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Discussed are two studies undertaken by the Commission: The Cost of Material Study and The Science-Mathematics Study. Early plans in The Cost of Material Study were to specifically tabulate costs of introducing and maintaining each of eight "new" science courses in elementary and junior high schools. This was abandoned in favor of tables presenting information relative to material availability, organization of equipment, relative percentage of materials to be purchased locally, types and uses of printed material, and other miscellaneous information. The Science-Mathematics Study sought to evaluate the effect of the "new" science and mathematics programs on students and teachers. Findings and conclusions are reported in the newsletter. Generally the findings are favorable. Principal negative feedback concerned the lack of coordination between mathematics and science programs. (BC)

COMMISSION ON SCIENCE EDUCATION

SE 005 389

American Association for the Advancement of Science

Commission on Science Education

COST OF MATERIAL STUDY

Purpose and Limitations

This study sought to compile information on the cost of materials for several government-supported science education programs at the elementary and junior high school level. In addition, the study sought similar information concerning a few local science programs. School superintendents have indicated that some authoritative statement on science equipment needs would be of assistance to them in obtaining increased budgets for elementary and junior high school science.

In early plans for this study, it was hoped that the cost of introducing and maintaining each of the new curriculums in elementary and junior high school science could be quite specifically tabulated as supporting evidence for the conclusion that adequate programs in science at these levels will cost considerably more than most school systems now have budgeted for this purpose. However, the investigations have made it clear that a presentation of costs by program at this time is neither possible nor desirable.

In the first place, such information would be premature for all of the federally supported elementary school projects and for most of the programs at the junior high school level. Most programs at present include materials both in experimental and in commercial stages of production. Prices fluctuate. Supplementary materials are being added and substitutions are being made, particularly in equipment items. In most instances equipment and teaching aids for use with a given program are offered for sale by different companies. Each program has several choices of materials, creating cost variations that would be almost impossible to tabulate in a completely accurate and fair manner.

Details on costs, obtained through interviews with key personnel in the various programs, were for materials available and prices on a given date. Six months later many changes had been made. The data collected have served an important purpose in determining approximate cost data, as reported in a later section, but further details would almost certainly be misleading and unfair to many of the projects concerned.

Each program is unique; and among the programs there are great differences, not only in printed materials, equipment, and supplies needed for instruction, but also in availability and recommended use of such items as films, filmstrips, and inservice teaching aids, all of which can be costly. All of these variations account for some of the differences in the costs of the various programs. Some of the ma-

terials and supplies required by the individual projects are listed in Tables 1, 2, and 3.

The intent of this report is not to provide data on relative costs of the several programs, but rather to show that elementary and junior high school science taught in the modern manner is going to cost money. Budgets of the past two decades for science at these levels will by no means be adequate for the decades ahead. In a later section of the report there is a discussion of the range of costs for the various programs included in the survey.

Procedure

An initial version of a questionnaire was reviewed with the staff of the AAAS Commission on Science Education. Suggestions for additions or deletions were incorporated in a revised version, which was field tested in two cities by supervisory personnel. Data obtained from these two school systems, and also two other school systems that were surveyed, are included in this report. The four cities are identified as A, B, C, and D. Cities A and D are the sites of large state universities.

Final questionnaires were then mailed to the four selected school systems mentioned above and to the eight course content projects listed below.

AAAS	*Science — A Process Approach*, American Association for the Advancement of Science
ESCP	Earth Science Curriculum Project
ESS	Elementary Science Study, Education Development Center, Inc.
IPS	Introductory Physical Science, Education Development Center, Inc.
ISCS	Intermediate Science Curriculum Study, Florida State University
MINNEMAST	Minnesota Mathematics and Science Teaching Project, University of Minnesota
SCIS	Science Curriculum Improvement Study, University of California, Berkeley
TSM	Time, Space, and Matter, Princeton University

Before the questionnaires were mailed, a telephone call was made to explain the purpose of the study

Chester E. Raun and David P. Butts

and to make arrangements for a personal follow-up visit. The follow-up visits and interviews with key personnel were conducted during the months of February and March, 1967.

Because the questionnaire was designed to cover both government-supported and local programs, not all questions were appropriate in all situations, and clarification was needed to secure precise information. Visits were considered essential. The questionnaire contained a large number of questions that were believed to be necessary in order to obtain data specific enough to provide a basis for conclusion on overall costs.

