit. All of the reviews were done by this month's co-editor, Sr. Angelo Collins, Science Education, University of Wisconsin-Madison.

Larkin, J.H. & Rainhard, B., A research methodology for studying how people think, *Journal of Research in Science Teaching,* 21(3), 235-254. The authors' address is Carnegie-Mellon University, Pittsburgh, PA 15213.

The purpose of this article is to illustrate research, done within an information-processing psychology framework, designed to understand and describe how people think while performing complex tasks such as problem solving. The authors do this by describing research that they have done on chemistry problem solving, in which detailed data from individual subjects has been collected to develop models of human behavior. The data is collected by having subjects think aloud while solving problems. The think-aloud data is then transcribed into protocols, or lists of verbal statements. The protocol does not list or explain each and every thought; it is an indicator of thoughts. From the protocol the researcher must infer a model of behavior. This is done by looking for the solver's current knowledge about a problem, the rules the solver developed while working the problem, and how the rules are sequenced. Often the model represents the rules as condition-action pairs, also called production systems. Condition-action pairs match knowledge and rules. "If I knew this (this condition is met), then I can do that (action)."

Guidelines for collecting protocols are given. A person constructing an information processing model is warned that protocols often yield interesting anecdotes, but the fullest use of the model is the construction of production systems. To do this it is necessary to encode the system and verify the model by using it to predict the problem solving behavior of others.

Two criticisms of this type of research are the small sample size and the apparent backward nature of the research by collecting data before the model is built. The authors respond to the first criticism by noting that sample size affects statistical significance, not generalizability, and by noting that only frequently used production systems are applied in the model building. In the area of sampling, they are more concerned about the nonrandom choice of subjects. In response to the second criticism, they note that the method is consistent with the type of research question, 'How do students currently understand the task?'.

Smith, M. & Good, R., Problem solving and classical genetics: Successful versus unsuccessful performance, *Journal of Research in Science Teaching,* 21(9), 895-912. The first author's address is Southeast Missouri State University, Cape Girardeau, MO 63701.

The authors of this article also use an information processing model for their research. They introduce their study by suggesting why problem solving is important, by defining information processing and by detailing expert/novice studies in content areas other than genetics. The primary aim of the study is to compare problem solving in genetics with that done in physics, to determine if the difference between experts and novices found in physics are the same for genetics. The major differences between experts and novices as noted from other disciplines are that: 1) experts have well defined, functionally integrated, hierarchically stored knowledge, while novices do not; 2) experts perceive a problem in terms of the discipline while novices perceive it in terms of its setting; 3) experts begin problem solving by clearly defining the problem; 4) experts use knowledge specific strategies while solving a problem; and 5) experts use powerful knowledge-producing strategies while novices 'work backwards.'

The researchers videotaped a session of 11 undergraduates (novices) and nine graduate students in genetics (experts) solving seven complex problems. They determined that expertise was not equivalent to success. Of more interest are a listing of 32 common tendencies that differentiate successful and unsuccessful problem solving behavior. Three of the tendencies are demonstrated in great detail. They are the tendency to perceive the problem as a task requiring analysis and reasoning, the tendency to use knowledge development (forward-working) approaches, and the tendency to have and use accurate knowledge of common genetics ratios, patterns of inheritance, and other relevant subject matter. They also list ten general problem-solving heuristics, including looking for common patterns, comparing work in various parts of a problem for consistency, and, when considering several possibilities, always considering the simplest first.

From their study they present four implications. If a goal in instruction is problem solving, considerable time should be devoted to individual practice at solving problems. Student generated solution paths should be compared with expert generated paths to note effective and efficient strategies. Probability should be considered whenever it applies in genetics problems. Common misconceptions such as confusion of dominance and frequency should be dealt with explicitly and early in instruction.

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Good, R., Scientific problem solving by expert systems, *Journal of Research in Science Teaching,* 21(3), 331-340. The author's address is Florida State University, Tallahassee, FL 32206.

Good begins by modifying a definition of intelligence by Simon to define artificial intelligence as 'that area of study which attempts to simulate goal achievement by symbol manipulators (computers) in the face of changing environments.' He feels that the greatest promise for artificial intelligence is in problem solving, especially simulations of expert systems. The article briefly reviews studies of expert and novice problem solving. It then details the heuristics of an artificial intelligence program, BACON.5.

Smith, E.L. & Anderson, C.W., Plants as producers: A case study of elementary science teaching, *Journal of Research in Science Teaching,* 21(7), 685-698. The authors' address is The Institute for Research on Teaching, Michigan State University, East Lansing, MI 48824.

