DOCUMENT RESUME

ED 069 482 SE 014 959

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TITLE	Science Education News, October 1972, Educational Research and Development.
INSTITUTION	American Association for the Advancement of Science, Washington, D.C.
PUB DATE	Oct 72
NOTE	8p.
AVAILABLE FROM	AAAS, 1515 Massachusetts Avenue, N. W., Washington, D. C. 20005
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Curriculum Development; *Educational Research; *Newsletters; Research and Development Centers; Research Projects; *Science Education

ABSTRACT

This issue of "Science Education News" is concerned with Educational Research and Development (R and D). The initial article, "Efforts of Laboratories and Centers," presents a brief historical sketch of the growth and development of the various R and D Centers in the United States. Other topical headings include: "Product Information Available," "R and D Institutions Share Interests," "Teachers Learn to Teach Science," and "Developers Discuss R and D Process." (LK)

SCIENCE EDUCATION NEWS

American Association for the Advancement of Science

October 1972

Educational Research and Development

Efforts of Laboratories and Centers

Eight years ago an attempt was begun to systematize educational research and development by conducting it within institutional settings.

The notion was practical. Much of what had been called educational research up to that time was conducted piecemeal on university campuses. Research, even when noteworthy, seldom resulted in classroom improvement.

Consequently, following task-force reports and considerable planning, Congress in 1964 appropriated funds to establish the first of several university-based educational research and development centers. The centers were charged by the U.S. Office of Education to bring together recognized scholars from a variety of disciplines so that their combined talents could be channeled to research and to respond to identifiable educational problems.

In 1965 a host of complementary institutions, known as regional educational laboratories, was established. These institutions were expected to use existing knowledge and established practice to develop improved materials and procedures for the immediate assistance of schools.

Shortly after the inception of the centers and laboratories, it became apparent that the simple act of establishing institutions to attack problems didn't just as simply result in solutions.

The research and development centers, for example, learned that educational problems were more complicated than many had realized. The laboratories, meanwhile, found that few solutions existed for them to capitalize on for the benefit of educators in their region.

Other needles jabbed at the bubble of optimism that encased the institutions. A war that wouldn't end caused a switch in national priorities, which resulted in a cutback in educational spending. Forced to respond, the Office of Education closed several of its centers and laboratories.

Today, the twenty-one institutions that remain—ten research and development centers and eleven regional laboratories—are lean but productive. Last year, for example, in a national competition to select the most promising new educational products, eight of the nine chosen came from centers and laboratories.

Originally, most of the operating funds of the centers and laboratories resulted from provisions of either the Cooperative Research Act of 1963, as amended by Title IV of the Elementary and Secondary Education Act of 1965, or the Vocational Education Act of 1963 and its 1968 amendments. Now most institutions will rely for support on the newly created National Institute of Education within the Department of Health, Education, and Welfare.

The products of the institutions cover the gauntlet of educational needs. Included are simple manipulative devices for preschoolers; extensive science curricula for elementary school children; vocational guidance material for high school students; and management systems for higher education institutions. Some are self-instructional paperbacks while others include multimedia materials that require extensive teacher training.

What makes the products noteworthy and the institutions successful is the research and development process they employ.

The research is conducted at the university-based R & D centers. Although the centers do produce products for direct use within classrooms, the emphasis is on conducting programmatic research, both basic and applied. The outcomes of such work can be described as knowledge products.

For example, the R & D center at the University of Wisconsin invested heavily in both basic and applied research before beginning the development of a reading

Dr. E. Joseph Schneider is Executive Director of the Information Office for Members of the Council for Educational Development and Research, Inc. When it was decided to devote this issue of *Science Education News* to educational research and development, the assistance of Dr. Schneider was sought. He prepared the lead article and solicited the other contributions. He can properly be called the special editor of this issue of *Science Education News*.

program. The program, Prereading Skills, attempts to prevent reading failure in children by identifying and overcoming deficiencies in their prereading skills at the preschool or kindergarten level.

The researchers first identified the skills needed by children to read successfully. Eventually, the research team identified certain visual and auditory skills that related directly to learning and correlated with reading success.[1]

But the researchers then had to apply their newly learned knowledge and to design ways of determining whether or not a child had achieved the skills.

