Organized to improve science teaching—through research

NARST NEWS

NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

Thaddeus W. Fowler, Editor, University of Cincinnati, OH

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PRESIDENT

William G. Holliday
University of Maryland at College Park

NARST—What We Are and What We Are Not

NARST is in the business of improving science teaching—through research with the standard of excellence. Specifically, our central objective includes producing the best research journal and conducting the most successful annual meetings in our field, focusing most of our energies in these two directions.

First, NARST publishes the most often-cited research journal (*Journal of Research in Science Teaching*) in the field, selecting a wide variety of research topics, regardless of type (e.g., ethnographic or non ethnographic, naturalistic or laboratory, empirical or theoretical). In addition, NARST has a policy of bending over backwards to be fair to all scholars submitting manuscripts while maintaining a policy of excellence.

Our Journal has been ranked as one of the highest quality educational journals (and the only science education publication in this category) according to studies published by Ward, Holland and Schramm (*American Educational Research Journal*) and Guba and Clark (*Educational Researcher*) for the American Educational Research Association—AERA. Today, there apparently is no more respected research journal in science education perhaps because NARST's editorial board attracts and encourages authors from around the world who want their studies to be promptly reviewed and published in the highest rated journal of its kind and read by the widest audience concerned about improving science teaching.

In regards to excellence, reports from our past and current editors show that our rejection rate is up by an additional one-third over the past eighteen months and our turnaround time—from submission by authors through the entire review process to acceptance/minor-revisions/major-revisions/rejection notifications mailed to authors—has been reduced to about two months. Past editors likewise have produced a journal of high quality, resulting in a recent rating of about sixth in citations among educational research journals published in the United States, according to remarks made at a recent NARST symposium. Unfortunately, NARST does have a problem of production-lag time but this problem is being corrected.

Second, NARST provides researchers with a forum at our annual meetings to present ideas and data. Almost half our membership—an unusually high proportion for any association—apparently attends these meetings. Comparing the quality of typical contributed papers presented at recent meetings of AERA and NARST, suggests that NARST is now equivalent in quality. This is especially true for papers presented by AERA's many SIGs (special interest groups).

NARST is not in the business of saving the world of science education by adopting and duplicating the efforts of other fine general associations such as ASE, NSTA, AERA, AAAS. For example, NSTA and other teacher-oriented groups have the mandate and the administrative and distributive systems to handle such tasks as disseminating research reviews to science teachers. Fortunately, NARST increasingly is able to assist other associations in this regard and continues to play a role in informing science teachers, limited only by our resources.

NARST is solely committed to the research dimension of improving science teaching. We study science teaching, which is different than doing or directly promoting science teaching in the general sense of NSTA's goal ("to promote and advocate science education," NSTA's minutes of the board of directors meeting, Summer 1987). To put it another way, associations like NARST, AERA (American Educational Research Association), and NRC (National Reading Conference) are scholarly associations focusing on research with delimited mandates. None of these associations are primarily focused on application, but are committed in varying degrees to lend assistance by cooperating with practitioner-oriented associations. Yet, NARST members provide considerably more assistance to practitioners than most other education research association members, often through our work with NSTA.

continued p. 2

(President)

NARST now needs to put more energies into our relationship with other research associations with the goal of balance between research and practice. For example, imaginative initiatives need to be constructed, bringing AERA and NARST closer together without injuring our current relationship with associations like NSTA. Forming one more AERA SIG is probably not the answer to improving science teaching, according to remarks made at previous board of director meetings.

So, I request that you provide the NARST board of directors with your suggestions for discussion at our Fall Board of Directors meeting in Stone Mountain, outside of Atlanta. Telephone me (301) 454-1512 or write me: Bill Holliday, Department of Curriculum and Instruction, University of Maryland at College Park, College Park, MD 20742. Let's discuss your suggestions. You may, instead, prefer to contact Lowell Bethel (for address, see notice appearing elsewhere in this issue) about this matter because of his chairing of the NARST committee on special membership projects. At any rate, let us hear from you.

Second Call for Proposals 1990 NARST Annual Meeting

This is a call to NARST members and others to submit proposals for the program for the 1990 NARST Annual Meeting. The 1990 annual meeting will be held in Atlanta, Georgia on April 8 through 11, 1990. All *presenters* must *register* for the NARST meeting.

The Program Committee encourages the submission of proposals that describe any of a variety of types of research including, but not limiterd to: case study, experimental, descriptive survey, documentary analysis, ex post facto, evaluation, historical, naturalistic, and philosophical.

PROPOSAL CATEGORIES, PREPARATION AND REVIEW

Proposals should fit into one of the seven categories of concurrent sessions presented at NARST annual meetings. Criteria and description of each category follow. Except in the case of poster sessions and seminars/workshops, it is anticipated that the research on which the session is based *will have been completed prior to proposal submission.*

1. **Contributed Papers:** This format accommodates three or four 15-minute reports on research papers by individual researchers or groups of researchers. Contributed papers are grouped by the Program Committee and discussants usually are assigned to such sessions. Presenters must provide discussants with a copy of the research paper before the annual meeting and are encouraged to distribute copies of the paper at the session. A *Contributed Paper proposal should include*: 1) an abstract, and 2) a three to six page, double spaced, synopsis (objectives or purpose of the study, significance, design and procedures, findings or results, and conclusions) with bibliography (not counted into the six pages). The materials should be stapled together in the upper left corner.
2. **Paper Sets:** This category accommodates several related research papers or a single paper, reporting on several studies which originate from a common base of research, presented in a single concurrent session. The format also allows for common elements of design or approach to be presented once rather than repetitiously. A discussant may be assigned to the session if one is not identified in the proposal. Presenters must provide the discussant with a copy of the research papers before the annual meeting, and are encouraged to distribute copies of the papers at the session. A *Paper Set Proposal should include:* 1) an abstract, and 2) a three to six page, double spaced, synopsis (objectives or purpose of the study, significance, design and procedures, findings or results, and conclusions) with bibliography (not counted into the six pages) *for each paper* proposed for presentation. The materials should be stapled together as a unit in the upper left corner.
3. **Poster Sessions:** Poster sessions are designed to enable researchers to share information on research *that may be in progress.* Poster sessions combine the graphic display of materials with an opportunity for individualized, informal discussions of the research. Authors are encouraged to bring copies of a paper for distribution to interested participants. A *Poster Session Proposal should include:* 1) an abstract, and 2) a three to six page, double spaced, synopsis of the research to date (e.g., objective or purpose of the study, significance, design and procedures, findings or results, and conclusions) with bibliography (not counted into the six pages). The materials should be stapled together in the upper left corner.
4. **Panels:** Panels are constituted to provide a mechanism for debating or discussing serious issues in science education. Each panel has a moderator, who may or may not have organized the panel, but who is expected to regulate the flow of discussion or debate. Panel members must provide the moderator with a copy of the paper in which their views on the issue are presented in a scholarly manner and are encouraged to distribute copies of their papers at the session. A *Panel Proposal should include:* 1) an abstract, and 2) a double spaced, Introduction which describes the issue focus of the panel, the research interests of panel members, and their varied backgrounds, *without naming the individuals* (maximum of two pages), and 3) a three to six page, double spaced, synopsis with bibliography (not counted into the six pages) *of each paper* proposed for presentation in the panel. These materials should be stapled together as a unit in the upper left corner.

5. **Symposia:** Symposia should promote discussion of current or needed research. Following a brief presentation by each member of the symposium, interaction among presenters and the audience is expected. *A symposium proposal should include:* 1) an abstract, and 2) a double spaced, Introduction which describes the research focus of the symposium, the research interests and professional backgrounds of symposium members *without naming the individuals* (maximum of two pages), and 3) a three to six page, double spaced, synopsis with bibliography (not counted into the six pages) of each paper proposed for presentation by a symposium member. This should be stapled together as a unit in the upper left corner.
6. **Round Table Discussions:** Round Table Discussions are used to provide a thorough analysis of one or more papers by a group of researchers. Presenters have an hour in which various aspects of the study are examined by others, the round table panel, in a discussion format. The researcher must provide round table panel members with a copy of the paper at least *two months* prior to the annual meeting. In addition, they are expected to bring materials such as protocols, instruments, computer printouts, experimental curriculum materials, and logs to aid in the discussion. A *Round Table Proposal should include:* 1) an abstract, 2) a three to six page, double spaced synopsis (objectives or purpose of the study, significance, design and procedures, findings or results, and conclusions) with bibliography (not counted into the six pages) of the research paper to be discussed, and 3) a description of each round table member, including their varied backgrounds, and respective research expertise, *without naming the individuals* (maximum of two pages). These materials should be stapled together as a unit in the upper left corner.

All proposals will be reviewed anonymously by the members of the Program Committee. The following criteria will be applied during the proposal reviews.