Printed Materials

Table 1 presents information about printed materials required, both for students and teachers, for the elementary and junior high school science programs developed with federal funds, as well as for local programs.

The four local school systems utilize a student textbook both in elementary and junior high schools. The government-financed programs use workbooks or worksheets for students. The AAAS has introduced a student worksheet in grades 5 and 6 in the

Table 1. Printed Materials

	For Students			For Teachers			
Program	Textbook (length of use)	Workbook (length of use)	Worksheets	Reference Books	Manuals	Textbooks	Picture Books
AAAS			Parts 6 and 7 (1 year)		Yes (indef.)	Yes (indef.)	
ESCP	Yes	Optional			Yes		
ESS			Yes (1 year)	Yes	Yes (3-4 years)		Yes (3-4 years)
IPS	Yes (indef.)	Yes			Guide (indef.)		
ISCS	Combined text-workbook (1 year at present)				Yes (1 year at present)		
MINNEMAST		Yes (contained in teachers manual)	Yes (1 year)		Yes, 6 to 8 per grade K-2 (4-5 years)		Yes (4-5 years)
SCIS		Yes (1 year)	Yes (1 year)		Yes (indef.)		
TSM		Yes (1 year)		Yes (3 years)	Yes (5 years)		
A	Yes (5 years)			Yes (5 years)	Yes (5 years)		
B	Yes (5-6 years)				Yes (5-6 years)	Yes (5-6 years)	
C	Yes		Yes (1 year)		Yes (2-3 years)		
D	Yes (5 years)			Yes (5 years)	Yes	Yes (5 years)	

Fourth Experimental Edition (1967). Worksheets will also be required for the grade 4 edition to be published by Xerox Education Division in 1968.

Teachers manuals or textbooks are required for all programs, local or government-financed. The composition of the printed materials for the teacher varies considerably—from one manual or textbook per teacher, to several manuals or textbooks, to a pack of materials. The AAAS pack includes a teachers text, a commentary, and evaluative materials. The MINNEMAST teachers pack includes student booklets, while TSM (Princeton) includes a teachers manual and overview. ESS includes manuals and picture books in a teachers pack for some of the units.

Reference books or materials are optional in most programs but are highly recommended in such programs as TSM and certain units of ESS.

Equipment and Supplies

Table 2 indicates the availability and organization of the materials and supplies considered essential to a program's operation.

A wide range of organization of the materials is apparent—from a two-student pack (IPS), to a grade-level box (MINNEMAST), to a choice of kits (cardboard or plastic) for the AAAS program.

Most of the packaging is designed for individual or small group instruction. However, the IPS project and also the programs in two school systems state that the teachers equipment may also be used for demonstrations.

Several programs have provided sufficient equipment in a classroom kit for thirty students. Other programs provide kits for a smaller number of students; for example, SCIS, a kit for sixteen students.

Table 2. Equipment and Supplies

Program	Availability	Organization of Equipment	Designed For	Number of Pupils per Kit	Approx. Amnt. Already in School	Materials To Be Purchased Locally
AAAS	Kits from publisher	Classroom kits packaged by exercise; cardboard or plastic storage boxes	Individual students and groups of 2-5	30	10%	Some
ESCP	Commercial kits	Individual and group kits for shelf storage	Individual students and groups of 2-4	2	Standard laboratory equipment	20%
ESS	Kits	Teacher, student, classroom, and optional kits	Individual students and groups of 2	6 (student kits) and 30 (classroom kits)	Very little	Some
IPS	Pack	Two-student pack, classroom pack, laboratory supplies	Groups of 2, large group and teacher demonstration	2 (student pack) and 30 (classroom pack)		5-10% (est.)
ISCS	Classroom pack	Classroom pack	Individual students and groups of 2-6	30	50%	Some
MINNEMAST	Kits	Class of 30 by grade level	Individual students and groups of 2-4	30	None	None when kit is purchased
SCIS	Commercial kits	By units. Specially packaged for ease of distribution	Individual students and groups of 2-4	16	10%	None when kit is purchased
TSM	Packs	Equipment packs and replacement packs for students, teachers and classroom	Individual students and groups of 2-4	30-150		15-20%
A	Very little		Teacher demonstration and individual students			10% (approx.)
B	1-6, no special kit 7-9, perm. lab. equip.	7-9, no organization	Teacher demonstration and individual students, 7-9	30 sets of equip. (7-9)	1-6 none 7-9 some	Some
C	Kits	Grade level	Individual students and groups of 2-6	30	25%	20%
D	Kits developed by district	Classroom kits	Individual students and groups of 4	30	5-10%	7-15%