Two research reports (Fall 1970 and February 1971) described the results of two versions of the Wisconsin Basic Prereading Skill Test.

Today, long into the developmental cycle, instructional packages, complete with games, songs, and related activities, help students learn the skills necessary for learning and reading. The center staff also has produced assessment procedures and a handbook for use by the teacher. Following extensive field-testing of the packages this school year, the materials will be revised and then made available for commercial dissemination.

This development cycle of basic research and applied research characterizes much of the work underway within the centers. The results of the basic research work often appear in scholarly journals. The applied research results also are shared with professional colleagues, but with the intent of leading to the development of practical products.

A primary audience of applied research is the educational developer, both in the R & D centers and in the regional laboratories. The developer synthesizes the research results, adds to this knowledge what he knows of the current educational situation, and produces products that hopefully will make a significant change in educational practice.

John K. Hemphill, executive director of the Far West Laboratory for Educational Research and Development, with Fred S. Rosenau, recently edited a book regarding this development process.[2] Hemphill describes two kinds of educational development: the product-development approach and the change-support approach.

Simply stated, the product-development approach creates something. The thing, be it an educational tool or device, produces specified outcomes when used as directed. Hemphill describes the outcome of this approach as "... complete packages that have physical identity." Often, the packages are accompanied by supporting materials such as manuals of instruction, teacher guides, and training guides.

The change-support approach works to modify behavior through intervention. Hemphill explains that this procedure seeks to "... improve the group or organizational interaction of people as well as the behavior of the individual educator." Materials, such as training books and teacher guides, often are included but they are incidental to the attitudes, skills, motives, and values of the educators.

The product-development approach assumes that teachers can be motivated to seek and use better materials and procedures and that, when improved materials are made available, improvements in education will occur. To produce a product utilizing this approach, most of the R & D institutions follow a similar process: they establish specifications; invent or design a prototype; test the product with users; redesign it based on preliminary testing; and retest until the product meets the specifications.

"This is the essence of the product-development approach," claims Hemphill. "We test a tentative design or model of the product against specifications and then we recycle our efforts until a product is created that performs in accord with them." After the product undergoes the development cycle it is ready for commercial publication.

The products resulting from the change-support approach generally undergo a different process. "The developers seldom can make explicit the steps they will take in reaching their objectives," explains Hemphill. "In fact," he says, "the development of specific objectives and their achievement often are integral activities. Consequently, they are not to be specified in advance. Educational development, then, using this approach, is a continuing process. It's never completed, since improvement can never be said to reach a point where further improvement is not possible. Instead of evaluation, as we think of it in terms of product development, we use feedback in a continuous process of refinement."

A product developer who uses the change-support approach attempts to stimulate the educator to change his present practice by providing the educator with information about what is possible and encouraging the educator as he changes.

"It is important to understand," explains Hemphill, "that educational development is not 'innovation'." Schools and teachers, he says, often are made to feel that anything new or different is an improvement over previous practice.

"Educational development can provide alternatives to present practices, which, in many cases, open opportunities for improvement," states Hemphill. "But just because an alternative is available does not necessarily mean it is recommended that it be chosen. Educational development makes intelligent changes possible, but it does not mandate change itself."

One area where several of the centers and laboratories have concentrated their efforts is on the research and development of elementary-level natural and social science curricula and supporting materials.

One example, "Individualized Science," developed by the Learning Research and Development Center at the University of Pittsburgh and field tested by Research for Better Schools, Inc., of Philadelphia, has been

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[1] See for example "Pronunciation of Synthetic Words with Predictable and Unpredictable Letter-Sound Correspondence," 1969.

[2] John K. Hemphill and Fred S. Rosenau, editors. *Educational Development*. Prepared by the Far West Laboratory for Educational Research and Development. Portland: Center for the Advanced Study of Educational Administration. (In press.)

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heralded as a major breakthrough in elementary science instruction. Each student's course of study is individualized for him. As he progresses through the program, he first learns basic processes of scientific inquiry. He later uses these skills to focus on problem solving as he begins to study such topics as biology and ecology.