Significance of the program and conclusion for the advancement of research in science education as evidenced by the link to or departure from previously published research theories, methods, or conclusions.

Clarity of expression.

Appropriateness of the procedures and conclusions, given the stated purpose and results.

Adherence to the proposal preparation criteria presented herein, *including the deadline.*

Please note that contributed papers, paper sets and round tables are designed to allow researchers to report on research projects which have been completed prior to the proposal submission deadline. The Program Committee wishes to accommodate as many papers as possbile and asks for cooperation from proposers if some proposals are moved from one category to another.

An individual may present in only one contributed paper or paper session at the Annual Meeting but may be listed as a co-author on other papers and may participate in a symposium, round table, seminar/workshop as well as serve as a presider or a discussant. Presenters are strongly encouraged to stimulate discussion around their presentations. Overhead projectors and screens will be provided. Participants needing other equipment are expected to provide that equipment. All presenters *must register* at the NARST meeting.

PROPOSAL SUBMISSION

Persons wishing to submit proposals need to send:

1. Two (2) copies of the completed cover page (provided at the back of the newsletter).
2. Six (6) copies of the proposal *as described under the respective concurrent session type* above. Please omit the name(s) and identifying information about the proposer and other session participants.
3. Two (2) *additional copies* of an abstract of more than 500 words for *concurrent sessions* and all *symposia.* The abstracts of accepted sessions and symposia will be published in the collection of NARST abstracts, so form and accuracy are important. Please omit author name(s) and other identifying information.
4. Two (2) self-addressed, stamped, envelopes which will be used to acknowledge receipt of the proposal and the Program Committee's final decision. [Non-US members need not provide stamps.]
5. Two (2) 3×5 inch typed cards containing name, address, and telephone (Fax and Bitnet, if possible) numbers of the individual proposing the concurrent session as well as the title of the session.

Send this material to: Jane Butler Kahle, Chair; NARST Program Committee, 221 WTHR Building, Purdue University, West Lafayette, IN 47907, (317) 494-8518.

DEADLINE: MATERIALS **MUST** BE POSTMARKED NO LATER THAN OCTOBER 1, 1989

Report From *JRST* Editor

Rodger Bybee, Tony Lawson, Marcia Linn, Joe Novak, and Jim Shymansky have agreed to serve as *JRST* Associate Editors. Each Associate Editor will organize one special issue during the 1990–'95 term and otherwise assist *JRST* Editor, Ron Good, in efforts to enhance the *Journal.* Larry Yore and Charles (Andy) Anderson have agreed to serve on the Editorial Board. Both Larry and Andy are longtime NARST members and they bring a great deal of research expertise to the Board.

Experienced NARST members not on the Review Board are occasionally asked to review manuscripts. If you are asked to review a manuscript but are unable to provide a careful, prompt review, please inform the Editor without delay. Every effort is being made to provide authors with a prompt review of their work.

At its November meeting in Atlanta, the NARST Executive Board will decide whether the number of *Journal* pages should be increased from 900 to 1200 per volume. A dues increase requiring a membership vote will be needed to fund the increase in pages.

5th Annual AAAS Forum for School Science Scientific Literacy

The meaning and acquisition of scientific literacy will be examined at the 1989 AAAS Forum for School Science to be held on October 6–7 at the Hyatt Regency Crystal City, Arlington, Virginia.

Forum '89 will offer views of scientific literacy from academe, politics, science, education and business and from selected national reports. Participants will learn about the national projects aimed at achieving scientific literacy including the new National Science Foundation-sponsored elementary-school curricula, the National Science Teacher Association's Scope, Sequence, and Coordination project, American Association for the Advancement of Science's Project 2061 report *Science for All Americans,* and the National Assessment for Educational Progress' *Science Objectives: 1990 Assessment.* The results of a nationwide survey on scientific literacy will be announced.

Registration for AAAS Forum '89 is: Regular $240, Nonprofit $195, AAAS Members and K–12 Teachers $175, and Students (no meals) $70. Registration includes *This Year in School Science 1989,* the companion volume to the Forum conference.

For more information about the AAAS Forum for School Science, write to: Betty Calinger, Forum for School Science, AAAS, 1333 H Street, NW, Washington, DC 20005 or call (202) 326-6629.

1990-'91 Visiting Scholar/Associate Editor at LSU

For the 1990-'91 academic year, LSU will again fund a visiting scholar in science education. This year's visiting scholar, James Wandersee, serves as *JRST* Associate Editor, teaches a gradueate seminar each semester, and is engaged in other activities at LSU. The 1990-'91 visiting scholar will likewise assist *JRST* Editor, Ron Good, and become actively involved with ongoing science education work at LSU, including major projects funded by the National Science Foundation and the Hughes Foundation. Ample time and resources are provided for personal scholarly work not necessarily related to ongoing projects at LSU. The visiting scholar receives a $32,500 stipend for the academic year.

Applications for the 1990-'91 position should include a complete vita, at least two letters of support, and a statement from the applicant's institution indicating that leave or sabbatical will be granted. The applicant must be a NARST member, have at least 10 years of experience as a university science educator, and have an established record of science education research. Applications and inquiries should be sent to Ron Good, JRST Editor, 223-E Peabody, LSU, Baton Rouge, LA 70803.

Jane Kahle Now at Miami University

Jane Kahle, NARST President-Elect, has recently accepted an endowed professorship at Miami University, Ohio. She will be taking up her new position this fall. Even though Kahle is changing institutions, all Conference Proposals should still be sent to Purdue University! Her new address is Dr. Jane Butler Kahle, Condit Professor of Science Education, McGuffey Hall, Miami University, Oxford, Ohio 45056, (513) 529-3736.

Ivany New President of University of Saskatchewan

George Ivany is the new president of the University of Saskatchewan. He is a long-time member of NARST, and has served as a member of the editorial review board of both the Journal of Research in Science Teaching and the American Journal of Physics. Ivany has been the academic vice-president of Simon Fraser University, and formerly he was the dean of education at Simon Fraser, the dean of education at Memorial University, and the head of the department of science education, Teacher's College, Columbia University.

NARST

April, 1988

Research Matters...To the Science Teacher

TEACHING CONCEPTUAL UNDERSTANDING TO PROMOTE STUDENTS' ABILITY TO DO TRANSFER PROBLEMS

By William C. Robertson

Consider the following steps in a basic algebra problem:
Solve for x

$$x + 3 = 5$$
$$x = 5 - 3$$
$$x = 2$$

Now suppose two different students have learned how to solve problems such as the one above and they now encounter a new situation:
Solve for x

$$4x = 16$$

Let us further suppose that our students have never seen a problem involving multiplication of algebraic variables. The students think out loud as they try to solve this problem. Here is what they might say:

Student 1
"I want to solve for x, so I need to get x by itself. In order to maintain the equality as before, I must do the *same thing* to both sides of the equation. I can isolate x if I multiply 4x by ¼, so that's what I'll do to both sides of the equation."

$$(\tfrac{1}{4})(4x) = (\tfrac{1}{4})(16)$$
$$x = (\tfrac{1}{4})(16)$$
$$x = 4$$

Student 2
"I need to get x by itself again. In the previous problems, I took the number to the other side and made it negative, so I'll do that again."

$$x = 16 - 4$$
$$x = 12$$

Which of the two students would you say *understands* the concepts associated with solving linear equations? Which student has *memorized* a set of procedures or algorithms? If you said that student 1 understands the concepts, you are in agreement with most cognitive psychologists who study how people solve problems. Student 1 is able to successfully apply the concepts in a *novel* situation, which is an indication that the student understands the concepts. Unfamiliar problems that require previously-encountered concepts for their solution are "transfer problems."

Conceptual understanding is superior to memorized algorithms for solving transfer problems (Katona, 1940; Mayer, 1974; Mayer, Stiehl & Greeno, 1975). Conceptual understanding is a worthwhile goal of science teaching; but what *is* conceptual understanding and how is it taught? In this article we shall take a look at the models of human memory and knowledge (cognitive structures) that are associated with conceptual understanding and the ability to do transfer problems. These models will then be used to recommend specific teaching strategies.

Cognitive Structures Associated With Understanding

Studies in complex domains such as solving science problems (Bromage & Mayer, 1981; Heller & Reif, 1984; Robertson, 1986) have suggested that conceptual understanding is associated with *connections*—connections between science concepts and everyday life and connections among the different science concepts in a discipline. Someone who is good at solving transfer problems does not randomly connect concepts (which might occur when using memorized algorithms to solve problems) but rather integrates the concepts into a well-structured knowledge base. Broad, organizing concepts are situated at the top of a hierarchy and useful ancillary knowledge is contained in lower levels, as Figure 1 shows for selected physics concepts. The concept map illustrated in Figure 1 is not complete, but it does clearly show the relative importance and appropriate connections among some physics concepts. For instance, the map shows that friction and electrical forces are not major problem-solving principles but merely types of forces that one might consider when using the principle of Newton's Second Law. Major principles such as Conservation of Energy are at the top of the hierarchy, and physical characteristics of systems (e.g., whether a spring is present) are at the bottom, which lets the student know the relative importance of these ideas.[1]

For the purpose of solving transfer problems, this well-structured knowledge base appears to be more important than the utilization of strategies such as setting goals and subgoals and working backwards from the goal. These strategies may be helpful, but without utilizing an accompanying "connectedness" of concepts specific to the discipline, one cannot be good at solving problems in science or other complex domains.

