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Chapter 9. Science

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The science education research literature of the last 10 years is replete with studies indicating that students at all levels possess many inaccurate conceptions of scientific knowledge. Although this may also have been the case in the past, it appears more prevalent now, and is at least in part caused by the rapid growth of scientific knowledge.

Analyses of textbooks indicate that they contain many more concepts than they have in the past, with fewer pages devoted to explaining or describing each particular concept. In addition, the science curriculum has shifted down, so that rather complex topics that 20 years ago were thought too difficult for students at particular grade levels are now being taught at those levels. Whether this increase of content coverage is the result of international comparisons of students in the United States with students in other countries is a moot point. The result is that students have little time to think about what they are learning, rarely see individual concepts taught in a multitude of contexts, do not see the relevance of what they are learning, frequently have negative attitudes toward science, and resort to memorizing facts and solving problems algorithmically in order to survive!

The teaching strategies and practices that research has shown to be effective in improving achievement in the teaching and learning of science all have one thing in common: they keep students' attention focused on learning. Whether this is done by pausing after asking a question before calling on a student to answer the question (wait time), by involving students in decision making (computer simulations), or by having students make comparisons with familiar situations (using analogies), all of these strategies require active learning. Many involve creating situations that challenge students' assumptions by having them make observations that are in conflict with their beliefs (cognitive conflict), and then resolving the conflict. It is only when instruction involves or at least begins with topics that are of interest to students, and is related to their world, that students will learn in more authentic ways. That is, they will see the relationship between what they are learning and what they already know; they will think instead of memorize.

Although several of the strategies included in this review can be used by teachers and students on an individual basis, there is a growing body of evidence that learning is a social endeavor and that strategies that include interactions between students (cooperative learning) are more effective than activities in which students work alone. This appears to be true even when students work at a computer using probeware or computer simulations. Interactions among students help them clarify their own ideas and those of their peers.

All of the teaching strategies presented here (with the exception of using computer simulations) also require additional time to implement in the classroom. This increase of instructional time per concept will require educators to consider carefully which of many important concepts should be taught at particular grade levels, and which should be delayed or even omitted from the curriculum. One way this can be accomplished is to integrate science instruction across the disciplines, as suggested by the American Association for the Advancement of Science's recommendations in *Benchmarks for Science Literacy, Project 2061* (1993), and by the National Science Teachers Association in *Scope, Sequence and Coordination of Secondary School Science* (1993). A reduction of the science content included at the pre-college level has also been recommended by the National Research Council in the *National Science Education Standards* (1994).

9.1. Learning Cycle Approach: The use of the learning cycle approach (exploration, invention, and application) results in better content achievement, improved thinking skills, and more positive attitudes toward science.

Research findings:

Numerous studies beginning in the 1960s and continuing today indicate that the learning cycle approach is effective in promoting both conceptual understanding and positive attitudes toward science and process skill acquisition for students at the elementary, middle school, and high school levels. When laboratory experiences (exploration and application) are combined with concept introduction (invention), positive outcomes occur. However, research on the effectiveness of laboratory instruction by itself, without concept introduction, does not support its effectiveness in improving student achievement in science.

In the classroom:

The learning cycle approach as originally envisioned in the early 1960s for the teaching of elementary science included three phases: exploration, invention, and discovery. During the exploration phase, students explore new materials and ideas with minimum guidance. This helps students raise questions about the phenomena being explored that cannot be resolved by their accustomed way of thinking and identify patterns of regularity in the phenomena. The invention phase is more teacher-centered. Terms and concepts are introduced that explain the patterns discovered in the exploration phase. In the application phase, students apply the terms and concepts to new situations, thus learning to generalize in a broader context.

The learning cycle approach has been incorporated into a variety of science curricula and programs, particularly at the elementary level. These include *Science Curriculum Improvement Study* (SCIS) and *Biological Sciences Curriculum Study* (BSCS). Recent studies have shown that using the learning cycle approach is an effective way to determine and correct students' misconceptions, and that it can aid in improving young students' reasoning abilities. Studies indicate that all three phases are necessary, although in some instances an in-depth laboratory experience may substitute for some phases.

