DOCUMENT RESUME

ED 272 377 SE 046 868

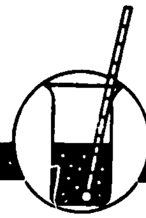
AUTHOR	Sealey, Jean
TITLE	Instructional Strategies. R & D Interpretation Service Bulletin. Science.
INSTITUTION	Appalachia Educational Lab., Charleston, W. Va.
SPONS AGENCY	National Inst. of Education (ED), Washington, DC.
PUB DATE	85
NOTE	8p.
AVAILABLE FROM	Appalachia Educational Laboratory, 1031 Quarrier Street, P.O. Box 1348, Charleston, WV 25325.
PUB TYPE	Reports - General (140) -- Collected Works - Serials (022)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Classroom Techniques; Elementary Secondary Education; Instructional Improvement; Instructional Systems; *Learning Strategies; Mastery Learning; Science Education; *Science Instruction; *Scientific Literacy; *Teaching Methods
IDENTIFIERS	Science Education Research; *Set Induction Techniques; *Wait Time

ABSTRACT

A recognized correlate of student success in science classes is the use of teaching strategies that are learner-centered and goal-oriented. Research has shown that several practices in particular are associated with increased student achievement and with developing scientifically literate students. The focus of this paper is on scientific literacy and some of the instructional strategies that have produced gains in students' achievements. Findings are presented related to: (1) current practices (citing the descrepancy between research suggestions and actual practice); (2) effective instructional systems (explaining mastery learning and the personalized systems of instruction); (3) effective instructional strategies (highlighting the benefits associated with the use of preinstructional strategies, focusing, questioning, wait time, manipulatives, altered materials, and testing); (4) new directions (enumerating conditions that promote scientific literacy); (5) effective science teachers (offering suggestions for improved teaching); and (6) scientific literacy (identifying the characteristics of a scientifically literate person). Also included are separate and expanded descriptions of the procedures and merits of set induction and wait time. (ML)

Instructional Strategies

Joan Sealey



QUESTION: *Are there methods and instructional strategies that are more effective than what teachers currently use? What can teachers do to increase their effectiveness in the science classroom?*

OVERVIEW

A known correlate of student success in science classes is the use of teaching strategies that are learner-centered and goal-oriented. Research has shown that several practices in particular are associated with increased student achievement and with developing scientifically literate students. This paper talks about scientific literacy and some of the strategies that have produced gains in students' achievement. The use of effective instructional strategies and the ability to relate content to other aspects of students' lives characterize the effective science classroom. More information on science education can be obtained from the R & D Interpretation Service *Research Within Reach* publication, *Science Education* (2). The numbers in parentheses correspond to references at the end of the article.

A science classroom differs from other subject area classes in physical appearance. The beakers, test tubes, bunsen burners, microscopes, and other laboratory apparatus are visible evidence of the nature of science. It is more than physical appearance, though, that distinguishes effective science classrooms from less effective ones. Teachers in effective science classrooms use strategies that are learner-centered. In an effective classroom you will see a greater emphasis on laboratory exercises; on student-led seminars, discussions, and demonstrations; and on independent study projects. You will see less time devoted to teacher-led lectures, demonstrations, and recitations.

Effective science classrooms prepare students for more than continued study of science. In a scientific, technological society, the general public needs to be scientifically literate. A certain level of scientific literacy is critical for the functioning of the individual and for the continuation of such a society.

Developing scientifically literate students demands more than explaining content or covering a specified number of topics. Students must be shown how the content of science — textbook information — relates to the broader aspects of science and society. Students must be shown how concepts, tools, and practice of the scientific method relate to content and to their own lives. They must be shown how scientific ideas and advances affect society in general, and themselves in particular. Nuclear power, the arms race, environmental responsibility, world hunger — all are topics of concern to individuals and to society. All include the content of science, and all must be related to the broader aspects of science.