Table 3. Miscellaneous Information

Program	Instructional Media Recommended					Field Trips	Storage Requirements	Evaluation of Program Being Conducted	Teacher Training Program Being Conducted
	16mm films	8mm loops	Filmstrips	Trans-parencies	Other				
AAAS		1 for Part 6		Yes		Optional	25 cu. ft./classroom	Yes	Yes
ESCP	Yes	Yes	Yes	Yes		Yes	24 linear ft. of shelf space	Yes	Recommended
ESS	Yes-for teacher training	Yes				Yes	1 or 2 tables and 10-20 linear ft. of shelf space	No	Pending. Publisher will offer.
IPS	Yes							Yes	
ISCS	Tentative		Tentative	Tentative		Yes	30 linear ft. of shelf space	Yes	Future
MINNEMAST				Yes		Yes	80 cu. ft./grade	Yes	Yes-2 hrs. per week during first 2 years
SCIS						Optional	4 linear ft. of shelf space	Yes	Yes
TSM			Optional	Optional		Optional	6-10 linear ft. of shelf space	Yes	Has been. Publisher will offer.
A	Yes		Yes	Yes	TV	2 per grade	8x7 ft. in school and central storage	No	Yes
B	Yes		Yes	Yes		Not required	1-6, independent classroom. 7-9, 100 sq. ft. central storage	No	Yes
C		Yes	Yes		Slides	Not required		Yes	Yes
D	Yes		Yes	Yes	TV and tapes	1-3 per grade	20-30 linear ft. of shelf space	Yes	Yes

AAAS offers a kit for one classroom. Two junior high school programs (TSM and IPS) indicate possible enlargement of student use to as many as 150 per kit. It should be noted that TSM and IPS are both junior high programs operating in a departmentalized environment.

The projects vary in their estimates of the amount of apparatus that may already be in a school district. TSM and MINNEMAST indicate that none of their apparatus is expected to be locally available. The other programs suggest that 5 to 50 percent may already be in the schools.

The amount of material that has to be purchased locally by a school district, in addition to kit material, also varies among the projects. SCIS and MINNEMAST indicate that nothing has to be obtained locally. ESS, TSM, and AAAS indicate that some is required, and estimates range from about 5 to over 20 percent. One school system reported that all material needed would be locally supplied. The remaining programs did not indicate what could or would be locally supplied.

Miscellaneous Costs

In Table 3 are listed additional items that affect the cost of a program's operation. These include films, filmstrips, transparencies, 8 mm cartridges, storage requirements, field trips, evaluation, and inservice assistance.

Although both the recommendations regarding field trips and storage requirements are shown in Table 3, there is no basis for even an estimate of the costs relative to either item.

Among the programs that reported costs of evaluation, the costs ranged from $10 per classroom per year for a local program to $125 per classroom per year for a government-financed program.

All the programs reported that a teacher training program was required. The duration of such training programs varies widely. Costs of programs range from $1 per teacher in one school system to $64 per teacher for a program for elementary teachers conducted by a state university under a Title III grant.

Overall Cost Estimates and Range

It was pointed out earlier in this report that most of the government-supported projects are still, at least partially, in an experimental stage. The AAAS program is a good example. The first three parts (K-2) have been published commercially, but at the time of this study only the experimental edition of the remaining four parts was available to schools.

For various reasons commercial versions of the programs are expected to cost more than experimental versions. Among the reasons is the government requirement that experimental versions be sold at the cost of printing and mailing. Clearly, commercial versions cannot be marketed on such a basis. For this and other reasons, the cost ranges for the government-supported programs that are shown in Table 4 will need to be revised upward as commercial versions of the programs come on the market.