Current research indicates that modifications of the learning cycle can make it an even more effective instructional strategy. Helping students to focus their exploration by adding an engagement or prediction/discussion phase and following the application phase with evaluation appear to promote conceptual understanding. A monograph by Lawson, Abraham, and Renner (1989) provides a rich description of the use and possible modifications of the learning cycle approach.

References:

Abraham 1989; Bybee et al. 1989; Campbell 1977; Carlson 1975; Davis 1977; Davison 1989; Glasson and Lalik 1990; Jackman, Moellenberg and Brabson 1990; Lavoie 1989, 1992; Lawson and Wollman 1976; Lawson, Abraham and Renner 1989; Lawson and Weser 1990; Marek and Methven 1991; McKinnon and Renner 1971; Purser and Renner 1983; Renner, Abraham, and Birnie 1985; Renner and Marek 1988; Rubin and Norman 1989, 1992; Scharmann 1992; Schneider and Renner 1980; Ward and Herron 1980; Westbrook, Rogers, and Marek 1990.

9.2. Cooperative Learning: Using cooperative learning for classroom and laboratory instruction increases student achievement, attitudes, and on-task behavior.

Research findings:

A considerable number of research studies on the effectiveness of cooperative learning using the jigsaw approach in the classroom and the investigative approach in the laboratory indicate its usefulness for the teaching of science. Although studies in the early 1980s focused on the elementary school level, studies from the mid-1980s show that middle school and high school science students also profit from the use of these cooperative learning approaches.

In the classroom:

The use of cooperative learning for the teaching of science has improved science achievement at all grade levels. In the classroom, cooperative groups of about four students frequently use the jigsaw approach, in which each student in a given group takes a particular role or part of a larger task. Students with the same role from each of the other jigsaw groups in the class form a new group in which each member investigates/learns his or her part of the topic. After members of this group have shared ideas and learned the material or performed the task, they return to their original group where they are responsible for sharing what they have learned and teaching students in that original group the new information.

In most investigative cooperative groups that are used for laboratory instruction, each member of the group of four takes on a different role such as recorder, checker, facilitator, or experimenter. Roles rotate with each lab investigation. In almost all studies of cooperative learning, there is positive interdependence, face-to-face interaction, individual accountability, interpersonal and small-group interactions, and group processing.

Some of the potential benefits of cooperative learning are increased achievement scores including long-term retention, more positive attitudes toward laboratory work, higher self-esteem, higher laboratory and process skill achievement, and greater on-task behavior. One area where cooperative learning has not been shown to be successful at the secondary level is increasing students' ability to solve problems. The most effective form of cooperative learning appears to occur when students are encouraged to cooperate within their group but to compete with other groups within the class.

References:

Hay 1980; Humphreys, Johnson, and Johnson 1982; Johnson and Johnson 1985a, 1985b; Jones and Steinbrink 1989, 1991; Kempa and Ayob 1991; Lazarowitz 1991; Lazarowitz et al. 1985; Lazarowitz et al. 1988; Lazarowitz and Karsenty 1990; Lazarowitz, Hertz-Lazarowitz, and Baird 1994; Lonning 1993; Okebukola 1985a, 1985b, 1986a, 1986b, 1986c; Okebukola and Ogunniyi 1984; Rogg and Kahle 1992; Sherman 1989; Slavin 1980, 1984, 1991; Tingle and Good 1990; Walters 1988; Watson 1991; Webb 1985.

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9.3. Analogies: Using analogies in the teaching of science results in the development of conceptual understanding by enabling the learner to compare something familiar to something unfamiliar.

Research findings:

Although some research studies prior to the 1980s have been conducted on the use of analogies, a new interest in this area has produced several in-depth studies which indicate that using analogies assists in concept development. This is particularly true when students have alternative conceptions about a particular concept. Research in this area tends to be qualitative in nature, and the conceptual change that occurs may not result in higher scores on multiple-choice science tests of facts and concepts.