CURRENT PRACTICES

ON THE ONE HAND WE have research and expert opinion that tell teachers what they need to do to teach science effectively. On the other hand, we have observations of actual teaching practices that tell us what teachers are doing. In the majority of cases, teachers in science classrooms are *not* using the most effective strategies, nor are they relating content to broader aspects of science. It's not that teachers don't read research journals or experts' opinions. Many do. Many teachers even report that they use the recommended strategies (1). But we can't ignore the evidence. Time and again, in study after study, teachers are observed doing things that merely

R & D Interpretation Service

AEL
Appalachia Educational Laboratory
1031 Quarrier Street/P. O. Box 1348
Charleston, West Virginia 25325
304/347-0445

National Institute of Education

U.S. Department of Education
Washington, D.C. 20202

NIE

increase students' scientific vocabularies (1, 3) Students may do well on norm-referenced tests, but they don't know how to apply what they have learned They don't know how what they have learned relates to their lives.

This bulletin was introduced with two questions. The first one, "Are there methods and instructional strategies that are more effective than what teachers currently use?" is easy to answer. Yes! Yes, you can affect changes in students' science achievement and students' attitudes toward science. The second question, "What can teachers do to increase their effectiveness in the science classroom?" can also be answered from the research. In this bulletin we briefly describe some instructional systems and strategies that research has shown to be effective in science classrooms. Here we emphasize your role in developing scientifically literate citizens of tomorrow's world

EFFECTIVE INSTRUCTIONAL SYSTEMS

THE INSTRUCTIONAL SYSTEM IS A framework within which teachers teach. It holds together the various combinations of strategies that teachers use. Some instructional systems have been around for a long time. You are no doubt already familiar with team-teaching, programmed learning, individualized instruction, contract learning, and audio-tutorial systems. In fact, you may have taught within one of these frameworks.

There are two newer instructional systems that stand out from the others in their effectiveness. Mastery learning and the personalized system of instruction (PSI) have consistently been found to be more effective when compared to other instructional systems and the more conventional systems they replaced.

The personalized system of instruction was originally designed for college-level students. Learning materials are divided into small modules, each of which must be mastered before going on to the next. The student sets the pace. Students grade the work and tutor each other. Printed materials are the primary form of communication, and a detailed study guide is provided. Frequent testing with immediate feedback is a key factor to the success of the system. This feature, testing with feedback, is also a characteristic of mastery learning.

Mastery learning is essentially a technique for teaching and for learning hierarchical, sequential material. In science classrooms using a mastery learning approach, the material is subdivided into natural units or steps, covering from one day's lesson to several weeks' lessons. Student performance is specified, and a mastery level, usually 80%, is determined. The science units are taught using group instruction, laboratories, and the other usual activities that occur in science instruction. Students get help when and where they need it through frequent diagnostic testing Students are given feedback accompanied by remediation, if required Remediation may be either teacher- or student-managed Additional time is provided for students to learn material they missed or did not learn the first time through the unit The diagnostic-remediation cycle — testing, followed by specific recommendations for improvement and additional time if needed — is the single most important feature of the mastery learning approach

EFFECTIVE INSTRUCTIONAL STRATEGIES

WITHIN THE LARGER FRAMEWORK OF THE instructional system, the variety of instructional strategies that teachers use can be categorized several ways. If the teacher directly controls instruction, we call the strategies teacher-centered. Examples include lectures, demonstrations, teacher-led discussions, and questioning. Student-centered strategies, on the other hand, allow students t play a more active or self-guided role. Common examples are laboratory activities, use of learning activity packets, and student-planned activities

Instructional strategies may also be classified as direct (or deductive) or as indirect (inductive), each encompassing both aspects of student and teacher-centered instruction. With direct teacher-centered strategies, science is communicated by the teacher to the student. The teacher is in control. With indirect teacher-centered strategies, the teacher facilitates, guides, or acts as a catalyst. Science is communicated through the materials to the student Direct student-centered activities allow the student to learn directly through hands-on experiences, such as laboratory experiments. Indirect student-centered activities give the opportunity to learn from the materials with a minimum of teacher involvement For example, students select a topic and design and carryout a project for independent study. Different strategies may require shifting role relationships and responsibilities for both teachers and students

Researchers have identified several specific instructional strategies that are part of an effective science classroom.