The Wisconsin R & D Center also has a science program concerned with ecology. The program, "Individually Guided Science: Man and the Environment," combines science, social studies, and environmental management.

The other research and development center with considerable involvement in science education is located at the University of Texas, Austin. Its program is described elsewhere in this issue (see "Teachers Learn To Teach Science").

The regional laboratories also are involved in developing validated science programs. In addition to Research for Better Schools, the Mid-continent Regional Educational Laboratory in Kansas City has several major developmental efforts concerned with biology at the secondary level. And the Far West Laboratory in Berkeley recently marketed an "Elementary Science Information Unit" to help school decision-makers decide about the relative merits of ESS, IDP, SCIS. S-APA, COPES, and Minnemast.

These programs and others that concentrate on social-science curricula or instructional development are described in the *CEDaR Catalog*, a 500-plus page, two-volume publication (see "Product Information Available" story).

The products resulting from the CEDaR institutions already have made an impact. Many are in use in schools and colleges; many more are being considered for adoption.

Already the institutions have demonstrated their potential. Before long, their impact should help raise the level of educational achievement for all members of society.—E. JOSEPH SCHNEIDER.

Product Information Available

The Information Office of the Council for Educational Development and Research, Inc., publishes two mediums. One, the *D & R Report*, is a monthly complimentary periodical. Each issue concentrates on a major educational category; e.g., early childhood education, urban education, and higher education. The other publication is the *CEDaR Catalog*. The third edition of this two-volume catalog discusses the major programs within the CEDaR institutions and describes both their anticipated products and available products.

Readers interested in receiving the complimentary *D & R Report*, an order form and informational brochure regarding the *CEDaR Catalog*, or an informational brochure describing the Council, may write: Dissemination Division, CEDaR Information Office, 775 Lincoln Tower, 1860 Lincoln Street, Denver, Colorado 80203.

R & D Institutions Share Interests

The charter members of the Council for Educational Development and Research, Inc., are either university-based research and development centers or regional education laboratories. In June 1971 the institutions incorporated into a nonprofit corporation, the Council for Educational Development and Research, Inc.

The Council, basically, has two purposes. It exists to advance the level of programmatic, institutionally based educational research and development and to help demonstrate the importance of that research and development in improving education in this country.

Current CEDaR members include the following:

Appalachia Educational Laboratory, Inc., Charleston, West Virginia

CEMREL, Inc., St. Louis, Missouri

Center for the Advanced Study of Educational Administration, University of Oregon

Center for Research and Development in Higher Education, University of California, Berkeley

Center for Social Organization of Schools, The Johns Hopkins University

Center for the Study of Evaluation, University of California, Los Angeles

Center for Urban Education, New York City

The Center for Vocational and Technical Education, The Ohio State University

Education Development Center, Inc., Newton, Massachusetts

Far West Laboratory for Educational Research and Development, Berkeley, California

Learning Research and Development Center, University of Pittsburgh

Mid-continent Regional Educational Laboratory, Kansas City, Missouri

National Center for Occupational Education, North Carolina State University, Raleigh

National Laboratory for Higher Education, Durham, North Carolina

Northwest Regional Educational Laboratory, Portland, Oregon

Research for Better Schools, Inc., Philadelphia, Pennsylvania

Research and Development Center for Teacher Education, University of Texas, Austin

Southeastern Educational Corporation, Atlanta, Georgia

Southwest Educational Development Laboratory, Austin, Texas

Southwestern Cooperative Educational Laboratory, Inc., Albuquerque, New Mexico

Stanford Center for Research and Development in Teaching, Stanford University

Wisconsin Research and Development Center for Cognitive Learning, University of Wisconsin, Madison

Teachers Learn to Teach Science

Science curriculum development, teacher training, and personality research have been merged in a programmatic R & D process at the Research and Development Center for Teacher Education. The center at the University of Texas, Austin, was established in 1965. Its mission was to develop and test new methods of training preservice teachers. The center's instructions were to move ahead on a wide, interdisciplinary front to research, develop, test, and implement total educational programs. Development of *The Teaching of Science, A*

Self-Directed Learning Guide at the Texas center is a case study of how such programmatic product development has brought new dimensions to educational R & D.