In the classroom:

Textbooks and teachers sometimes use analogies to help familiarize students with concepts that are abstract and outside their previous experience. To be effective, analogies must be familiar to students, and their features/functions must be congruent with those of the target. Since adult perspectives are not identical with those of adolescents, it is not surprising that, even though students are familiar with the physical phenomenon or event that might be used as the analogy, they are not always familiar with those features that provide the similarity to the target. Once a suitable analogy is found, considerable time must be spent by students in discussion of similarities between the analogy and the target. It is also important for students to understand how the analogy and target differ. Sometimes this can be done by using multiple analogies to teach the same concept. At other times it may be necessary to construct "bridging" analogies.

Analogies occurring in texts may be simple—based on surface similarities—or more complex (particularly in chemistry and physics)—based on similarities of function. The use of functional analogies appears to be more appropriate at the secondary level where students have developed appropriate reasoning strategies.

The discussion that occurs when using analogies not only helps students construct their own knowledge but also assists teachers in basing instruction on students' prior knowledge and existing misconceptions. Analogies may also motivate students to learn by provoking their interest. Finally, having students create their own analogies also appears to be an effective instructional strategy.

References:

Brown 1992; Clement 1993; Dagher 1994; Dagher and Cossman 1992; Duit 1991b; Dupin and Joshua 1989; Flick 1991; Friedel, Gabel, and Samuel 1990; Gabel and Samuel 1986; Garnett and Treagust 1992; Glynn 1991; Griffiths and Preston 1992; Harrison and Treagust 1993; Lawson 1993; Stavy 1991; Stavy and Tirosh 1993; Sutula and Krajcik 1988; Thagard 1992; Thiele and Treagust 1994; Treagust et al. 1992; Wong 1993a, 1993b; Zeitoun 1984.

9.4. Wait Time: Pausing after asking a question in the classroom results in an increase in achievement.

Research findings:

In most classrooms, students are typically given less than one second to respond to a question posed by a teacher. Research shows that under these conditions students generally give short, recall responses or no answer at all rather than giving answers that involve higher-level thinking. Studies beginning in the early 1970s and continuing through the 1980s show that if teachers pause between three and seven seconds after asking higher-level questions, students respond with more thoughtful answers and science achievement is increased. This finding is consistent at the elementary, middle school, and high school levels and across the science disciplines.

However, some research studies have suggested that the benefits of increasing wait time may depend on factors such as student expectations and the cognitive level of the questions. In a study of increased wait time in a high school physics class, students became more apathetic in classes where the wait time was increased. This might have occurred because this strategy did not match students' expectations of how a high school physics course should be conducted. In a study at the elementary level, a decrease in achievement was attributed to waiting too long for responses to low-level questions.

In the classroom:

Increasing the wait time from three to seven seconds results in an increase in 1) the length of student responses, 2) the number of unsolicited responses, 3) the frequency of student questions, 4) the number of responses from less capable children, 5) student-student interactions, and 6) the incidence of speculative responses. In addition to pausing after asking questions, research shows that many of these same benefits result when teachers pause after the student's response to a question, and when teachers do not affirm answers immediately.

Increasing wait time also increases science achievement. Research indicates that when teachers increase their wait time to more than three seconds in class discussions, achievement on higher-cognitive-level science test items increases significantly. This holds for test items involving content, the process skills, and items involving probabilistic reasoning.

However, care must be taken in applying wait time judiciously. The optimal wait time for a given question should be adjusted to the cognitive level of the question, and student responses should be carefully monitored.

References:

Altiere and Duell 1991; Anderson 1978; Fowler 1975; Garigliano 1972; Lake 1973; Riley 1986; Rowe 1974a, 1974b, 1986; Samiroden 1983; Tobin 1985, 1986, 1987; Tobin and Capie 1982.

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9.5. Concept Mapping: The use of student-generated and teacher-generated concept maps for teaching science concepts results in improved student achievement and more positive student attitudes.

Research findings:

Over 150 studies on concept mapping have been reported since the late 1970s. A careful meta-analysis conducted by Horton et al. of 19 studies that qualified out of 133 reported by 1990 indicates positive effects on student achievement and attitudes. (The analysis included only studies that occurred in actual classrooms using control groups and in which sufficient quantitative data were reported.) One hundred references related to concept mapping have been reported by Al-Kunifed and Wandersee.