- Preinstructional strategies take several forms. Advance organizers allow the teacher to anchor what is to be learned to what is already known. Advance organizers may be diagrams or a question at the beginning of the lesson. An understanding of conservation of mass and energy can be called upon

TYPES OF INSTRUCTION

Classification:	Teacher-Centered	Student-Centered
Direct	Lecture	Laboratory
	Demonstration	Reading Text
	Discussions	Learning Activity Packets
	Questions	Writing Reports
Indirect	Preinstructional Strategies/Focusing	Games
	Questions/Wait-time	Manipulatives
	Altered Materials	Independent Study
	Diagnostic Testing	Instruction Modules

to make fission, fusion, and breeder reactions more meaningful. Similarly, food chains can be linked to other cycles that students have studied in, for example, history classes. Advance organizers relate the unfamiliar to the familiar. Set induction is another form of preinstructional strategies. The teacher reviews a familiar concept. A similar, but usually more complex or sophisticated, concept is introduced. The teacher's objective is to help students discover the new concept for themselves by reviewing the familiar one. (See the insert for examples of set induction.)

•Focusing techniques are also highly effective strategies. Before, during, and after instruction, students are told the objectives or intent of instruction. This helps to direct their attention to what is to be learned (2). General examples of focusing include using advance organizers, providing students with objectives, and reinforcing objectives at various points during instruction.

•Questioning techniques can be altered to improve learning in an effective science classroom. By varying the levels of intellectual activity required by questions asked or the positions of questions asked during instruction, teachers can help increase student achievement. Teachers might ask more questions requiring comprehension, application, or analysis skills instead of relying solely on knowledge-level questions. Or, teachers may ask questions during films, or before, during, or after assigned reading. Questioning is a deliberate attempt to involve students in the instructional process and helps call attention to significant facts or concepts.

•Wait-time is a component of questioning strategies that has been shown to affect science learning significantly. Wait-time is the time between when the teacher asks a question and the student answers and again after the students gives a response. When teachers increase wait-time by 3-seconds, the length of student responses increases, the failure to respond decreases, the incidence of speculative thinking increases, student-to-student interactions increase, and more questions are asked by students (4). Researchers have found that wait-time strategies significantly increase cognitive outcomes, critical thinking, creatively logical thinking, and affective measures. (Our insert has more information on the benefits of wait-time increases.)

•Manipulative activities require students to handle, operate, work, or practice with physical objects as part of the instructional process. Being involved with concrete objects is much more effective in producing gains in achievement than having students observe someone else performing an experiment, or merely reading about it. Manipulatives are more concrete than pictures; pictures are more concrete than printed text material. A student's lab experiment is more concrete than a teacher's demonstration, and the teacher demonstration is more concrete than a lecture. Research has shown that greater concreteness in supporting instructional materials leads to greater cognitive achievement. Teachers who use manipulatives, pictures, or hands-on experiences in appropriate instructional situations will be more effective in promoting cognitive achievement than those who do not. In an effective science classroom, students interact physically with in materials whenever possible through handling, operating, or practicing. Teachers provide greater realism or concreteness with their choice of materials. Teachers make greater efforts to include manipulatives and pictures along with the text and other printed materials.

•Altering materials and procedures to increase their impact is characteristic of teachers in effective science classrooms. For example, teachers may rewrite materials for clarity or reading level. They may present directions in other than written forms. They may provide alternative reading materials for those students who have reading difficulty. Some students will need more information than the textbook contains. Teachers may provide more challenging reading materials and project activities for these students. Teachers may also modify sequencing, testing, grouping, and how content is presented to accommodate all ability levels and to increase achievement.

•Testing, too, is related to improved achievement. Specifically, the frequency of testing, the purpose of testing, and the level of test items can all be modified. Examples of effective testing are formative testing, immediate or explanatory feedback, diagnostic testing and remediation, optional testing, and testing to mastery.