What Kind of Transfer?

The distinction between transfer problem-solving ability *within* a discipline and transfer problem-solving ability *between* disciplines is important. A classic example of transfer between disciplines is the (false) notion that the study of Latin can help someone think more clearly in other subjects and in everyday life. Transfer within disciplines refers only to, say, the ability to do problems within chemistry once one has studied the appropriate chemistry concepts.

Which kind of transfer can a science teacher hope to achieve with students? Students should be able to solve transfer problems within a discipline by acquiring conceptual understanding through an appropriately structured knowledge base. Evidence exists that such general strategies as setting goals and subgoals do transfer to new disciplines (Simon and Simon, 1978)[2] but these strategies alone do not ensure the successful solution of a problem if the subject matter is complex. Teachers would do well, then, to concentrate on the ability to solve transfer problems within a specific subject area.

What to Do?

If one agrees that conceptual understanding in a discipline is desirable, then what can a teacher do about it? The following are appropriate teaching strategies suggested by research:

1) Help your students to see the structure of your discipline. Show them the "big picture"—how concepts connect with one another and with everyday experiences. Concept Mapping (Novak and Gowin, 1984), shown in Figure 1, is an excellent tool for illustrating how concepts are related. Explicate the "ancillary knowledge" associated with formulas and principles—this is the knowledge that students use to "make sense" of a formula rather than just memorize it.

2) The most important thing you are presenting to students is the big picture, so allow them to concentrate on the big picture by making sure that they can use certain skills almost automatically. For example, one is not free to acquire a conceptual understanding of an equation such as $F = ma$ if the use of algebraic symbols in an equation is not second nature. Similarly, one cannot begin to concentrate on the meaning of words if one doesn't know the alphabet well. This is not to say that skills should be memorized; you should teach them in a meaningful way, just as you should teach higher-level concepts in a meaningful way. However, students should then practice the skills until they no longer present a hinderance to concentrating on more important matters.

3) Instill in your students the desire to make sense of the subject matter. Encourage them to look for the connections among concepts and to structure these concepts in a hierarchy. Encourage your students to be dissatisfied with explanations that are to be memorized rather than understood. Although a well structured knowledge base in one discipline will not transfer to another discipline, perhaps the ability and desire to look for the appropriate conceptual structure in the new discipline is transferable.

4) Test your students for their ability to solve transfer problems. Testing students on problems that are exactly like ones they have done in their homework is a sure way to promote memorization of problem types. If, however, students know that the test problems will be unfamiliar, they are more likely to try to acquire the conceptual understanding necessary to do them. If you are able to help your students truly understand concepts, perhaps at some point during the year they will stop referring to the transfer problems as "trick questions!"

5) Finally, allow your students the *time* necessary to acquire conceptual understanding. People need time to establish connections and see how concepts fit together. Reduce the number of topics you cover in your science course. Teach fewer (important) concepts in greater depth. Allow more time for laboratory explorations that are meaningful rather than an exercise in following recipes. It is better for your students to understand a limited number of science concepts than to memorize many concepts that they are unable to apply in novel situations.

William C. Robertson is a staff associate at the Biological Sciences Curriculum Study. He is a member of the National Association for Research in Science Teaching, an organization dedicated to improving science teaching through research.

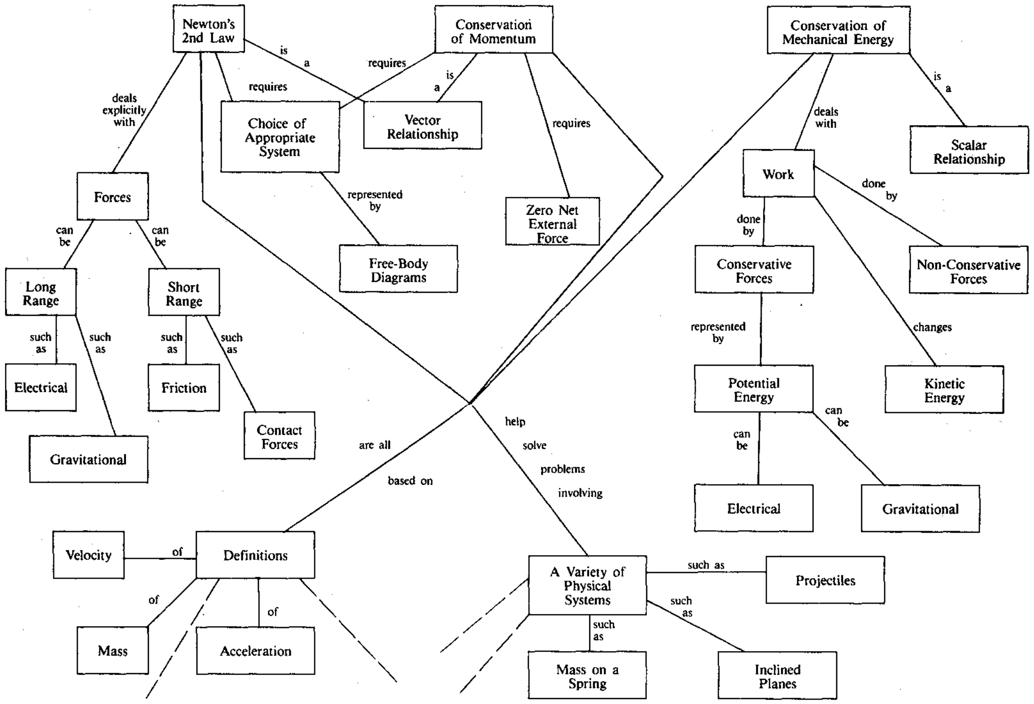

Figure 1. An incomplete concept map showing how selected physics concepts are related.

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[1] Novice physics students commonly classify problems solely on the basis of physical characteristics and not according to the major principle used to solve the problems (Chi, Feltovich, and Glaser, 1981).

[2] This issue is not clear-cut. A considerable amount of evidence indicates that, when working in one subject area, people do not often utilize even simple problem-solving skills that they have learned in another subject area.

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April, 1989 No. 21

Research Matters...To the Science Teacher

ENHANCING LEARNING THROUGH CONCEPTUAL CHANGE TEACHING

By William C. Kyle, Jr. and James A. Shymansky

From the moment of birth infants begin to generate views about their new environment. As children develop, there is a need construct meaning regarding how and why things behave as they do. And, long before children begin the process of formal education, they attempt to make sense of the natural world. Thus, children begin to construct sets of ideas, expectations, and explanations about natural phenomena to make meaning of their everyday experiences. The ideas and explanations that children generate form a complex framework for thinking about the world and are frequently different from the views of scientists. These differing frameworks are referred to in the literature as misconceptions, alternative conceptions, or alternative frameworks. Since the early 1970s, research in science education and cognitive science has enriched our understanding of the importance of the ideas and explanations that students possess prior to instruction. This research has direct implications concerning the nature of learning science, as well as the process of teaching science.

Prior Knowledge and Conceptions of Students

Teachers have always recognized the need to start instruction "where the student is." David Ausubel (1968) emphasized this by distinguishing between meaningful learning and rote learning. For meaningful learning to occur, new knowledge must be related by the learner to relevant existing concepts in that learner's cognitive structure. For this reason, Ausubel contends that, "The most important single factor influencing learning is what the learner already knows." Ausubel also commented on the importance of preconceptions in the process of learning, noting that they are "amazingly tenacious and resistant to extinction...the unlearning of preconceptions might well prove to be the most determinative single factor in the acquisition and retention of subject-matter knowledge."

Perhaps the most comprehensive interdisciplinary assessment of children's conceptions of science is the Learning in Science Project in New Zealand (Osborne & Freyberg, 1985). The following examples, from the work of the Learning in Science Project, exemplify conceptions that children ages 5 to 18 possess on a variety of topics, while contrasting those views with the scientific perspective.

LIVING

Scientific Perspective: Living things are distinguished from non-living things in their ability to carry on the following life processes: movement; metabolism; growth; responsiveness to environmental stimuli; and, reproduction.

Children's Views: Objects are living if they move and/or grow. For example, the sun, wind, and clouds are living because they move. Fires are living because they consume wood, move, require air, reproduce (sparks cause other fires), and give off waste (smoke).