In the classroom:

A concept map is a schematic diagram or semantic network that includes concepts arranged in a hierarchical order linked by words that form propositions. Concept maps can be made by teachers or students either individually or in a group. They are used in a variety of situations, such as in an overview at the beginning of a unit, during instruction to assess conceptual understanding, and at the end of a unit to review for a test or to evaluate learning. Concept mapping in the science classroom, particularly for biology instruction, improves science achievement and attitudes. The use of concept maps appears to be more beneficial at the end of a unit than at the beginning. Although there appears to be no difference in student achievement whether the maps are constructed by the teacher or by the students, there are greater gains in achievement when students supply the key terms to construct the maps.

In addition to their direct use in classroom instruction, concept maps also have other educational benefits for students. They can help teachers become more effective and can be used as an aid in curriculum development.

References:

Al-Kunifed and Wandersee 1990; Beyerbach and Smith 1990; Fisher 1990; Horton et al. 1993; Hoz, Tomer, and Tamir 1990; Novak and Gowin 1984; Novak and Musonda 1991; Pankratius 1990; Roth 1994; Roth and Roychoudhury 1992; Starr and Krajcik 1990; Wallace and Mintzes 1990; Willerman and Mac Harg 1991; Wilson 1994.

9.6. Computer Simulations: Using computer simulations to represent real-world situations enables students to become more reflective problem solvers and to increase their conceptual understanding.

Research findings:

Data from a survey of secondary science departments in the fall of 1992 indicate that 49 percent of those surveyed used computers in teaching science at least occasionally. Although the most common use of computers was for simulations, only 18 percent of the schools surveyed indicated that computers were used once or twice per week.

Convincing research studies on the use of simulations in science instruction at the upper elementary and secondary levels are needed to justify more widespread and frequent use of this strategy.

In the classroom:

Many scientific models are difficult or impossible to observe, or are so complex that they are difficult to study in the laboratory. In chemistry, for example, students cannot observe the motion of atoms in solids, liquids, and gases because of their size. In physics, the study of velocity and acceleration becomes difficult in the laboratory because the observer has to account for friction. In biology, studies of genetics might have to extend over a prolonged time period.

Computer simulations can overcome these obstacles by simplifying complex systems, and then incorporating the various complexities to show their effect on the system. Use of simulations tends to result in increased achievement on complex and difficult concepts in less time than conventional instruction. Simulations (sometimes referred to as microworlds) can be used by instructors in classroom settings; however, the most effective use is by students either alone or in small groups. This permits guided exploration by students of the variations of the system, leads to better conceptual understanding and achievement, and appears to increase students' problem-solving and process skills. As with analogies, the use of simulations may create misconceptions, and so requires careful teacher attention to the understandings (or misunderstandings) produced. They should not be used exclusively in place of laboratory activities, and care must be taken by teachers to help students identify the limitations of the simulated models.

References:

Berge 1990; Berger 1982, 1984, 1987; Choi and Gennaro 1987; diSessa 1988; Faryniarz and Lockwood 1992; Geban, Askar, and Ozkan 1992; Hakerem, Dobrynina, and Shore 1993; Jungck and Calley 1986; Kinnear 1983; Krajcik 1989; Lehman 1994; Linn 1988; Njoo and de Jong 1993; Rivers and Vockell 1987; Simmons 1989; Wells and Berger 1986; White and Frederickson 1989; White and Horowitz 1987, 1988; Williamson and Abraham 1995; Wiser and Kipman 1988; Zeitsman and Hewson 1986.

9.7. Microcomputer-Based Laboratories: Using computers to collect and display data from science experiments enables students at the secondary level to understand science concepts and learn to use science process skills.

Research findings:

Although the research in this area is somewhat limited, several studies indicate the value of students' participation in microcomputer-based laboratories; these studies outweigh other studies showing no improvement over traditional laboratory approaches. The use of computers in the science classroom is still limited in scope, and hence only a limited number of studies have been conducted to date.

In the classroom:

In a microcomputer-based laboratory (MBL) experiment, students use electronic probes that are interfaced with a microcomputer that directly records and graphs data being collected. This enables students to immediately see the trends in the data as they are being collected, and to focus on the meaning of the experiment rather than on completing a data table or making a graph. This may enable students to question their prior beliefs and to ask new questions related to the experiment. The effectiveness of using these scientific probes depends greatly on the instructional sequence in which they are used.