Delightful is not an adjective usually used to describe a research report, but it fits this paper well. In an easy to read style the authors briefly lay out a major research program, focus on one aspect of it, and make recommendations for improved instruction from a conceptual change framework. Succinctly stated, conceptual change holds 'that rather than having no knowledge at all, learners beginning to study a topic usually have their own preconceptions, some of which are misconceptions, that must be changed.'

The research program is a study of 14 teachers planning and teaching fifth grade science. Four aspects are noted: curricular materials, teacher planning, classroom instruction, and student conceptions of the topic. The report of one teacher presenting the concept 'producer' from the *Communities* unit of SCIIS is detailed. The sequence of instruction is so clearly laid out that even one who has never seen SCIIS would understand. The authors judge this as the most philosophically and psychologically sound program studied. The teacher was experienced. She managed her classroom well, prepared carefully, understood the science content, and was clear about what she wanted her students to learn.

Despite a good teacher with good curricular materials, the majority (80 percent) of the students did not meet the instructional goals. After instruction students had misconceptions about the role of light in photosynthesis and the relation of photosynthesis to a plant's food needs. The authors trace the causes of this breakdown to the teacher's beliefs about science and about how students learn. She was surprised that the students had not followed her carefully built chain of reasoning, but had their own explanations for common observations. She was amazed at the significance and persistence of students' prior conceptions. She had also anticipated that students would be able to infer the role of light in food manufacture, even though the teacher's guide directed that it be clearly presented.

The authors recommend that the teacher's guide, even while acknowledging its limited effectiveness, should include explicit information on conceptual change, some expected preconceptions of children, explicit goal conceptions and the relationship between the learning activity and the goal. This essential information should be integral to the guide and not an appendix. The authors further recommend that teacher education include a view of conceptual change, knowledge of generic strategies to teach for conceptual change, knowledge of common misconceptions, and skills in adapting curricular materials based on common preconceptions of children. In addition to including sound content knowledge, such courses should also include some philosophy of science, especially about the relationship between theory and observation.

Cho, H. & Kahle, J., A study of the relationship between concept emphasis in high school biology textbooks and achievement levels, *Journal of Research in Science Teaching,* 21(7), 725-734. The authors' address is Department of Biology, Purdue University, West Lafayette, IN 47907.

and

Rosenthal, D., Social issues in high school biology textbooks, 1963-1983, *Journal of Research in Science Teaching,* 21(8), 819-832. The author's address is Graduate School of Education and Human Development, the University of Rochester, Rochester, NY 14627.

In the 1984 volume of *JRST* there are two articles on trends in textbooks. In the first, scores were obtained from the National Assessment of Educational Progress studies on student achievement in ten concept areas of biology. The content emphasis of the 1973 editions of three frequently used textbooks, *BSCS Green Version, BSCS Yellow Version,* and *Modern Biology,* were analyzed. Emphasis was determined by the number of objectives for each concept area. It was determined that there was a high correlation between concept emphasis in these textbooks and student achievement in every area except growth and development. In 1983, three textbooks (Merrill, Scott, and Ginn), were analyzed for emphasis in the same areas in the same manner. Statistically, the only concept area to change emphasis was growth and development, where there was a documented increase in student achievement. The authors suggest this might be due to recommendations to include biosocial and bioethical topics in biology courses, or to increased scientific research in this area. The authors note that, although not statistically significant, there was a decreased emphasis in the concept area of evolution in textbooks between 1973 and 1983.

In the second article, the author analyzed 22 textbooks for their emphasis on social issues. A social issue is defined as "a matter that has been or is disputed by society or is yet to be decided by society." Objectivity in classifying a topic into a category as a social issue was determined by two methods. Despite the definition and the attempts to ensure objectivity, the author acknowledges that other researchers might use a different classification scheme. In this study, emphasis was determined by the percent of pages that addressed a topic when compared with all the text pages in the book.

Of the texts considered in this study, *BSCS Yellow* consistently ranked highest in emphasis on social issues while *Modern Biology* consistently ranked lowest. Textbooks published for the first time since 1980 also ranked low in social issues.

In summary the author states that "although the quality of treatment varies from category to category and from textbook to textbook, in general the treatment of science and society in high school biology textbooks minimizes the controversial aspects, avoids questions of ethics and values, lacks a global perspective, and neglects the interdisciplinary nature of problems."