The costs of local programs, on the other hand, are based on the costs of student texts that are already available commercially and on whatever supplies and equipment are needed for teaching science from these texts. The costs of these local programs will probably remain about as shown in Table 4 as long as the school systems do not change the program now in use.

It is evident from the data in Table 4 that the cost of a program developed by one of the government-supported projects is several times more than the cost of a local elementary program. Because the size of the sample of the local programs is small, and because of the variations among the other projects mentioned earlier, it is not helpful to try to compute median costs. However, a rough estimate indicates that it will cost at least three times as much to introduce one of the new elementary programs, which requires supplies and equipment for pupils to use, as it does to introduce a traditional program, which requires mainly student texts. Also, the annual

Table 4. Range of Costs of Printed Materials, Equipment, and Supplies for Science Programs in Elementary and Junior High Schools

Program	Grade Levels	Initial Cost Per Class of 30	Annual Cost Per Class of 30
Local	Elementary School	$40-$150	$10-$25
	Junior High School (one school system)	$180	?
Government-Supported	Elementary School	$180-$420	$75-$150
	Junior High School	$400*-$825*	$50-$150

*These materials may be used by more than one class of 30 students.

costs of the new programs will be perhaps five to six times greater than the old ones.

Only one of the four school systems surveyed reported a cost of introducing a science program into grades 7, 8, and 9. One inference that might be drawn from this fact is that school systems are giving even less attention to science in junior high school than they are in the elementary grades. The cost of introducing one of the new programs into junior high school appears to be about double that of introducing a new elementary program. However, in junior high schools where science teaching is departmentalized, the equipment can be more easily used by several classes so that the initial cost, as well as the annual cost per class, may be less in junior high school than in the elementary grades.

General Conclusions

One of the objectives of this study was to provide school superintendents with an authoritative statement about the costs of introducing and maintaining one of the new science programs in their schools. For the reasons mentioned earlier, it is not possible at this time to make such a statement. It is possible, however, to make a rough estimate of these costs. Even a rough estimate should be of some help in planning budgets for the next few years.

Assuming that the commercial versions of the new programs will cost about 50 percent more than the experimental versions, the cost of introducing a new science program into the elementary grades might range from $250 to $600 for each grade, with a median cost of perhaps $400. The cost of introducing a new program into the junior high school would be comparable to, or even less than, this if the equipment were used by several classes. These estimates include the cost of an inservice training program to prepare teachers to use the new materials.

Annual costs of supporting the programs in the schools would be about the same for the elementary grades and for junior high school. The average annual costs would probably be about $100 per classroom, or something over $3 per child. This amount is considerably higher than the amount now allotted by most school systems for the annual support of science education in grades K-9. Indeed some school systems seem not to make a special allotment for science supplies. However, one of the school systems surveyed, which allocated in its 1966-67 budget a little more than $75 per elementary classroom for science education, also provided each elementary classroom teacher $20 to $30 per year for the purchase of supplementary science materials. These funds came from three sources: local, 71 percent; state 12 percent; and NDEA, 17 percent.