In comparisons with traditional instruction, MBL use frequently results in a different set of outcomes. For example, students using MBLs are better able to interpret graphs, whereas students with conventional laboratory experiences are better able to construct graphs. Because both are important instructional outcomes, it is recommended that MBLs be interspersed with conventional laboratory experiences, rather than used exclusively.

References:

Adams and Shrum 1990; Beichner 1990; Berger 1987; Brasell 1987; Friedler, Nachmias, and Linn 1990; Grayson and McDermott 1989; Jackson, Edwards, and Berger 1993; Krajcik and Layman 1989; Lewis and Linn 1989; Linn and Songer 1988; Mokros and Tinker 1987; Nakhleh and Krajcik 1994; Tinker 1985; Wise 1988; Wiser and Kipman 1988.

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9.8. Systematic Approaches in Problem Solving: Planning the solutions to mathematical chemistry and physics problems in a systematic way enables students to more frequently solve the problems correctly.

Research findings:

Most of the studies on mathematical problem solving in the sciences have examined processes students use to solve chemistry and physics problems. Mathematical problem solving in biology focuses on genetics, and research on using a systematic approach in solving these types of problems is lacking. Polya in the 1940s suggested the four-step approach described below, which researchers have modified over the years.

In the classroom:

Expert problem solvers take a considerable length of time in planning and analyzing a given problem before using mathematics for its solution. Novice problem solvers appear to use cues in the problem to search their memory for a formula or algorithm that they can use to solve the problem. Unfortunately, if superfluous information is given in a problem, this frequently causes them to use an incorrect formula.

Novice problem solvers can improve their problem solving skills if they use a systematic approach such as: 1) understanding the problem; 2) devising a plan; 3) carrying out the plan; and 4) looking back. In order to understand the problem, students must identify what information is given in the problem, and what is sought. Sometimes drawing a picture (such as a force diagram in physics or a picture of what is happening on the molecular level in chemistry) aids in understanding the problem. Using this information, students then formulate plans for the problem solution. Helping students categorize problems into specific types enhances the planning stage. The final step, looking back, involves checking the mathematics used, the execution of the plan, and the reasonableness of the answer.

These steps are not necessarily sequential in nature. For example, during the planning stage it may be necessary to revert to the understanding phase to recall additional information needed or to eliminate superfluous information. The steps do not come naturally to students, and need to be illustrated and practiced when students are taught to solve problems. In addition, because using a systematic approach requires more time than simply using a formula, care must be taken to assign fewer, but more varied, problems for practice, and to allow more time for problem solving on tests.

References:

Bhaskar and Simon 1977; Bunce et al. 1990; Bunce, Gabel, and Samuel 1991; Bunce and Heikkinen 1986; Cameron 1985; Chi, Feltovich, and Glaser 1981; de Jong and Ferguson-Hessler 1986; Frank and Herron 1987; Hegarty 1991; Heller and Hollabaugh 1992; Heller, Keith, and Anderson 1992; Heller and Reif 1984; Kramers-Pals, Lambrechts, and Wolff 1982; Larkin 1980; Lesgold and Lajoie 1991; Mettes et al. 1980; Polya 1945; Reif 1983; Reif and Heller 1982; Schoenfeld 1978; Stiff 1988; Van Heuvelen 1991; Wright and Williams 1986.

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9.9. Conceptual Understanding in Problem Solving: Understanding concepts qualitatively enables students to solve quantitative problems in physics and chemistry more effectively.

Research findings:

Research at the secondary and even post-secondary level on understanding of basic concepts that are involved in solving many chemistry and physics problems (such as mass and volume) indicate that students do not understand these concepts. This is confirmed by many research studies on problem solving in which students solve problems aloud. Although there is a limited amount of research to indicate that understanding basic concepts qualitatively improves mathematical problem solving, it appears that this would be the case.