NEW DIRECTIONS

THE RESEARCH ON SCIENCE EDUCATION points to new directions for teachers. Specifically, teachers assume much of the responsibility for promoting scientific literacy. To fulfill that responsibility, you are urged to increase the effectiveness of your teaching by striving toward the following understandings and conditions:

1. Relate science to relevant settings by providing experiences with science-related social problems and issues.
2. Give students practice in problem-solving strategies.
3. Be conscious of instilling career awareness in the curriculum to show students their options in our scientific and technological society.
4. Go beyond the textbook into the local community to make science relevant to students.
5. Give students frequent opportunities to apply science to their own lives and the life of the community.
6. Teach students to resolve problems through cooperative efforts on real problems.
7. Broaden students' view of science by placing an emphasis on the multiple dimensions of science.
8. Evaluate students' ability to obtain and use information (5).

EFFECTIVE SCIENCE TEACHERS

WE'VE TALKED A LOT ABOUT THE effective science classroom. Throughout our discussion, we have focused on ways to make science more meaningful to students and to increase students' science achievement by using research-tested strategies. It is the teacher's responsibility to make the science classroom an effective one.

Do you want students to leave your science classroom with an increase in factual knowledge only? Do you want them to leave with less interest in science than when they entered your classroom? Current practices in science classrooms are turning out hundreds of such students each year.

We believe most teachers want more. Most teachers want students' excitement about science to grow, not diminish. As a teacher, you enjoy watching students develop confidence in using their new skills. You want to share their pride as they discover new concepts. You want students who can apply what you've taught them to their own needs and to the needs of society. You want students to leave your classroom on the road to scientific literacy.

If you're satisfied with current practices in science classrooms and with the students coming out of them, yours is an easy task. Rely exclusively on your textbook, don't include laboratory sessions or demonstrations, and lecture without asking questions or encouraging student participation. You won't need to read about current research. You won't need this bulletin. This bulletin is directed to those of you — the majority of teachers — who want more and are willing to work for it. You are the teachers who are aware of the limitations of textbooks, are uncomfortable with having to cover a certain number of topics in a short period of time, and are asking for more resources and information about science education. You recognize the problem. You've probably even tried one or two recommended strategies. Without a framework and a better understanding of the goals of scientific literacy, however, isolated strategies will have disappointing results.

Not all of the problems facing science teachers can be resolved by the teachers alone. Finding time to set up and carry out experiments and demonstrations is a problem that requires the cooperation of other teachers and the school administrators. But it can be done with some relatively simple schedule changes.

SCIENTIFIC LITERACY

Victor Showalter and his colleagues define the scientifically literate person as one who

1. understands the nature of scientific knowledge;
2. applies appropriate science concepts, principles, laws, and theories in interacting with his universe;
3. uses the processes of science in solving problems, making decisions, and furthering his own understanding of the universe;
4. interacts with the various aspects of his universe in a way that is consistent with the values that underlie science;
5. understands and appreciates the joint enterprise of science and technology and the interrelationships of these with each other and with other aspects of society;
6. has developed a richer, more satisfying, and more exciting view of the universe as a result of his science education and continues to extend this education thoughout his life; and
7. has developed numerous manipulative skills associated with science and technology (4).

One school solved the problem by scheduling two-hour chemistry and English classes on alternating days (2). On Monday and Wednesday, for example, students have two hours of chemistry, and on Tuesday and Thursday, they have two hours of English. On Friday, they have one hour each. The extra time allows the chemistry teacher to conduct laboratory sessions. The English teacher also benefits. The double periods give time for extended activities in both subjects.

Whether or not you can bring about schedule changes, you can change your instructional strategies. You can extend the content of the science textbook so that is relates to students and to society. You can use more student-centered approaches to learning. You can modify your presentation and the sequencing of content to increase achievement. You can ask more questions that require students to show they comprehend, can apply, and can analyze what they have learned. You can also give students more time to respond to questions and then wait longer before acting on a student's response.

SUMMARY

AN EFFECTIVE SCIENCE CLASSROOM differs from other science classrooms in teaching strategies more than in physical appearance. Teachers in effective science classes use more student-centered approaches to learning. They relate science content to the tools and practices of science, and they relate content to the impact of science on the individual and on society.