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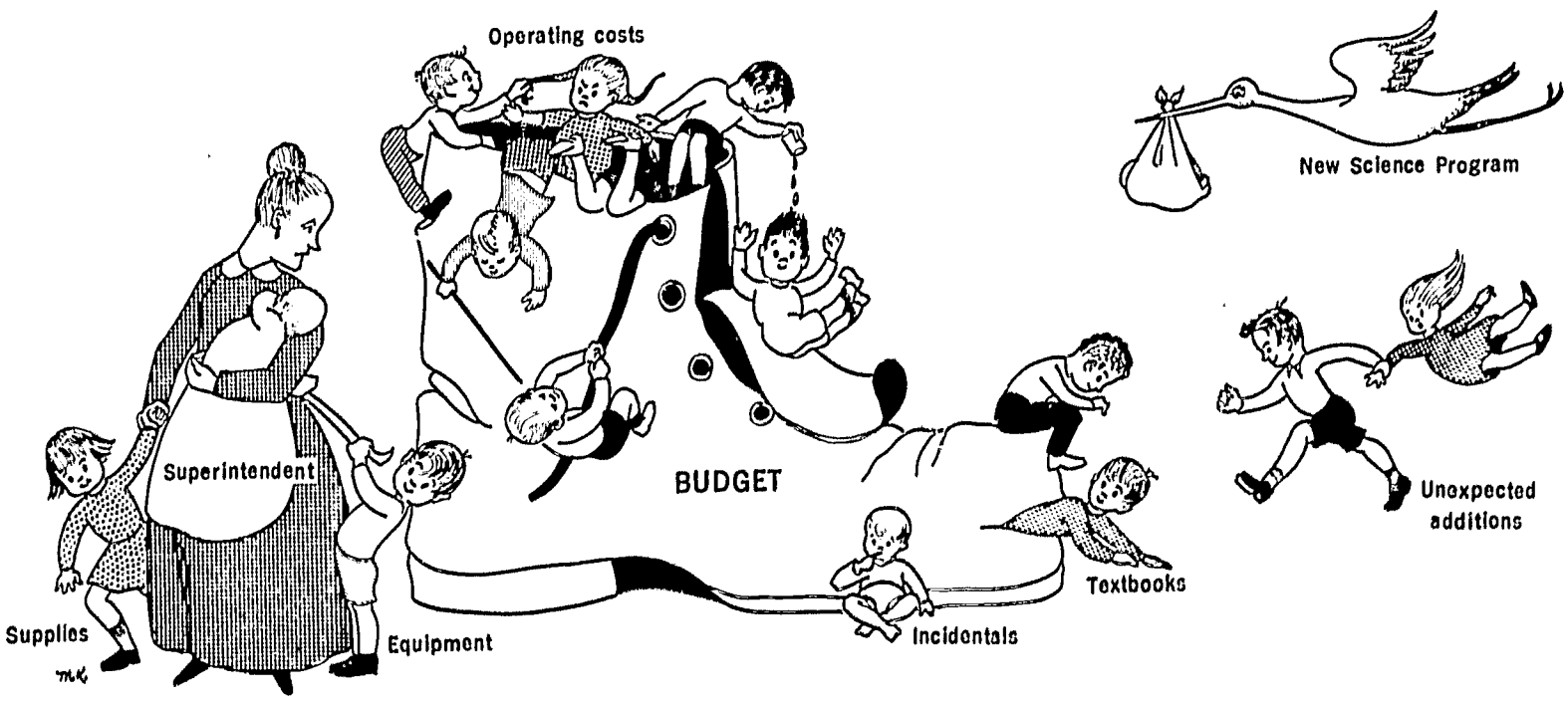

Persons responsible for the development of experimental programs in science and mathematics for elementary schools have been concerned about the demands of the new programs on the pupils and on the teachers. A new program in science or in mathematics may be more demanding for the pupils than a traditional one, and it is likely that more preparation time and inservice study will be required of the elementary school teacher who teaches a new program. Will introducing two new programs double the difficuties for the pupils? Will two simultaneous new programs double the difficulties for the teachers?

The concern for the teacher has been greater in developing elementary school curricula than high school curricula, since in elementary school one teacher is usually responsible for reading, writing, social studies, art and music, as well as mathematics and science, while the high school teacher is usually a specialist in, at most, two subjects. The concern is increased when it is recognized that soon many elementary schools will be offering both "new science" and "new mathematics."

There is another question that has interested those who have been developing new programs in mathematics and science. What effect, if any, does work in a new mathematics program have on a student's achievement in a new science program? And, conversely, does a new science program increase, decrease, or have no effect on, a student's achievement in a new mathematics program?

The AAAS Commission on Science Education invited several school systems already using, or preparing to introduce, *Science—A Process Approach* to cooperate in a study of these questions. In cooperating school systems it was expected that one or more classes would be using a new program in science and a new program in mathematics simultaneously. It was hoped that teachers in these school systems could provide information upon which to base some estimate of the difficulties that result for both teacher and pupil in the introduction of the two new programs. Neither funds nor staff made possible carefully organized research. The Science-Mathematics Study reported here was intended to serve as a demonstration project, from which information could be derived that would be useful to curriculum developers and schools and would suggest guidelines for curriculum change.

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The purposes of the Science-Mathematics Study were as follows:

1. To identify problem areas inherent in the concurrence of a contemporary mathematics program and *Science—A Process Approach*.*
2. To offer observations and inferences that may be useful in the design of elementary mathematics and science programs.