Faculty members of the University of Texas Science Education Center began in 1963 to participate in the first tryout installations of a new elementary science program* in several Austin public schools. The curriculum innovation was a success. However, inservice training materials were badly needed for the elementary school teachers being asked to use the product. To develop such materials, the Science Inservice Project was established.

Concurrent with this development, the Research and Development Center for Teacher Education was being established with the gathering of a critical mass of educational researchers working in the University's Personality Research Center. National Institutes of Mental Health and U.S. Office of Education funding was being applied to studies of behavioral characteristics of student teachers and how those characteristics affected their success as teachers. New techniques were being developed to help prospective teachers understand and build teaching styles based on the ways their personalities, attitudes, and teaching behavior affect children.

The Science Inservice Project needed support for the evaluation of the teacher education materials they had developed. The R & D Center was able to provide that support, so the two programs joined forces.

The R & D Center's focus was on training prospective elementary school teachers. Although the faculty from the Science Inservice Project had been concerned with inservice teachers, once that work neared completion the faculty began to prepare student teachers to use innovations such as *Science—A Process Approach*. Thus began the process that led to publication of *The Teaching of Science, A Self-Directed Learning Guide.*

Twenty-three skills were identified as essential for the successful teaching of an inquiry-based science curriculum. The development of these skills in college students preparing to be elementary teachers became the focus of a project of the R & D Center and the Science Inservice Project. Similar curriculum-based instruction projects were conducted in mathematics, social studies, and language arts education. The project was to develop teacher training modules for use alone or as part of the center's Personalized Teacher Education Program.

In developing the modules consideration was given to some philosophies and techniques derived from the Center's empirical research into teacher personalities and teaching behavior. For instance, that research had demonstrated that the feelings of the teacher should be a legitimate concern of those who train teachers. Teacher education programs attuned to this viewpoint are referred to by the center as "personalized." Two kinds of feelings are considered. First are feelings that can be expected to augment learning. These often are called motives, goals, or concerns. Teachers' concerns occur in a fairly regular sequence, as demonstrated by early research at the center. The second consideration is feelings that may interfere with learning. For example, feelings that a student teacher is unaware of may interfere with his learning to teach, especially if his pupils notice those feelings. Hence, some personalization procedures are calculated to bring to the student teacher's attention, and hopefully under his control, feelings that might otherwise interfere with his learning to be a teacher.

The Personalized Teacher Education Program includes procedures for assessing teacher concerns and selecting course content and experiences for teachers consonant with their assessed concerns. In addition, the program arouses teaching-related concerns, resolves interfering concerns, provides psychological assessment and counseling, and allows for self-confrontation counseling with videotapes of teaching encounters.

There is a sequence of experiences in *The Teaching of Science, A Self-Directed Guide*. Early experiences address early concerns (e.g., concerns about self and one's ability to cope with the new situation). More mature concerns (e.g., concerns about pupil needs and how to assess them accurately) are dealt with later in the series of units. A student teacher who has mastered the required competencies and who demonstrates more mature concerns early in the program period is allowed to advance out of units that pretests show him to have mastered already.

The *Guide* includes a set of instructional objectives, based on the 23 skills required for successful science teaching, and pre- and post-evaluation materials. Science educators in some 14 colleges participated in the product's pilot and field tests, using the materials with more than 600 students.

Features such as self-pacing and provisions for advanced placement out of individual course units made the *Guide* ideally suited to the PTE Program. So, while the product was being evaluated as a science education curriculum, it also was undergoing examination for its contributions to the success of the Personalized Teacher Education Program. This latter work took place in the College of Education of the University of Texas.

The *Guide* actually evolved through several formats, each change being dictated by field-test results. The earliest prototype consisted of a series of manuals, each addressing a particular science-teaching competency (e.g., describing observations and stating behavioral objectives). These competencies were brought into focus for student teachers by having them work through tasks selected from *Science—A Process Approach*.