ANIMALS

Scientific Perspective: An animal is a consumer.

Children's Views: Animals have four legs, have fur, make noise, are bigger than insects, and/or are found on land. Cows, dogs, elephants, and lions are easily identified as animals. People are not animals. Similarly, spiders, butterflies, birds, fish, and earthworms are not animals.

PLANTS

Scientific Perspective: A plant is a producer.

Children's Views: A plant is something growing in a garden. Carrots and cabbage from the garden are not plants; they are vegetables. Trees are not plants; they are plants when they are little, but when they grow up they are not plants. Seeds are not plants. Dandelions are not plants; they are weeds. Plants are only things that are cultivated; the more food, water, and sunlight they get the better. Plants take in their food from the environment. They have multiple sources of food. Photosynthesis is not important to plants.

ELECTRIC CURRENT

Scientific Perspective: A current of electricity, or electric current, is a flow of electrically charged particles through a conductor.

Children's Views: Electric current flows from battery to bulb and is used up.

FORCE AND MOTION

Scientific Perspective: Force is a push or a pull on an object. A body remains at rest or in uniform motion unless acted upon by a force.

Children's Views: A body requires a force to keep it in motion. Force is always in the direction of motion. There is no force acting upon a body that is not in motion.

GRAVITY

Scientific Perspective: Gravity is a force between any two masses. Gravity depends on the size of the masses and the distance between their centers.

Children's Views: Gravity is something that holds us to the ground. If there was no air there would be no gravity. For example, above the earth's atmosphere there is no gravity, and you become "weightless." Gravity increases with height above the earth's surface. It is associated with downward falling objects.

Research related to students' conceptual reasoning and the elucidation of alternative frameworks has also been conducted on the following scientific concepts and/or topics: air and air pressure, density, dynamics, the earth, ecological matter cycling, energy, heat and temperature, light and vision, mechanics, natural selection, the particulate nature of matter, and respiration and photosynthesis (readers interested in more comprehensive reviews should refer to Driver & Erickson, 1983; Driver, Guesne, & Tiberghien, 1985; Gilbert & Watts, 1983; West & Pines, 1985; as well as publications available from The Institute for Research on Teaching[1]).

Learning science for most students involves a process of conceptual change. Anderson and Roth (in press) note that students who achieve an understanding of a scientific topic successfully integrate accurate scientific knowledge with their own personal knowledge of the world. Research suggests, however, that many students fail to do this; instead, they view scientific knowledge as being separate and distinct from their personal knowledge. For these students science is merely a compilation of strange, obscure facts rather than a system of conceptual schemes for understanding their environment.

Formal science instruction does not change the alternative frameworks held by many students. In fact, while we have referred to alternative frameworks in the context of children's views, the alternative conceptions common to elementary school students have been found to exist among high school students and college students. We observe many adults who have conceptions that are substantially different from those of scientists. With this in mind, if preconceptions are as tenacious as Ausubel contends, how can teachers enhance the likelihood of conceptual development and thereby improve students' science conceptions?

Teaching for Conceptual Change

Driver (1983) notes that the alternative conceptions that students have constructed to interpret their experiences have been developed over an extended period of time; one or two classroom activities are not going to change those ideas. She emphasizes that students must be provided time individually, in groups, and with the teacher to think and talk through the implications and possible explanations of what they are observing — and this takes time. Improving students' science conceptions may begin by recognizing that "less is more." That is, we may need to *decrease* the amount of new material introduced to students each year if we truly desire to enhance their conceptions of scientific phenomenon.

In teaching for conceptual change, students must experience conflict with their expectations. It is only reasonable that students would not accept a new idea with first feeling that their existing views are unsatisfactory in some way. Posner et al. (1982) suggest that if students are going to change their ideas:

1. They must become dissatisfied with their existing conceptions.
2. The scientific conception must be intelligible.
3. The scientific conception must appear plausible.
4. The scientific conception must be useful in a variety of new situations.

Teaching for conceptual change then, demands a teaching strategy where students are given time to: identify and articulate their preconceptions; investigate the soundness and utility of their own ideas and those of others, including scientists; and, reflect on and reconcile differences in those ideas. The Generative Learning Model (GLM) is a teaching/learning model that substantially provides this opportunity. In the GLM, the learner is an active participant in the learning context rather than an empty cup to be filled (refer to Osborne & Freyberg for a more detailed description of the Generative Learning Model). The GLM has four instructional phases aimed at enabling the learner to construct meaning. Using the GLM, a teacher:

1. Ascertains students' ideas, expectations, and explanations prior to instruction.
2. Provides a context through motivating experiences related to the concept.
3. Facilitates the exchange of views and challenges students to compare ideas, including the evidence for the scientific perspective.
4. Provides opportunities for students to use the new ideas (scientific conceptions) in familiar settings.

Teachers who effectively implement the GLM promote a learning environment that engages students in an active search and acquisition of new knowledge. Learning is characterized by a process of interaction between the student's mind and the stimuli providing new information. Such a learning environment enables students to modify their existing cognitive structures. Students experience a dynamic interaction between their preconceptions and the appropriate scientific conceptions.

The generative model for teaching/learning acknowledges a constructivist approach to the process of learning. That is, students construct meaning from their experiences. This is precisely how Piaget viewed the process or learning (1929/1969). Piaget referred to the process of acquisition and incorporation of new data into an existing structure as "assimilation" and the resulting modification of that structure as "accommodation." In learning science then, the new facts, ideas, and concepts that are acquired gain more meaning by being organized (assimilated) into a cognitive structure; at the same time, the existing cognitive structure is given further clarification and support, or perhaps even changed, by incorporating new information (accommodating itself to the new data). The instructional process to facilitating conceptual change must therefore: 1) identify and address students' alternative conceptions, 2) provide opportunities for students' ideas to evolve, and 3) enable students' new ideas to be applied in a context familiar to them.

Summary

If teachers are to improve students' science conceptions we must recognize that:

- students come to science class with ideas,
- students' ideas are often different from scientists,
- students' preconceptions are strongly held,
- traditional instruction (rote learning) will not lead to substantial conceptual change, and
- effective instructional strategies enable teachers to teach for conceptual change and understanding. The key to altering the ideas, explanations, and conceptions of science that students possess is to find out and use what students already know. The challenge of teaching science is to ensure that you do not leave intact students' alternative conceptions or fill students with ideas and explanations which have little chance of being understood. The conceptual change teaching literature on generative learning may provide you with a solution to that challenge.

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[1] Researchers at The Institute for Research on Teaching at Michigan State University are assisting teachers in the process of teaching for conceptual change through curriculum development and teacher education initiatives aimed at improving students' science conceptions.

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Research Matters...To the Science Teacher

CHANGING AND MEASURING ATTITUDES IN THE SCIENCE CLASSROOM

By Thomas R. Koballa, Jr.

Teachers realize the importance of how students feel about science subjects and courses; nevertheless, they place little emphasis on affective objectives. The affective domain is often neglected because teachers have difficulty designing strategies to develop positive attitudes among students and documenting their development. The seemingly arbitrary use of terms associated with the affective domain has further contributed to this neglect. Recent research provides suitable guidelines to focus attention on this important domain.

The literature indicates that the affective domain related to science education is primarily concerned with attitudes related to science. The development of positive attitudes toward science has long been viewed as a legitimate goal of science education. Science curriculum developers have for some time sought to improve students' attitudes toward science and scientists. Concern for student attitudes toward science has also risen with regard to the possibility of increasing enrollment in elective science courses by improving attitudes toward science among adolescents.

Attitude and Related Concepts

The term attitude encompasses a wide range of affective behaviors (e.g., prefer, accept, appreciate, and commit) and is used too loosely and without basis by some writers. It is also applied in a number of contexts and with a variety of meanings, which has led to considerable confusion. Nevertheless, a distinct, yet complex definition of attitude is emerging within the literature.

The most prominent quality is evaluative directionality, our favorable or unfavorable feelings toward something. Some experts contend that evaluation is the only element of attitude; the element that our attitude instruments seem to measure. Attitudes are learned either actively or vicariously, thus they can be taught. Because attitudes are learned they are susceptible to change, but stable enough to be enduring. Each attitude has an object and the changeable nature of an attitude is tied to the specificity of the object. It is harder to change one's attitude towards science, for example, than an attitude toward dissecting a frog in biology class on Monday. Attitude is also a correlate of behavior with personal, social, and cognitive variables thought to influence their level of consistency.

Other terms such as value, belief, interest, and opinion are often confused with attitude. Values are rules that direct moral or ethical decisions that are considered either right or wrong. They are broader in scope than attitudes and unlike attitudes that range from positive to negative, values seem to be always positive in nature. Truth, beauty, goodness, liberty, equality, and justice are six values basic to Western civilization cited by Mortimer Adler (1982). Recognized by Shrigley, Koballa, and Simpson (1988) as values held by science teachers are academic achievement, a pollution free environment, and symmetry in nature. Values are considered more complex than attitudes and are less easily changed.