Specifically, the Science-Mathematics Study sought answers to the following questions:

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*In the original listing of purposes the term "experimental mathematics program" was used instead of "contemporary mathematics program." In this report the term "contemporary" is used to imply that the mathematics program has been developed recently by teams of mathematicians and teachers and tried out and revised several times before being made available for general use. The mathematics programs are representative of what is commonly called the "new mathematics." At the time of the study, *Science—A Process Approach* was in an experimental edition.

1. What are the effects on school atmosphere, teachers, and principals of the teaching of two contemporary programs (one in science and one in mathematics) at the same time? How does the teaching of two new programs affect the distribution of the teacher's time in preparation and in the classroom?

2. In what ways does the study of a contemporary mathematics program appear to strengthen, or to interfere with, a program based on *Science—A Process Approach*; and the other way around, in what ways does the study of the experimental science sequence appear to strengthen, or to interfere with, a contemporary mathematics program?

3. Scientists often report that even the best students in mathematics are unable to apply their mathematical competencies in simple applications in science. Does the concurrent study of two contemporary programs (one in mathematics and one in science) make this generalization less tenable?

4. Would changes in the ordering of topics in a contemporary mathematics program be beneficial to the experimental science sequence and, particularly, to the development of an ability to use mathematics in science experiences? In what ways would such reordering affect the mathematics program?

To accomplish these purposes and to answer these questions, two techniques were employed—one quantitative and one qualitative. The two parts of the study are quite separate. The quantitative part is a comparative study of the achievement in mathematics by students with and without contemporary programs in science and mathematics. The qualitative part is directed to the questions listed above.

The quantitative technique was the administration of a test designed to measure the presence of a collection of competencies in mathematics. Three groups of children took this test:

Group	*School Experiences*
CSM	*Science—A Process Approach* and contemporary mathematics
CS	*Science—A Process Approach* and traditional mathematics
CM	Contemporary mathematics, but not *Science—A Process Approach*

The collection of quantitative competencies of which the test was comprised were representative of some of the objectives of exercises in *Science—A Process Approach*. The same test was administered early in the school year and again late in the school year. It was administered in schools in Lakewood, Ohio; Overland Park, Kansas; Campbellsville, Kentucky; Wenatchee, Washington; and several schools in the vicinity of Newark, Delaware.

The qualitative technique was to collect and assess the observations and inferences of teachers from classrooms in which contemporary programs in mathematics and science were being taught. Two school systems provided these data—Lakewood, Ohio and Overland Park, Kansas. The two programs were taught in the school years 1965-66 and 1966-67.

In the Lakewood schools the mathematics program was uniformly contemporary—the Greater Cleveland Mathematics Program (GCMP). In contrast, the mathematics program in Overland Park was nonuniformly eclectic—derived from several contemporary mathematics programs, with different schools using different programs or combinations of programs.

The observations and inferences of the teachers were collected on special feedback forms. Each form covered a two-week period and was structured around the questions listed above. A total of about 270 feedback forms were collected. Teachers in Lakewood submitted about 200 forms, which covered science exercises taught in grades K through 6. For each grade there were usually two or three feedback forms for each of about half of the science exercises. From Overland Park seven science exercises in grade 2 were covered by twelve feedbacks, and ten science exercises in grade 5 were covered by about sixty feedbacks.

Some exercises from each of the basic and the integrated processes of *Science—A Process Approach* were included in the feedback. Ninety of the 175 exercises in Parts One through Seven were covered.

Qualitative Results

Feedback forms provided a variety of answers to the question: *What are the effects on school atmosphere, teachers, and pupils of the teaching of two contemporary programs?*

A problem, described more often by teachers in the early grades (K-2), was that the children disliked mathematics, especially twice a day. They do not yet enjoy mathematics. They do not like mathematics during the science period. One second-grade teacher remarked, "At times the students appear to be stimulated, yet sometimes are unsure that this is science since the program in second grade is so math-oriented." A first-grade teacher offered the

Lakewood, Ohio children in *Science—A Process Approach* classes. Photograph by Michael Cavanagh.

following evidence: "I continually find that the class cannot accept two lessons in math. Whenever a science unit is one on math, I have had to avoid teaching new math concepts during math time. Last week I attempted to teach 'place value' after a lesson in the metric system. I had listless children—some who said 'More numbers.' I find no such reaction, for example, this week doing 'Mold Gardens' along with 'place value.' "

In contrast, a second-grade teacher reported, "Math and science worked so closely this time that the children had more confidence in each one and participated eagerly in both—math is in the morning and they were eager to get to the afternoon science." And a kindergarten teacher remarked that correlation between the two experimental programs was so close "that it is more like teaching one program than two."