Then the separate volumes were combined into a single volume with a logical content sequence (based on the sequence of teacher concerns identified in the research). This improvement was applauded by test users, but another problem arose. Some teachers saw little relevance in some of the tasks for their particular needs. First-grade teachers, for example, couldn't understand why they needed to know how to teach lessons directed at sixth graders. The solution was to prepare

* *Science—A Process Approach*, developed by the Commission on Science Education of the AAAS with support from the National Science Foundation.

a series of parallel manuals. six directed at the specific elementary grade levels and one general volume for the student teacher who doesn't know what grade he will be teaching. The general volume was field-tested during 1971-72 with 429 students in nine institutions. Minor revisions were made before it was turned over to Harper & Row for publication in January 1973. The other volumes still are under development.

While the final field-test was still in progress, the general volume of *The Teaching of Science, A Self-Directed Learning Guide* was nominated by Educational Testing Service as one of the top five educational products in 1971 deserving focused dissemination help from the U.S. Office of Education. This nomination was made after a review of the product in competition with a pool of other educational innovations.

The *Guide* is a strong innovation for several reasons. First. the product underwent four years of development, including three field-tests with revised versions.

Second, the product enjoys the benefits of a skilled science curriculum development team's long-range efforts. It also benefits from cross-fertilization from other educational research and development, most notably the personality and behavior research conducted with the same student teachers using the science education materials. This information from another educational discipline was a strong influence in determining the final form of the product and the sequence of presentation.

The R & D Center provides a unique environment for this sort of cross-stimulation by gathering a task force from a variety of disciplines and then encouraging multiple roles for its members. Not only do the psychologists help the curriculum developers; often, the roles are reversed as the curriculum people test the psychologists' products and ideas in the classroom.—DAVID A. WILSON, *Director of Communication Services, Research and Development Center for Teacher Education, University of Texas, Austin.*

Third grade level girl working with CSMP individualized activity package exercise in concept of probability.

Developers Discuss R & D Process

CEMREL's Comprehensive School Mathematics Program is developing curriculum to enable every school child to go as far in the study of mathematics as his talents and inclinations allow. The program is discipline oriented. Although all pedagogical aspects of mathematics education are of deep concern, priority is placed on selecting sound, relevant, and enjoyable mathematical content. Three international conferences of eminent mathematicians and mathematics educators, a national advisory committee made up of outstanding leaders in mathematics in the United States, and staff associates and consultants from universities in the United States and Europe have input into the CSMP content and teaching methods.

This article relates portions of a conversation among Verna Smith, CEMREL director of dissemination; Burt Kaufman, director of CSMP; Vincent Haag, mathematics coordinator-in-residence and staff associate on leave from Franklin and Marshall College; and Peter Braunfeld, University of Illinois professor and CSMP staff associate.

Smith: Scientists have criticized educational researchers and developers for their pseudo-scientific approach in curriculum development. What can you tell me about the approach you take in CSMP?

Kaufman: Our approach is empirical, not scientific. If you took our development cycle and judged it by any reasonable scientific standard, you'd be laughed out of the forum, and rightly so. I certainly wouldn't call what we do a science. It is more of an art.

Haag: It isn't that there are no theories of learning, per se. But usually a theory of learning is not related to the particular content being learned. When we have an idea about new content. we try it and see how it works empirically. I don't think educational curriculum development should be based on a so-called scientific method in the sense that we have experiments in science.

Smith: But don't you use a scientific approach in surveying the field and getting all possible information about what already has been done?

Kaufman: If you take all the mathematics curricula, K-6, all the commercial textbooks, and, as far as I know, most of the mathematics projects that exist in this country, scant difference exists among them content-wise. Consequently, there is no sense surveying anything.

Third grade level boy working with CSMP activities related to a mathematical concept.

Haag: I think many people, when they talk about research and development in education, usually mean taking some accepted body of content in a particular subject field, then applying some theory of learning to design an experiment to see if they can teach that content more effectively. We're not in that game at all. We are not accepting the traditional content in school mathematics and finding out how to teach it better. We are in the business of throwing out any preconceived notions about the content and trying to decide what it really should be.

Kaufman: For us, it would be best to commute the letters—R & D. It is for us to develop first the mathematics curriculum and *then* to research it, not to research and then develop it. Clearly you can't research a program before you have it.