Research in science education challenges you, the science teacher, with the encouraging news that what you do makes a difference in student achievement. You don't have to invest in expensive laboratory equipment to incorporate the techniques we've described here. All that may be required is a change of emphasis from teacher-directed activities, such as lectures, to student-centered activities, such as laboratory experiments. We're not suggesting that because the activities are student-centered you will spend less time. In fact, most of the strategies discussed above require more preparation time. We believe, though, the rewards will be rich as you see increased student interest and achievement.

REFERENCES

1. Goodlad, J. (1984). *A place called school: Prospects for the future*. New York: McGraw-Hill Book Company.
2. Holdzkom, D., & Lutz, P. B., (Eds.) (1984). *Research within reach: Science education*. Charleston, WV: Research and Development Interpretation Service, Appalachia Educational Laboratory.
3. Mitman, A., Lash, A., & Guthrie, L. (1985). Three studies on science and math at Far West Laboratory. *Resources and Practices*, *3*(5), 1-4.
4. Simpson, R. D., & Anderson, N. D. (1981). *Science, students, and schools: A guide for the middle and secondary school teacher*. New York: John Wiley & Sons.
5. Yager, R. E., & Lunetta, V. N. (1984). New foci for science teacher education. *Journal of Teacher Education*, *35*(6), 37-42.

Sponsored by the National Institute of Education

The Appalachia Educational Laboratory, Inc (AEL) is a private, nonprofit corporation created to improve education and educational opportunity for those who live in its Region Through its R & D Interpretation Service, AEL transforms existing R & D outcomes into products for use by school personnel The *Research Within Reach* books and bulletins developed by the R & D Interpretation Service answer specific questions about teaching and learning asked by educators with research-based information

AEL's primary source of funding is the National Institute of Education (NIE), U S Department of Education The work upon which this publication is based was performed pursuant to Contract No 400-83-0001-P7 Dissemination of this publication was approved by the U S Department of Education's Publication and Audiovisual Advisory Council (PAVAC) The contents herein do not necessarily reflect NIE, AEL, or any government agency policies or views

AEL is an Equal Opportunity/Affirmative Action Employer.

We invite you to contact us for additional information about the *Research Within Reach* publications or about any of the topics presented in this series. We encourage you to duplicate, distribute, and use these materials. We welcome your comments about the usefulness of the information you receive. Let us hear from you!

SCIENCE INSTRUCTIONAL STRATEGIES
Set Induction and Wait-Time

Set Induction

Set induction, as defined and elaborated by Robert Schuck, is a teaching strategy that relates new information to familiar information (2). The object of using set induction is to allow students the opportunity to discover the new concepts for themselves.

To explain photosynthesis, for example, a teacher first reviews the process of milk production. A cow eats grass and drinks water. The cow's body produces milk. It is a familiar concept and one that students already know. By reviewing the familiar, the teacher has established a set, or a "predisposition to think in similar terms" (3). The set allows students to discover similarities in the way green plants make food.

Let's look at some examples of set induction in practice:

Orientation. The teacher begins the lesson by showing the students a model railroad car. The demonstration is intended to lead into a discussion of the role of the hemoglobin molecule in respiration.

Transition. The teacher draws an analogy between the red blood cell and the railroad car. The red blood cell takes on and carries an important raw material (oxygen) to the body cells, where it plays a key role in the oxidation process.

Operation. The teacher explains that the function of the heme molecule in hemoglobin. He tells students that the iron atoms bond to the oxygen. These bonded atoms are carried in the blood cells to the living cells. When these molecules arrive at the cell membrane, they are released. The oxygen is transported to the cells, and carbon dioxide is then transported to the cells in the lung tissue. From there, the carbon dioxide is expelled from the body. The heme molecules function like a railroad car: they take raw material to the cells and take away waste products.

Evaluation. The teacher looks for evidence of student comprehension. He asks questions about the chemical bonding, the oxidation process, etc. The teacher may go on to related material — the role of red blood counts, anemia and its affect upon the human body, or the reasons for ingesting iron — depending on the instructional objectives and on the nature and level of students in the class.