Beliefs are the cognitive basis for attitudes. They provide information for attitudes by linking objects and attributes. For example, "Cotton is fluffy," is a belief with "cotton" serving as an object and "fluffy" serving as an attribute. Information provided by beliefs may be factual (e.g., copper is malleable) or nonfactual (e.g., the atomic bomb is the most important scientific breakthrough of the 20th century). Nonfactual or evaluative beliefs differ little from attitudes. A person has many more beliefs than attitudes and far fewer values than either attitudes or beliefs.

An interest is a learned response of liking or preferring. It involves the selection and ranking of responses along a like-dislike continuum. Interests are directed toward activities and objects and they are usually expressed by action verbs, such as *reading* a book or *playing* football. Some writers have attempted to make a distinction between interest and attitude by pairing interest with preferences for activities and attitude with preferences for groups, institutions, or objects. However, this distinction seems artificial. In usage, the terms are essentially synonymous.

Usually manifested in the form of verbal expression, opinions are more cognitive than attitudes. Opinions over the years have competed for the position now firmly held by attitudes and have been used to represent cognition, evaluation, and behavior. The terms opinion and interest seem to serve no useful purpose as constructs for science education research and communication with the evaluation of rather distinct definitions for attitude, value, and belief. (A more comprehensive analysis of attitude and other related concepts can be found in the work of Shrigley, Koballa, and Simpson, 1988).

In addition to the terms just mentioned, science educators toil with scientific attitudes, a concept that further adds to the confusion. A cognitive concept, scientific attitudes are normally associated with the mental processes of scientists, (e.g., curiosity, rationality, and willingness to suspend judgment). Scientific attitudes possess attributes thought to be either true or false and do not express an evaluative quality. To lessen the semantic confusion, scientific attitudes may be better labeled as "scientific attributes".

Persuasion

For the most part, efforts to improve attitudes by science educators have taken the form of learning science content or comparing innovative forms of teaching with more traditional ones. These efforts are similar to ones abandoned by attitude researchers nearly fifty years ago. Recently, theoretical models derived from social psychology have been employed in science education. Although no options for improving science attitudes should be overlooked, basing the study of attitudes on theoretical models derived from social psychology seems to be a fruitful option. Suggesting that we look to the social psychological literature for theoretical rationales for attitude change are the key elements found in the definition of attitude and a wealth of theoretical development.

Recognized by social psychologists are seven major approaches to attitude change, with each approach subsuming numerous related theoretical models (Petty and Cacioppo, 1986). Conditioning and modeling, message-learning, judgmental, motivational, attributional, combinatory, and self-persuasion are the seven approaches. Petty and Cacioppo contend that the vehicle responsible for attitude change in all of the approaches is persuasion, even though the approaches differ in the outcomes that they specialize in explaining.

Persuasion refers to "any change in attitudes that results from exposure to a communication" (Petty and Cacioppo, 1986, p. 5) and embodies many aspects of teaching. Particularly when operationalized by means of Hovland's (Hovland, Janis, and Kelley, 1953) theoretical model, persuasion resembles classroom instruction. Persuasion and instruction both involve communication which includes giving arguments and evidence for the purpose of getting someone to believe something or to do something. Nevertheless, the use of persuasion as a vehicle for attitude change is suspected to have prompted much trepidation among educators. Bloom, Hastings, and Madaus (1971) contend that neglect of the affective domain is in part due to the fear of indoctrinating or brainwashing students when teaching to achieve affective outcomes.

Persuasion is easily distinguished from indoctrination and brainwashing. Persuasion depicts a situation which is marked by the conscious intent of the source to persuade and in which both the source and receiver function as active agents in the persuasion process. The aim of persuasion, like that of instruction, is to establish certain beliefs (and attitudes) so that they are held in conjunction with their foundation in argument and evidence. The recipient of a persuasive appeal is always free to accept or reject it; the same is not true for indoctrination and brainwashing. Like persuasion, indoctrination is concerned with the change and formation of beliefs; they differ, however, in that in persuasion the emphasis is placed on the reasons for the belief as opposed to the content of the belief. Much of what young children learn in school, public or private, is implanted by indoctrination.

Brainwashing, as coined by journalist Edward Hunter in the 1950s, refers to the coercive techniques applied by the North Korean military to obtain the cooperation and compliance of Allied Prisoners of War. Unlike persuasion, brainwashing involves physical brutality, psychological pressure, and intensive interrogation. Nevertheless, brainwashing was found to be quite ineffective as a means of ideological conversion. Of the several thousand Americans captured during the Korean war and "brainwashed", fewer than 50 collaborated with the enemy and fewer than 25 refused repatriation (Striker, 1984). Most of the men who originally refused repatriation later returned home.

Numerous studies based on the persuasion paradigm have been conducted over the last ten years primarily by a group of science educators led by Robert L. Shrigley (see Shrigley and Koballa, 1987). Their studies were organized around the question, "Who says what to whom how with what effect?" Using this question, they investigated how attitude change (the effect, or the dependent variable) is influenced by four stimuli (1) the source of the message (who), (2) the message (what), (3) the channel through which the message is delivered (how), and (4) the audience (whom). The persistence (retention) of changed attitudes who also a part of many of the studies. These research efforts led to the following conclusions.

- Carefully designed belief-laden messages built on Hovland's model can be used to change attitudes.
- Over the short-term, highly credible (expert and trustworthy) sources enhance the effectiveness of persuasive messages.
- Longer treatment periods are not better. In fact, messages of less than 30 minutes in length can change attitudes.
- Changes in attitudes are unrelated to gains in factual information.
- Messages that present both sides of an issue are more persuasive than those that present only one side.
- Anecdotal messages (containing vivid, concrete sensory information) appear to be superior to data-summary messages (containing aggregated, statistical data) in changing attitudes.
- The channel by which a message is presented does not seem to affect its persuasiveness. Videotape, audiotape, and printed messages have been tried, without a clear advantage for one over the others.
- The attitudes of males are more positive than those of females.
- The effectiveness of persuasive message is not affective by the recipient's self-esteem, intelligence, or level of cognitive complexity.
- Attitude change and the persistence of attitude change are related to the recipient's self-generated thoughts to a persuasive message, but not to his ability to recall message arguments.

Attitude Measurement

Inadequacies in the design of closed item questionnaires are often blamed for the lack of consistent research findings regarding science-related attitude. Since attitude is a construct that must be measured indirectly, usually through self-report, it is imperative that instruments used to assess attitudes be both reliable (i.e., produce consistent results) and valid (i.e., measure what you want to measure). Mathematical computations to determine instrument reliability are routine but the absence of a systematic plan for establishing validity is a flaw common to most attitude instruments. Establishing validity is a process that involves human judgment in addition to statistical procedures according to Abdel-Gaid, Trueblood, and Shrigley (1986). Heeding this warning, a number of closed item attitude scales were developed. Likert scales and semantic differential scales made up the majority of the instruments.

Likert scales. A Likert scale consists of a series of attitude statements that are clearly either positive or negative. A wide range of scores is achieved by having respondents report the intensity of an attitude. This is accomplished by having them indicate their agreement with each statement on a 5-point scale.

The development and testing of Likert scales evolved alongside the adaptation of Hovland's approach to the needs unique to science education. The goal was to see how well scales with only 20 to 25 items could withstand the rigor of both quantitative and qualitative analysis. Over the years a number of scales were developed as part of research endeavors in this area. Unfortunately few of the scales are appropriate for use by teachers with their classes, since the subjects of the research were primarily preservice and inservice teachers.

Measuring the attitude objects on each of the scales developed are positive and negative items similar to the one presented below that appears on the Revised Science Attitude Scale (Thompson and Shrigley, 1986):

I enjoy manipulating science equipment. (positive statement)

(a) strongly disagree	(b) agree	(c) undecided	(d) disagree	(e) strongly disagree
2	1	0	-1	-2

Semantic differential scales. A scale of this type consists of a series of bipolar adjective pairs (e.g., good-bad, beneficial-harmful) listed on opposite sides of a page with seven spaces in between. The attitude object is identified at the top of the scale and may be a word, statement, or picture. The respondent is instructed to evaluate the attitude object by placing a mark in one of the seven spaces between each adjective pair.

Development of semantic differential scales stems from the use of Fishbein and Ajzen's theory of reasoned action to investigate science-related attitudes. The theory is Fishbein and Ajzen's attempt to deal with the weak link often observed between attitudes and behaviors. Studies conducted within the framework of this theory have had a substantial impact on the field of attitude research since the mid-1970s.