Braunfeld: . . . At CSMP we've asked lots of mathematicians the question: "What is the subject really all about from a modern point of view? What kinds of things does a person have to know to get a sense for that point of view?" All that is more philosophical than scientific. It's finding out what the people in the field think. Of course, once we have a curriculum, and once it is in the schools, then we certainly will have to subject ourselves to evaluation. But Burt's point is that the creation of testing instruments to test for the new things we are doing is an intellectual, creative effort of the same order of magnitude, if not greater than, the development of the new curriculum in the first place. And I agree with him.

Kaufman: . . . Our Basic Program Plan states our case well:

"Mathematics is an important intellectual discipline—not merely a collection of algorithms. One of the primary aims of the proposed curriculum will be to exhibit mathematics as a method of inquiry that enables us to answer interesting and important questions. If we are to lead children to this kind of an appreciation of mathematics, then we must not set our sights so low that we teach only the trivial; for example, we must not become obsessed with teaching only algorithms. This is not to denigrate the importance of computational skills—much of mathematics will be inaccessible to a child who is not reasonably skilled in arithmetic. But it is not necessary to drill students endlessly in mindless algorithms. We have found time and again that there are ways of introducing and practicing the algorithms that at the same time involve interesting mathematics. . . . The typical over-concern with only the routine and drill in the primary grades is a sad thing, because in our own work we have noticed repeatedly that even little children can derive great pleasure from the power and elegance of elementary mathematical ideas."

Braunfeld: We really do concern ourselves with building up various kinds of mathematical languages in the sense of building systems for denoting mathematical ideas. Any given idea can be represented in lots of different ways. Obviously, some ways are more apt for solving certain problems than other ways. The more ways you have at your disposal for stating a problem or for restating a problem that has been given, the better off you are for solving it. Frequently, mathematics is simply a matter of restating a problem given to you in an awkward language into transparently clear language.

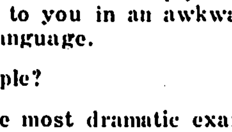
Smith: For example?

Haag: One of the most dramatic examples is a simple one. Suppose we pose a question concerning some objects and their attributes. Let's say we have a certain set of objects and three attributes, and objects in the set that possess various combinations of attributes. The problem is to deduce from this information certain new information concerning other combinations of attributes. Such a problem sounds complicated when stated in ordinary language. But if we translate into the language of sets and draw a set diagram, the problem is immediately clear and the answer is almost obvious.

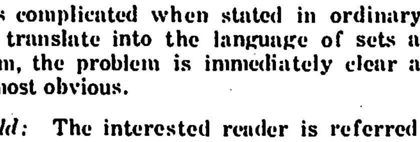
Braunfeld: The interested reader is referred to a large collection of such examples in a book by Lewis Carroll. He has endless syllogistic puzzles that become transparently clear if you use Venn diagrams.

Smith: What are Venn diagrams?

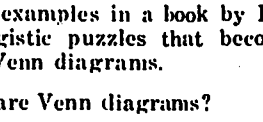
Braunfeld: What we are concerned about when we draw Venn diagrams is representing *sets* and relationships between sets. A set is just a collection of objects. The important thing about any given set is that everything in the universe is either a member of that set or it is not a member of that set. There are only two possibilities. Now, to represent a set, it often is convenient just to draw a simple closed loop, like this:



Now let's represent objects by dots. If a thing is a member of a given set, its dot goes inside the loop. Otherwise the dot goes outside the loop. For example, let's suppose that we are considering the set of all states in the Union. Then, we can draw the following diagram to represent the fact that Illinois is a member of that set and Saskatchewan is not:



. . . Here's a diagram for three sets:



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With three sets, if you state things purely verbally, they can get very complicated, but the diagram will often make them completely clear.

Smith: And you say that second graders use these diagrams?

Kaufman: First graders, even children in kindergarten. Kindergarten kids only use two-set diagrams, but the first graders are using three. And they can describe these various regions because it's nonverbal language. . . . They are learning classification skills that should be useful to them later in other mathematical studies and also in science. . . .