Another example of set induction would be to relate the role of cells as the basic unit of structure of living things to the organization of a book. You could begin by explaining how books are (usually) self-contained units of information. Books are arranged by chapters. Such organization permits ideas to be conveyed more clearly. Within each chapter, there is even more organization. Paragraphs are the units of organization within the chapter, each paragraph containing a main idea or concept. Paragraphs can be broken into smaller units, the sentence. Certain words are critical to the sentence. If these critical words are removed, the sentence no longer conveys its original meaning. Example: John wants a candy bar. If we remove the word "wants," we no longer have a complete thought.

Once the set has been established, you can draw the analogy between a human being and a book. A human being is a unique combination of inherited and acquired characteristics, just as a book is a complete unit of essential information. Each human is organized, with systems that provide nutrition, exchange gasses, transport materials, and regulate body processes. The book's chapters present specific information; the body's systems perform specific functions. The systems each are made up of specialized organs and tissues that function together as a unit like a paragraph functions to convey a major concept. Similar to the words in a book, all living matter is made up of individual cells. If certain parts of the cell are removed, the cell no longer functions. Example: If the nucleus is removed from most cells, the the cell will not function properly and will eventually die.

We have reason to believe that set induction is a powerful instructional tool. It anchors new information on knowledge the student already has. It is supported by research findings and learning theory. We suggest you develop appropriate analogies relating new concepts to familiar ones and try set induction in your science classroom.

Wait-Time

Questions from students and from teachers are natural in a science classroom. Questions from students indicate their interest and curiosity. Questions from teachers are designed to stimulate interest, focus attention, evaluate knowledge, and make students think. There are some deliberate questioning techniques that improve their effectiveness. But here we want to talk about the *time* between your question and a student's response and about the time between the student's answer and your reaction. So that you will have a fuller appreciation of the amount of time we're talking about, try this exercise. Close your eyes and count off five seconds. Five seconds is not very long. Or is it?

Mary Budd Rowe, a science educator at the University of Florida, studied teacher-student interactions over a six-year period and reports some interesting findings. Rowe found that the average time teachers wait between asking a question and taking further action to elicit a response is only one second When a student responds, teachers wait, on the average, less than a second before reacting to the response Rowe calls these two time periods — the period between asking the question and acting further, and the period between the student's response and the teacher's reaction — wait-time. By manipulating wait-time, specifically by extending it to 3-5 seconds, she observed some amazing changes in both student and teacher behaviors. In one study, Rowe reported an increase of 300% in the length of students explanations (1). Think about it. Students' science-related language production increased 300% when teachers waited 3-5 seconds after asking a question.

Extended wait-time produced the following changes in students:

1 Response length increased.

2. Spontaneous, appropriate responses increased

3 Fewer students failed to respond.

4 Students appeared to have more confidence

5. Student-to-student comparisons of data increased.

6. Students exhibited more speculative thinking; they made more inferences.

7 Students asked more questions.

8. Students proposed more investigations.

9 Lower achieving students contributed more

10. Students varied their responses more (3)

Teachers' behavior changed, too.

1. Teachers showed more flexibility in accepting student response.

2. Teachers asked fewer questions; they asked an average of two to three questions per minute instead of from seven to ten.

3. Teachers asked more probing questions and fewer closed or informational questions

4. Teachers expected higher levels of performance from lower achieving students (3).

Can you afford to give students an additional 2-4 seconds to respond to questions? Can you afford to wait a few seconds more when they have responded initially? Can you afford not to? Research shows that the benefits gained are well worth the investment

REFERENCES

1 Rowe, M. B (1983). Science education A framework for decision-makers *Daedalus*, *112*(2), 123-142

2 Schuck, R. F. (1985) An empirical analysis of the power of set induction and systematic questioning as instructional strategies. *Journal of Teacher Education*, *36*(2).

3 Simpson, R. D, & Anderson, N D (1981) *Science, students, and schools: A guide for the middle and secondary school teacher* New York: John Wiley & Sons