A related and revealing comment came from a fifth-grade teacher: "The children feel the math is part of the science and seem to divorce it from their regular math program." Apparently these children distinguish between mathematics and mathematics in science. Not unrelated is the report of a first-grade teacher: "The children's attention span during science was very short when working with just shapes. When shapes were applied to animals they were more interested."

Another fifth-grade teacher commented, "Children were happy to have an exercise in science that was not so mathematically oriented. (So was I.)" In contrast, however, another fifth-grade teacher reported, "The children were delighted when they could do the two-dimensional graphing. Several times they asked if we were doing math or science. The answer? Both."

Feedback data did not provide an answer to the question: *How does the teaching of two new programs affect the distribution of the teacher's time in preparation and in the classroom?* Although occasional comments mentioned that a great deal of preparation time was required, no measure of an increase in preparation time was reported as compared with preparation time before the new programs were introduced.

The feedback data provided evidence that in all grades some prior mathematics exercises in the mathematics program strengthened exercises in *Science*—

A Process Approach, but not without exception. Such strengthening occurred for the following mathematical topics: Empty sets, geometrical shapes, number line, sets and subsets, graphing, number pairs, decimals, metric system, measuring, computing means, and fractions. Typical positive comments were: "Previous work with graphing made understanding of a three-dimensional graph easier." "Previous math work in decimals helped with the decimals obtained as a result of averaging. . . ." "Previous use of the number line with positive integers aided the use of the number line with negative integers." In contrast, there was an occasional comment such as, "The children were unable to work with a graph although they had previous graphing in mathematics."

Conversely, the teachers generally reported that exercises in *Science—A Process Approach* reinforced the mathematics previously studied in mathematics classes. Often there were comments like: "Science helped visualize previous mathematics; science provided a chance to use mathematics in a useful situation rather than just classroom exercises; science provided more activity to apply what had been learned in the mathematics program."

The reports of the teachers also identified a number of instances in which the children were deficient in mathematical competencies at the start of an exercise in *Science—A Process Approach.* As a result the ensuing science exercises were difficult for the children. One teacher summed it up with the comment, "There seems to be the most conflict when the science relies heavily on math which should have been learned prior to the activity." Difficulties of this sort were reported for the following topics:

Grade 1: metric system; two- and three-dimensional shapes

Grade 2: telling time; negative numbers; graphing

Grade 3: metric system; multiplication

Grade 4: converting minutes to seconds; averaging; division by two-digit numerals; graphing; subtraction of fractions

Grade 5: use of protractors; computing averages; graphing (even though previously covered); decimals; ratios; scientific notation

Grade 6: metric system; division of decimals, graphing; liter and liquid measurement

Comments typical of the teachers' descriptions of inadequate mathematical skills were: "When I asked my children to measure something in centimeters, they had no idea what I wanted. . . . They had a hard time understanding why not use inches, etc." "Children have no experience with decimals." "Teaching ratio was absolutely necessary before approaching the exercise on ratio in science."

A couple of third-grade teachers referred to direct interference between the two programs. One reported that the mathematics program interfered with *Science—A Process Approach.* She stated her evidence so: "These children are measuring in inches, feet, and yards in math, which they are having problems with. When they were told to drop a marble 5 centimeters from the tail of the fish, they became very confused." The other teacher reported simply that the mathematics program was concerned with measurement in feet and inches, while *Science—A Process Approach* used the metric system. In contrast, a fourth-grade teacher in the same school district remarked that the children's background in the metric system helped in *Science—A Process Approach,* whereas a sixth-grade teacher, also in the same school district, reported that her students were concurrently studying the metric system in mathematics and the two programs had excellent rapport. And yet another sixth-grade teacher stated that the mathematics program did not seem to be very helpful to *Science—A Process Approach.*