In their theory, Fishbein and Ajzen suggest that attitude measures should focus on a person's attitude toward a behavior rather than on the person's attitude toward particular objects. That is, instead of asking about students' attitudes toward science, or computers, teachers should assess their attitudes toward learning science or writing Logo computer programs. The role of specificity in the model is operationalized by the deliberate inclusion of four elements:

- action — reading
- target — my biology textbook,
- context — during study hall, and
- time — for 15 minutes every day throughout the school year.

Fishbein and Ajzen argue that the correlation between attitude and behavior is determined in part by the degree of correspondence between the elements comprising the attitudinal and behavioral variables.

Fishbein and Ajzen also identify another variable, operationalized in a similar manner, which should be measured along with attitude toward the behavior to facilitate behavioral prediction. The variable is called subjective norm. It reflects the person's perception that significant others think the behavior should or should not be performed. Derived from a combination of the attitude and subjective norm scores is a behavioral intention score, considered the best predictor of actual behavior.

Measuring intention, attitude, and subjective norm with respect to the behavior would require the use of semantic differential items similar to the one modeled below:

I intend to read my biology textbook during study hall for 15 minutes every day throughout the school year.

Likely____:	____:	____:	____:	____:	____:	____: unlikely
extremely	quite	slightly	neither	slightly	quite	extremely
3	2	1	0	-1	-2	-3

Few semantic differential scales have been developed that measure the antecedents of science-related behaviors. Nevertheless, scales based on the theory of reasoned action offer several advantages over Likert scales. Their development and use is based on a systematic theory of human behavior, the goal of which is to predict and understand behavior. Clear distinctions are made between belief, attitude, intention and behavior. Attitude is assumed to be a function of all salient beliefs about the attitude object. As a result, the refinement of measures by means of item analysis or to assure unidimensionality by means of confirmatory factor analysis are not required according to Ajzen and Fishbein (1980). Furthermore, scales based on the theory of reasoned action are closely linked to the development of belief-based, persuasive messages. Efforts to develop and test Likert and semantic differential attitude scales led to the following conclusions.

- Attitude instruments provide us with a convenient means of assessing behavior. The only true reason for studying attitude is its relationship to behavior.
- Without reliable and valid measures of attitude, assessing attitude change is impossible.
- The phrase "monitor and modify" should be synonymous with the use of any attitude scale. Instrument reliability and valid data are not static, but change from sample to sample and from one administration to the next.
- Attitudes toward science cannot adequately predict nor provide a satisfactory explanation of science-related behaviors. (Yet investigators persist in measuring students' feelings about field trips, working with science equipment, and six-week units on electricity or ecology using scales that measure attitude toward science!)
- The prediction of behavioral intention, and hence behavior, is improved when the elements of the attitudinal and behavioral intention variables are calibrated at the same level of specificity as the behavioral criterion.
- The use of semantic differential scales based on the theory of reasoned action are preferred over Likert scales to predict and understand behavior and to assess the effects of persuasion.

Teaching for Attitude Change

Affective objectives should be clearly identified and strategies designed to achieve these objectives must be employed.

Changing attitudes using Hovland's model does not require treatments lasting weeks or months; attitudes can be changed in as short a time as one class period, provided that attention is paid to the variables harbored within the question: Who says what to whom how with what effect?

Who: the communicator. Cues discharged by the communicator provide the message recipient with information beyond the arguments and evidence presented in a message. A teacher can enhance his credibility by the way he introduces himself to his students. At the outset of an attempt to persuade students to handle non-venomous snakes, for example, a teacher should describe past activities in which he has handled non-venomous snakes (to appear more qualified). In addition, he may wish to tell the students that their failure to handle the snakes will not affect their class grades or chances to participate in future class activities.

Because most persuasive communication situations are unlikely to occur under conditions in which the speaker is suddenly made known to his audience, people make judgments about the source before they begin to process the message. As Bettinghaus (1968) points out, "it is not the momentary exposure to the source at the time of message transmission which is important, but the total set of impressions from the time the receiver first becomes aware of the source" (p. 118). The teacher who wishes to become persuasive must act accordingly during his daily activities, not merely at the time the message is delivered. Indeed, a communicator can impede attitude change when his perceived credibility is low and help to facilitate attitude change when credibility is high.

What: the message. An appropriate message variable would be a brief, belief-laden communication describing for adolescents reasons for not taking drugs. Teaching strategies identified as innovative (e.g., museum tours, process skills, self-paced and computer assisted instruction) when compared with traditional teaching lack the necessary precision and would not qualify as message variables in Hovland's model.

Achieving desired affective outcomes can be accomplished without being indoctrinary by constructing messsages that emphasize the reasons for belief as opposed to the content of belief. If the goal of persuasion is to have the message recipient modify his beliefs (and attitudes) for reasons that are good and sufficient, messages that present both sides of a debatable issue (e.g., evolution, abortion, aluminum recycling) are essential.

Most people, scientists included, are more easily persuaded by anecdotal, case histories than by aggregated, statistical data (like that found in *Consumer Reports).* Explanations for the finding range from the greater potency of concrete, vivid information over abstract, pallid evidence to a lack of understanding of the fundamentals of statistical inference. Teachers can take advantage of the power of anecdotes by using personal testimonies to aid in the learning of science principles. Also, teachers can use their understanding of the power of anecdotes to curb reckless thinking such as when students insist on generalizing in tubful proportions from a thimbleful of facts.

How: the channel. Common sense might suggest that the order of channel persuasiveness would be: live, videotape, audiotape, and printed. But this does not always seem to hold true. The effectiveness of the channel seems to be affected by the complexity of the message (Chaiken and Eagly, 1976). An easily comprehended message should engender the most attitude change when it is live or videotaped and the least attitude change when it is printed. However, printed media is likely to be the most effective when the message is complex, because the reader can process it at his own pace. Over all, printed messages are preferred because they are easy to construct and can be reproduced with little chance of being unintentionally altered.

Whom: the recipient. Unlike the "hypodermic needle" approach to attitude change that guided research and seemed to mold public opinion in the 1950s, current persuasion theory suggests that humans are not passive and defenseless message recipients who can be injected with a persuasive message that will change their attitudes. As currently conceived, attitude change and persistence are linked to the active participation of the recipient as he elaborates upon the message's arguments and evidence. From this constructivist framework, teachers should not expect unwavering acceptance of the position advocated by a message because students will respond to persuasion in terms of their preexisting perspectives regarding the topic of the message.

With what effect: measurement. Because affective objectives are important, they should be the focus of formal evaluation. Formal evaluation may be carried out most easily with the aid of closed item questionnaires, either obtained or constructed. Using instruments developed by others can save much time and can provide the user with the benefits of the developers' experience. In choosing to use an existing scale, one should check to see if it has been tried and if the audience for which it has been designed matches the intended audience. An existing instrument should also carry some reliability and validity data. Depending on what data are available, pilot testing and modifying the scale may be necessary before it can be used.

If an existing scale cannot be found to meet a particular need then one must be built. Abdel-Gaid and her colleagues (1986) provide a fairly comprehensive report of the step-by-step Likert scale building process. Explicit directions for building scales based upon the theory of reasoned action are presented in Ajzen and Fishbein's (1980) book, *Understanding Attitudes and Predicting Social Behavior.* The development of an attitude scale is no easy task; time and computer access are a must. However, the final product, a reliable and valid attitude scale, will be well worth the time and effort invested.

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Research Matters...To the Science Teacher

USING RESEARCH TO IMPROVE THE QUALITY OF CLASSROOM DISCUSSIONS

By J. Nathan Swift, C. Thomas Gooding, and Patricia R. Swift

Studies conducted by the staff of the Classroom Interaction Research Laboratory at the State University of New York College at Oswego reveal that teachers find it difficult to engage in guided discussions with their students. In many cases, discussions change into drill or lectures, as teachers strive to cover the material. We believe that interactive discussions should occur more often than usual. This idea led us to study ways in which teachers can become more successful discussion leaders and questioners.

At our Laboratory, we listened to hundreds of audio tape recordings of middle school and high school science discussions. We prepared transcripts of these discussions. Careful analyses followed. We classified questions and other teacher-student interactions. Pauses in dialogue were measured. We counted the students' words and, whenever possible, we noted the sex of the students. Many other factors were evaluated in an effort to describe typical interaction patterns and to facilitate the development of increased effectiveness of teacher-led questioning and discussion.

Our first major study was a research project funded by the National Science Foundation, and entitled "Wait Time and Questioning Skills of Middle School Science Teachers" (Swift and Gooding, *Journal of Research in Science Teaching,* 1983, 20, 721-730). The study was designed to determine the effects of allowing longer pauses in the classroom for teachers and students to think and interact. We found that without special training wait time in teacher-student dialogue is short. Pauses average only 1.25 seconds between teachers' questions and replies by students (wait time 1) and only .55 seconds between the students' replies and subsequent comments by teachers (wait time 2).