In the classroom:

Many secondary students use algorithms to solve chemistry and physics problems that require the use of mathematics. They substitute data given in a problem into a formula (or use the factor-label method), perform appropriate mathematical operations, and arrive at a correct solution. However, when asked about the meaning of what they have done or requested to describe the variables and the relationship among the variables involved, they are unable to do so.

There is some evidence that having students perform numerous problems in this manner does not necessarily lead to conceptual understanding. If conceptual understanding is the expected outcome of science instruction, a more reasonable approach would be to emphasize a qualitative understanding of the underlying concepts first, and then to use mathematical problem solving to provide deeper insight into the concepts. For example, many students can calculate the density of a solid, yet when shown samples of identical mass but different volumes, are unable to serial order the samples by density. It is unlikely that having students solve numerous density problems by substituting values into the density formula will help them distinguish between density and volume.

References:

Anamuah-Mensah 1986; Bhaskar and Simon 1977; Bunce, Gabel, and Samuel 1991; Chi, Feltovich, and Glaser 1981; de Jong and Ferguson-Hessler 1986; Finegold and Mass 1985; Gabel 1981; Gabel, Sherwood, and Enochs 1984; Gorodetsky and Hoz 1980; Griffiths, Pottle, and Whelan 1983; Hegarty 1991; Heller, Keith, and Anderson 1992; Herron and Greenbowe 1986; Larkin 1980, 1983; Larkin et al. 1980; Lythcott 1990; McMillan and Swadener 1991; Niaz and Robinson 1989; Reif and Heller 1982; Robertson 1990; Schmidt 1990; Sumfleth 1988; Sweller 1988; Ward and Sweller 1990.

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9.10. Science-Technology-Society: Using a Science-Technology-Society approach in the teaching of science results in an increase in the number of students taking additional science courses and advanced-level courses, as well as changing students' attitudes towards science and their understanding of the nature of science and its relationship to technology and societal issues.

Research findings:

Studies in this area are somewhat limited. Most comparative studies have been performed by one major researcher, and include students in grades four through nine. However, AAAS's *Project 2061* and the National Research Council's draft of the *National Science Education Research Standards* endorse the inclusion of science, technology, and society issues in the curriculum. Furthermore, curriculum developers in Canada and in the United Kingdom include this approach in widely used national curriculum projects at the secondary levels.

There is little evidence that STS increases students' knowledge of facts, concepts, or principles, but no evidence that it decreases it. When STS is integrated into the curriculum as a major thrust (not as vignettes), positive outcomes occur. These include an increase in understanding the process and applications of science, as well as improving creativity and attitudes toward science. An additional benefit found in Canada was improving students' understanding of science as a way of knowing. In the United Kingdom, STS was found to dramatically increase the number of students taking additional science courses. In the U.S., new curricula have been developed by the ACS in chemistry using this approach at the middle school and high school levels.

In the classroom:

Educators should consider using Science-Technology-Society (STS) approaches to the curriculum as a way to make science more relevant to students' lives. STS issues can be included as vignettes as a small part of the curriculum. However, based on the research results, a more promising approach is to use STS as an entire course that has as its objectives the development of an appreciation of the interactive nature of science, technology, and society; knowledge of technology as applications of science; the ability to respond critically to technology issues; or a combination of these goals with teaching science concepts and principles.

References:

Aikenhead and Ryan 1992; American Association for the Advancement of Science 1993; Barker 1993a, 1993b; Ben-Zvi and Gai 1994; Bybee 1987; Campbell et al. 1994; Hart and Robottom 1990; McFadden 1991; Myers 1988; National Research Council 1994; National Science Teachers Association 1982, 1991; Ramsden 1992, 1994; Rosenthal 1989; Rubba, McGuyer, and Wahlund 1991; Sutman and Bruce 1992; Waks and Barchi 1992; Winther and Volk 1994; Yager and Tamir 1993; Yager, Tamir, and Mackinnu 1993; Yager and Yager 1985; Zoller et al. 1990.

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9.11. Real-Life Situations: Using real-life situations in science instruction through the use of technology (films, videotapes, videodiscs, CD ROMS) or through actual observation increases student interest in science, problem-solving skills, and achievement.