Haag: . . . Venn diagrams are only one of several languages interwoven in our curriculum and each language has its own best uses in certain kinds of situations. The children learn to translate back and forth from one language to another.

Kaufman: We have three basic languages that we consider essential for young children: the language of Venn diagrams, the language of arrow diagrams, and the language of the Minicomputer. Other languages come later. We interrelate these languages to solve problems. Each language has various levels of complexity, and one of the primary goals of our program is to bring as many students from one linguistic level to the next in a certain amount of time. How long it takes for various kinds of students is something we're trying to find out. . . .

Smith: But do you introduce all three of the languages in kindergarten?

Kaufman: In kindergarten certain children make jumps rapidly and seem to skip levels. The bright students seem to skip levels. The bright students seem to go in a short time from the basic level of the particular language to the sophisticated level. Incidentally, I think that's a better way of distinguishing between slower and faster children than their ability to memorize facts.

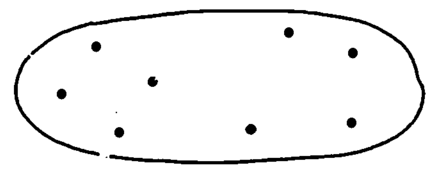
Braunfeld: This emphasis on languages is not a trivial thing or just a concession to children. The facts are that when you finally get a good language for expressing a problem it can make a significant difference. . . .

Haag: All the emphasis on language is extremely important in the learning process for a child. We believe that this is the way to get children eventually to learn certain mathematical content that we think is appropriate. . . .

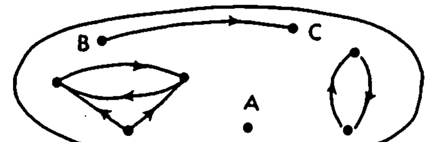
Kaufman: Yes, and because of these languages, little kids can cope with problems in areas of mathematics that were never available even in high school. I'm not talking just about the brilliant students. I think that most children can do a lot more because of the introduction of these new languages at the elementary level.

Smith: Did you say the second language was arrow diagrams?

Braunfeld: The language of the arrow diagram is rich. Here is just one example. Suppose that this is the school playground containing some children represented by the dots:



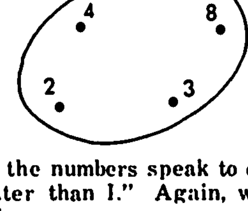
. . . Now let's imagine that the children are playing the following game: Each child points to his or her sisters and says, "You are my sister." Now here comes the language part. We're going to represent these acts of pointing in our picture by drawing arrows, like this:



Remember, each arrow is saying, "You are my sister."

Smith: There seems to be a child that doesn't have any sisters.

Braunfeld: That's right. A doesn't have any sisters, at least not on the playground. They could be at home. Notice that C has to be a girl, since there is an arrow from B to C. And now comes the most interesting part of all. I claim that B has got to be a boy. Argument: Suppose B were a girl. We know from the diagram that C is B's sister. Now if B were a girl, there would have to be an arrow going from C to B. But, there is no arrow going that way. Therefore, the hypothesis that B is a girl is false. Conclusion: B is a boy. The kids can make the arguments like that. So by looking at this sister relationship on the set of these children, we can tell all kinds of interesting things. We can tell something about the sex of the children. We can tell something about the size of families, and so forth. There are lots of other things we can do with these arrow diagrams. . . . The arrow diagrams also can be used within mathematics itself. For example, here is a set of four numbers:



Now let us imagine the numbers speak to each other. They say, "You are greater than I." Again, we use arrows to represent the situation.

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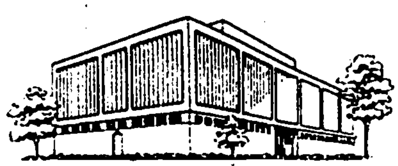

Published quarterly by the

American Association for the Advancement of Science

1515 Massachusetts Avenue, N.W.
Washington, D. C. 20005

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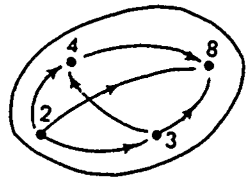
AAAS Misc. Pub. No. 72-19



Notice that 2 speaks the most (there are three arrows coming out of the dot for 2) and 8 does the most listening (there are three arrows coming into 8). That's just a way of saying that 2 is the smallest number in one set and 8 the greatest. The children can draw these arrow diagrams long before they could express all these ideas in English or even with the standard mathematical symbolism.