In the middle school study of thinking time, we asked 40 teachers to tape record a discussion in one of their classes each week for 15 weeks. Most of the interactions were fast-paced drill, review for tests, with emphasis on low-level memory questions, or lectures punctuated by brief questions designed to keep the students alert. Few teacher-student interactions could be classified as discussion or inquiry lessons intended to develop the intellectual processes of students. We found that students typically do not ask questions in classroom discussions, nor are they encouraged to do so. This it seems that, while research has revealed that memory-level drill and lecture are not the best tools for learning, teachers persistently follow these strategies.

We were able to help teachers slow the rapid pace of instruction with the introduction of a wait time feedback device (Wait Timer [TM]) in each of their classrooms. The device consists of voice-activated switches and a variable timer that triggers an amber light. The light is activated when a person is speaking. The light remains on as a signal to allow thinking time to occur. When three seconds elapse, the light goes out, indicating that it is appropriate for another participant to enter the discussion. Introduction of the Wait Timer resulted in changing interactive behavior to include more extensive use of evaluative questions, longer student responses, and improved level of student participation in discussion.

Increasing thinking time to at least three seconds following a high cognitive level question and a quality reply is crucial. That pause helps students extend and enrich their answers. This time also facilitates more effective follow-up questions by the teacher and other students.

A second project was supported by the National Science Foundation. This study entitled "Increasing the Effectiveness of Biology and Chemistry Instruction through Research Applications" enhances the ability of high school biology and chemistry teachers to use effective skills for questioning and discussion. The results of the first phase of this study revealed that even though high school students are developmentally more advanced than middle school students and the content more complex, high school teachers have some of the same difficulties in guiding discussions effectively. Teachers of biology experience greater difficulty in moving beyond the memory level of questioning than chemistry teachers. More of the discussion in the biology courses was at the lowest level of Bloom's taxonomy as redefined for science by Blosser (*Handbook of Effective Questioning Techniques,* 1973, Worthington, OH: Education Associates), whereas the chemistry courses were found to involve a greater proportion of evaluative questions and analytical thinking. Of special interest in regard to this finding is that the high school biology course contains a large technical vocabulary of more than 1,100 terms to be memorized. Chemistry, by contrast, has an analytical focus with lower emphasis on definitions. Teachers of biology may be focusing on memory level learning, at the expense of the analytical and ethical issues that are inherent to the field of biology. In an effort to achieve mastery at the memory level, some of the most exciting and important biology may be omitted.

To help teachers address concerns of a mutual interest to them and to the research laboratory staff, we are developing a Teachers as Researchers Project in selected high schools in central New York. Our goal is to move from the linear model of research and development, with its "top down" approach, to a collaborative model that incorporates classroom teachers in all phases of research from problem definition to evaluation.

Our focus is on the quality of questioning and discussion in the classroom. We have invited teacher researchers to join with us on mutually designed studies on wait time, questioning skills, student and teacher attitudes, and a variety of related topics influencing effective teaching and learning. The science teachers involved in the Teachers as Researchers Project report that the opportunity to participate in the project reduces their sense of isolation and leave them exhilarated and motivated to teach science. Working on shared professional concerns is perceived as vital to their continuing growth as teachers.

The most direct implication for this project, as a facet in the improvement of teaching, is that teachers want and need professional development opportunities. They make sacrifices of time and energy in order to access programs where they are offered partnerships in research on classroom teaching. This approach, wherein the teacher researcher is creatively involved in the selection, design, implementation, analysis, and outcome assessment of research programs, is worthy of further study. We see this as a practical way to move research findings into professional practice.

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Research Matters...To the Science Teacher

USING TEXTBOOKS FOR MEANINGFUL LEARNING IN SCIENCE

By Sarah L. Ulerick

Much of science teaching is guided by and based upon the contents of science textbooks. Gatherings of science educators frequently condemn this practice, as they recommend more and better hands-on science activities in the K-12 curriculum. If we look carefully at classroom practice and textbooks, however, we might ask, "Is it the books themselves that are the problem or is it the manner in which students and teachers use them?" This article presents a rationale and strategies for teachers to facilitate meaningful learning from science textbooks.

Constructing Meaning

Over the past 20 to 30 years, views of how learners acquire knowledge has shifted from behaviorist theories of the 1950s and 60s to a "constructivist" view (e.g., von Glaserfeld, 1981). The constructivist view of knowledge acquisition holds that learning is a process of connecting new knowledge to existing knowledge, involving active engagement of the learner's mind. What we learn from any experience, including the experience of reading, depends upon what we already know and how we choose to "connect" our knowledge with the sensory input we perceive. Said differently, we use what we *already know* to make sense of what we don't.

Reading researchers have acknowledged for some time that reading is a process of active construction of meaning; and, the ideas supporting constructivism are well-documented by research on comprehension of written text (Bransford, 1979; Spiro, 1980). A number of studies have shown how a reader's knowledge interacts with text to influence comprehension, recall, and usefulness of what is read. For example, in a study described in Bransford (1979), readers were given the passage below to read and comprehend. Read the passage and see if you think it is easy to understand.

> The procedure is actually quite simple. First you arrange items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step; otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once then too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one can never tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is a part of life. (Bransford, 1979; p. 134-135; original study by Bransford & Johnson, 1972)

Most readers find this description of a procedure difficult to understand when read without a title. When the title was provided, readers had no difficulty following the paragraph. The title was "Doing the Laundry!"

Why is this non-technical description of a familiar procedure so difficult to make sense of without its title? Most of us have prior knowledge to understand the paragraph, but are unable to use it without the "cue" or "context" which the title provides. If we are reasonably good readers, we probably tried to make sense of the sequence of sentences as we read along; we might have had one or two tentative hypotheses about the topic of the paragraph as we struggled to construct some coherent meaning for ourselves. If we are less persistent and resourceful readers, we might have given up halfway through the paragraph in frustration, concluding that it simply "made no sense."

Now read the following paragraph from a popular high school biology textbook:

> Water enters the mouth, where it passes over the gills on either side of the head. The water is then forced out through separate pairs of gill slits. The gills are respiratory organs of the fish. The shark has large, well-developed eyes on either side of the head above the mouth. Paired nostrils on the ventral side if the head lead to olfactory sacs. These olfactory sacs sense odors in the water. As already mentioned, shark skeletons are made up of cartilage rather than bone.

Unless you have recently taught a unit on "Class Chondrichthyes," you might not have recognized this passage as a description of the respiratory system of the shark. Even when presented in the context of the printed textbook page, this passage is difficult to visualize in any concrete manner. Now, imagine you are a science-indifferent or science-phobic tenth grader with poor-to-average reading skills. How will you make sense of this passage? Even if you want to try, will you have the skills to do so? And why should you struggle to understand the passage to begin with?

Difficulties in Learning from Science Textbooks

The effort a reader puts into comprehending or making sense from text depends on several factors. The reader's purpose in reading is foremost among these. We tend to put more effort into figuring out things we really want to know. Our purpose also prescribes the context for the connections we will make between the information we are reading and what we already know. For example, readers who are told to compare and contrast ideas in a passage tend to read more slowly and to recall ideas in a compare/contrast structure. In many science classes, the traditional approach to using a textbook is to have students read a chapter and answer questions typically found at the end of the chapter. The questions tend to be low in cognitive level, inviting a search-and-find learning strategy (Stake & Easley, 1978; Tobin & Gallagher, 1987). Since answering these questions is their only purpose, students tend to engage at a very low cognitive level. Therefore, we should hardly be surprised that many students fail in the difficult task of making meaning from science prose.

The shallow purpose students are given for reading presents the first of several difficulties students have in learning from science textbooks. The low cognitive demands of such assignments discourage students from actively making meaningful connections to their existing knowledge and from actively monitoring their comprehension. When difficult passages are encountered, many students simply skip them, rather than undertake the effort to sort out a meaning for themselves.

Second, most science textbooks (particularly middle and secondary level books) are written in an impersonal, seemingly objective tone, which ignores the readers' needs. The style seldom offers invitations to the reader to access or "check-in with" his or her prior knowledge about a topic. Textbook authors write as if the reader has as much prior knowledge as they do; and, they assume that readers are familiar with the style and structure of expository writing.

A third problem in learning from science textbooks is that many do a poor job of making connections clear between ideas within the text. One of the unfortunate casualties of applying readability formulas to science writing is that many of the linking connections, such as "because," or "therefore," are removed in the interest of creating shorter sentences. Long, technical words are used only once to keep the word-length count down, when using them repeatedly might allow students to understand the terms through their contexts of usage (Schallert & Tierney, 1982). The abundance of technical words in science textbooks adds to the problem of identifying key ideas and their interconnections.