Research findings:

Research support for the use of real-life situations (or simulations of these) in classroom instruction continues to increase as the technologies for bringing real-life situations into the classroom become more available to teachers. The leading research group in the United States using anchored instruction to increase middle school students' problem-solving skills is located at Vanderbilt University. Several of the bibliographic entries include summaries of its work.

In the classroom:

Students frequently compartmentalize learning. For example, many students who have studied mathematics are unable to apply it in solving problems in chemistry and physics. Many fail to associate the variable "x" used extensively in algebra problems to letters standing for variable names in physics problems. Even within the science course itself, many students fail to recognize that the topics they are studying apply to real-life situations. One reason proposed for this lack of transfer is that problem solving and learning have not taken place in real-world contexts. The use of videotapes or discs depicting real-life situations or simulations of these (either alone or in tandem with computers) makes it much more feasible to teach using real-world situations.

Videodiscs using simulations of real-world problem-solving situations, developed to improve students' mathematics and science problem-solving skills, have been used successfully by middle school students at several different sites. Although results indicate no difference in standardized test achievement, this finding was considered to be positive because time normally spent on conventional instruction was reduced to allow for the use of the problem-solving videodiscs which did have a positive effect on students' problem-solving skills. The instruction surrounding the use of the videodiscs was very carefully structured by classroom teachers, and this appears to be an important factor in the use of technology in the classroom.

The use of interactive videodiscs is also proving to be an important instructional strategy. Guidance in using the videodiscs is programmed and controlled by a computer that directs students' attention and frequently requires students to make decisions about their own learning. Effective programs, particularly at the secondary and college levels, show that student achievement and attitudes improve with their use, and that in some cases interactive videodiscs are an effective substitute for conventional laboratory experiences such as dissections in biology.

References:

Bereiter and Scardamalia 1989; Bohren 1993; Brown 1992; Brown, Collins, and Duguid 1989; Cobb 1994; Cognition and Technology Group at Vanderbilt 1992, 1993; Dawson 1991; Hofmeister, Engelmann, and Carnine 1988; Kinzie, Strauss, and Foss 1993; Leonard 1992; Lockhart, Lamon, and Gick 1988; Meyers 1993; Savenye and Strand 1989; Smith and Jones 1988.

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9.12. Discrepant Events: Using discrepant events in science instruction results in cognitive conflict that enhances students' conceptual understanding.

Research findings:

There is little direct research evidence that using discrepant events (occurrences in nature that are at odds with students' current thought) promotes conceptual understanding. However, two of the practices included in this chapter (Learning Cycle Approach and Real-Life Situations) are thought to be effective because they frequently include discrepant events. Discrepant events are one form of anomalous data that help students focus on their prior conceptions, a step that is thought to be necessary if students are to alter their conceptions so that they become closer to the accepted scientific view. During the exploration phase of the learning cycle, students may confront anomolous data, or such data may be included in instruction based on real-world situations. The reference by Chinn and Brewer provides the theoretical framework for using anomalous data in science instruction.

In the classroom:

Many science teachers use discrepant events frequently in their teaching, and this practice has been advocated by authors of methods texts over the years. An example of a discrepant event from physics instruction would be to drop a Styrofoam and a steel ball of equal volumes from the same height at the same time and note that both hit the floor at the same time. Because most students think that the heavier ball will hit first, the event is discrepant.

Although discrepant events frequently take the form of demonstrations, all demonstrations do not necessarily include discrepant events. Discrepant events can be built into hands-on activities that students actually perform and can be included in computer simulations and on videodiscs.

Just because students view or experience something that is discrepant does not guarantee that they will learn from the situation. Students may ignore or reject it. In order to maximize its effectiveness, the anomolous data must be credible and unambiguous. A recommended strategy for effective instruction includes the following steps: 1) consider a physical scenario of unknown outcome; 2) predict the outcome; 3) construct one or more theoretical explanations; 4) observe the outcome; 5) modify the theoretical explanation; 6) evaluate competing explanations; and 7) repeat the previous steps with another discrepant event illustrating the same theory or concept.

References:

Chinn and Brewer 1993; Dreyfus, Jungwirth, and Eliovitch 1990; Duit 1991a; Lawson 1990; Linn and Songer 1991.

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