Kaufman: Did you notice Peter said that the numbers are speaking to each other? What we do for the children is to animate objects and to personify objects and actually make the children feel that they are a part of the action. They play the role of numbers and other mathematical objects and actually come up and act out some of the ideas. That's the way to activate kids in the process of learning. From the purely content point of view, these things like "less than" and "I am your sister" are called *relations*. Relations with certain special properties are called *functions*. I think most mathematicians would agree that functions probably are the most important mathematical concept of all. In the past, the concept of function either didn't get introduced at all before the end of the 12th grade, or it was just barely mentioned—usually the wrong way. Here we are able to bring the concept of function and its variations and its particular language to children as young as age 5. So, a fundamental concept of mathematics really becomes the basis of a lot of mathematics for the child.

Smith: Tell me how this is going to be valuable for the factory worker, or the mechanic, or the man in the street, and not just for the mathematician.

Braunfeld: Well, in the first grade we surely don't know who's going to be a factory worker and who is going to be a Ph.D. mathematician. Second, the world in which we live has become more and more a world of symbols. It is crucial to almost any kind of job these days to be able to manipulate symbols rather than things and to be able to reconstruct the reality that is supposed to be behind the symbolic representation. We try to find the mathematics that is not only practical today, but that will be practical 20 years from now.

Smith: This seems to have so many applications in other subject matter areas, too. You were talking about the involvement of children in dramatizing the arrow diagrams.

Kaufman: Oh, I think there's a real base here for interdisciplinary work. It's a problem of getting people together to do it. It took us several years to realize the role of language in our program, so it would have been silly three years ago to say we should get together with language people and develop language programs. Now we're starting to see the issues more clearly. I think a potential exists in the future to put together a truly coordinated kind of program for young children that interrelates one subject with another. I do think, however, that there still needs to be a time in the day when students deal solely with mathematics and a time when they deal solely with each of the other subjects.

Smith: Let's talk about the Minicomputer.

Braunfeld: The Minicomputer is a system for symbolizing numbers.

Haag: You manipulate it in an actual physical way.

Braunfeld: . . . You literally take stuff from the one's board and carry it over to the ten's board.

Haag: Most important, the Minicomputer allows young children to deal with large numbers—something little children find interesting. They can handle all kinds of calculations without having to wait until they have learned some strange algorithm written down on paper.

Smith: Let's go back and talk again about the D & R process. How do you know something works with a child? How do you test it? How can you make a positive statement about whether it does work or whether it does not work?

Kaufman: The first thing we do is to decide what it is we want to teach the student. Originally, we were unorganized in that respect. Then we came into contact with Frederique Papy's work. We saw it as a base for the kind of curriculum we wanted to develop. She has since become a program associate for us, advising us on content, teaching demonstration lessons, and helping with our teacher training.

After writing the lessons, our staff tries them out on a daily basis with small groups of children. There are four classes of children taught by four different CSMP staff members, so we actually have four different looks at each lesson. Each of the CSMP classes is observed by at least one of our staff members. After each lesson the teachers and observers discuss what happened, and then decide what to do with that lesson. . . .

The materials then are revised based on all this feedback and tried again the following year with the regular teacher who has observed a development class the previous year. . . . After the second revision, they are used in all the schools in Carbondale during the next year with much less control from us.

Smith: You have a three-year development-and-testing cycle for every grade?

Kaufman: Yes. Each lesson is tried three years before it is ready for expanded pilot test outside of the Carbondale area. First it's tried by our staff; then by the teachers in one school who have observed CSMP development classes for a year and have had training in the summer and during the year; finally, it's used by all the teachers in the system who are trained in a short workshop the preceding summer and bimonthly during the year. Only then is a lesson ready for an extended pilot test on the outside. We are hoping to begin such an extended pilot test at the kindergarten and first grade level next September (1973).

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