Lastly, successful comprehension also depends on the relevant prior knowledge a reader has. This includes knowledge about the topic of the text and about the conventions of writing. Good readers appear to utilize their knowledge of text and purpose and to monitor comprehension in an almost automatic fashion; poor readers are unaware or uninformed of the knowledge they need and often are lacking in metacognitive skills as well (Brown, Campione, & Day, 1981).

Alternate Ways to Use and Learn from Science Textbooks

Given the difficulties outlined above, the reactionary stance has been "Don't use textbooks in science." This stance, however, seems to "throw the baby out with the bathwater." If we want our students to be scientifically literate, surely they should be able to learn about science issues through reading critically about them. Also, we should remember that the "standard" list of science process skills is only a partial list of what scientists actually do. Scientists read and learn from their reading. Like scientists, students can obtain useful knowledge from textbooks.

In order to get students to learn from their textbooks in more meaningful ways and to use their textbooks in more resourceful ways, we, as teachers, need to examine our beliefs about the role of the textbook in our teaching. Are we being overly-dependent on the contents of the text in our science teaching? Or, do we see the textbook as only one of many resources we can provide our students? Are we emphasizing learning about the products of science; or, does our teaching emphasize the processes of science and how science knowledge is created? How we view the role of the textbook strongly affects the way our students will perceive the textbook and the nature of science. In using textbooks, we should assist students to view them as resources, as opposed to "sole sources" for knowledge in science; and we should assist our students to become more active and constructive readers of science prose.

Meaningful purposes for reading. The most powerful strategy we, as teachers, can implement is to provide our students more meaningful purposes for reading; and more meaningful texts to read (Schallert & Roser, in press). If we reflect on the purposes scientists have for reading, we can discover other uses for textbooks to promote meaningful learning. Scientists read to (1) obtain background or explanatory information for a project; (2) obtain data that other scientists have already published; and (3) to challenge their own ideas with new viewpoints. In essence, they read because they have questions which can be answered by reading. The questions tend to be purposeful and research or project related.

The key to providing meaningful purposes for reading is to have the students determine their own purposes for reading. Have students generate *their own questions* to answer using the textbook, or other resources. Meaningful questions can arise when students conduct hands-on experiences *prior* to reading relevant portions of their textbook. During the hands-on activity, students are told to record all questions that arise. The questions are categorized into those that need more experimentation to answer, and those that could be answered through reading. Students use their books to find answers to their own questions. In this way, the textbook becomes a resource, in the way that you, as a teacher, probably use your own books.

You can probably think of strategies in which one or more textbooks can be used as data resources. A useful practice is to have students use several texts to gather information. In doing so, they learn that authors present information differently; and, even established "facts" will vary from book to book. Learning can occur as students argue about and discuss variances they have found.

There are other opportunities for creating meaningful purposes in reading textbooks. For example, you can help students to identify a conclusion that the textbook author has drawn. Students are then directed to look back in the text and assemble the evidence the author has presented for the conclusion. Students can evaluate the conclusion both in terms of the evidence presented and the outcomes of hands-on experiments performed in class. Similar conclusions in other textbooks can be analyzed for evidence presented there. Here, students have an analytical purpose in reading. The strategies given here can also be used in reading scientific articles. By using a number of text resources in your class, you demonstrate to students that science information does not "live" in one textbook, but can be gained from many different books and viewpoints.

Understanding science prose. Strategies to assist readers to understand expository prose involve identifying key topics or ideas and the relationships among them. Traditional outlining of a chapter generally fails to identify the nature of the relationships among ideas. Graphic strategies, such as networking, relational mapping, schematizing (Holley & Dansereau, 1984; Mayer, 1987) and concept mapping (Novak & Gowin, 1984), assist the reader to show in a "web" or interconnected visual form how key ideas are related to one another. These techniques are easy to learn with practice, and assist students in recognizing the connections among ideas in texts.

Students' personal "maps" of ideas can be related to text readings. Prior to reading, students can map their understanding of how concepts (preferably those they come up with) are related to a particular topic. As they read, they can add to their map or revise it, in light of the information presented. Or they can make a map of the reading and compare it to their own.

Strategies for metacognition. Metacognition refers to how we know or think about our thinking or comprehension processes. Good readers tend to know when they are having difficulty comprehending a text, and they automatically put in extra time and effort to "untangle" the difficult prose. Readers who do not automatically monitor their comprehension can practice strategies to do so. Any process that involves checking one's understanding is a metacognitive strategy.

The graphic learning strategies described above are metacognitive strategies because they encourage students to assess their understanding. As students work to identify key ideas and relationships they are engaged in thinking about what they are reading. Another strategy is to read and summarize, paragraph by paragraph or section by section. Have pairs of students read together and discuss each section they read. The students would need to agree on their understanding of the section. Their consensus can be written out, to create a summary of the reading. Students in pairs can also write questions for each other about particular sections, taking turns asking and answering the questions.

Still another metacognitive strategy is to give students a "checklist for comprehension" to accompany their reading assignments. The checklist might be as simple as a 5-point "comprehension" rating scale, which is checked for each paragraph read. Paragraphs which are rated low in comprehensibility by an individual student can be involved in further class discussion or in individual assistance.

All of these suggested strategies are intended to assist students to pay attention to their comprehension. Learning to monitor breakdowns in comprehension is a necessary step toward the goal of learning more effectively from a textbook (Brown, Campione, & Day, 1981).

Summary and Conclusions

Textbooks have a role to play in science learning, although that role is vastly different from the traditional role. This piont is critical. The traditional student-reads-textbook interactions, if left unchanged, will probably not result in meaningful learning. However, if teachers mediate the interaction of students and texts with strategies for meaningful learning, the interaction can be productive. As teachers, we can provide meaningful purposes for reading, we can assist our students to understand the complexities of science prose, and we can provide strategies for metacognition. All of these interventions call upon students to engage in learning from texts at a much high cognition level than has been the case. We should not be surprised if students initially resist our "invitations to think." We should expect that they must think in order to learn meaningfully.

For further information on this topic, contact Dr. Joseph D. Novak, Department of Science and Mathematics Education, Cornell University, 404 Roberts Hall, Ithaca, New York 14853-5901.

AAAS Publication Announcement

The *AAAS Science Education Directory 1989*, a resource for anyone who is involved in science, mathematics, or technology education, is now available. The *Directory* lists key persons in the nation who are responsible for science, mathematics, and technology education. It contains addresses and telephone numbers of principal executives, directors, administrators, and policy-makers who are leaders in associations, scientific academies, museums, educational research centers, educational laboratories, and state and federal government agencies. The *Directory* also provides information about the major science and mathematics education activities of these organizations. Some 1700 individuals, programs, and organizations are included.

The 1989 edition has been revised and expanded. A new section has been added that lists more than thirty national educational organizations with interests in science, mathematics, and technology education. The "Resources" section includes many new listings of programs and activities for students and teachers. This section contains a variety of information that should be useful to teachers, university educators, community organizations, and others who work on specific programs to strengthen science, mathematics, and technology education. In addition to the state supervisors of mathematics and science, the 1989 edition includes the names and addresses of the specialists in social studies. Key Congressional committees responsible for science education funding and their members, reflecting the latest changes in the new administration, are listed, too.

A detailed table of contents and four indices help readers quickly information.

For a free copy of the 180-page *AAAS Science Education Directory 1989*, write to Barbara Walthall, AAAS, Office of Science and Technology Education, 1333 H Street, NW, Room 1139, Washington, DC 20005

NARST Monographs Available

A Theory of Instruction: Using the Learning Cycle to Teach Science Concepts and Thinking Skills, A. Lawson, M. Abraham, and J. Renner, $6US

Learning Environment Research in Science Classrooms: Past Progress and Future Prospects, B. Fraser, $6US

Send orders with check payable to NARST to Glenn C. Markle, NARST Executive Secretary, College of Education, University of Cincinnati, Cincinnati, OH 45221-0002

SPECIAL OFFER FROM NSTA

The National Science Teachers Association has published *A Practical Guide to Modern Methods of Meta-Analysis* by Larry V. Hodges, James A. Shymanski, and George Woodworth. The list price for this book is $9.50. As a member of NARST, you can purchase the meta-analysis guide at the special price of $8.55, if your order is submitted on the following order form. All orders should be mailed to Dr. Glenn Markle, Executive Secretary, NARST, University of Cincinnati, Cincinnati, OH 45221-0002. Enclose a check or money order payable in **US funds** to NARST.

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The National Association for Research in Science Teaching seeks to improve Science Education through research. To this end the Association desires to recognize individuals who have made significant contributions to Science Education through research. Contributions may be of several types, including but not limited to empirical, philosophical or historical research, evaluative studies, policy-related research and studies reflecting new techniques to be applied in research. To be considered for this award an individual should have contributed over a period of at least 15 years and should be at the pinnacle or his or her career.

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