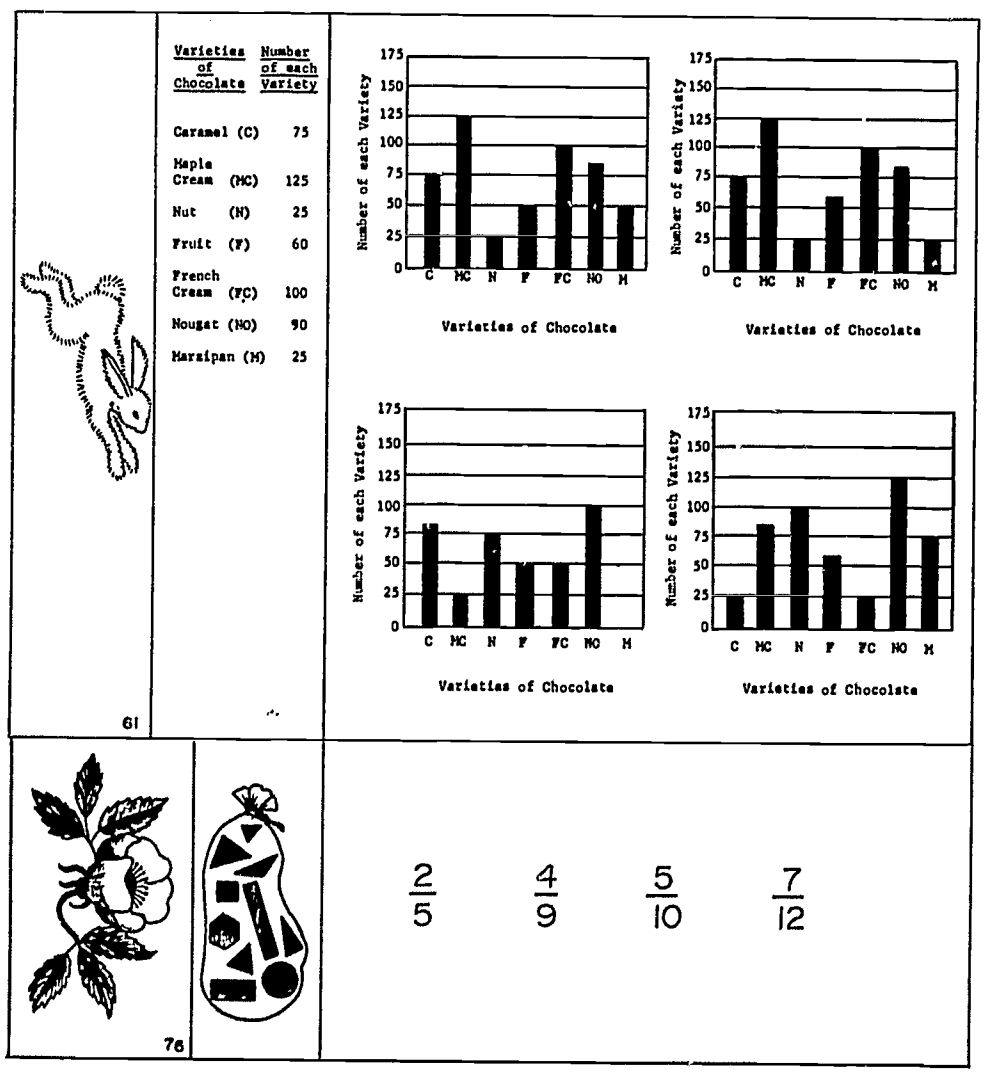
The reported interference can perhaps be summed up by the comment, referring to the sixth grade, "When these students have not been previously exposed to the Process Approach, there seem to be too many mathematical principles which are lacking or do not mesh because of the two separate programs." Some teachers reported certain differences in interpretation between *Science—A Process Approach* and other programs. Specifically, one contemporary mathematics program teaches negative numbers always to the left on the number line, whereas *Science—A Process Approach* encourages the use of the number line in various orientations. A second-grade teacher said, "The graphs in *Science—A Process Approach* interfere in structure with graphs in [our reading program] and with health graphs."

Does the concurrent study of contemporary mathematics and science increase the pupil's ability to apply mathematical competencies to simple applications in science? The feedback does not provide

a direct answer to this question. However, there were occasional reports of carry-over of competencies from *Science—A Process Approach* to other areas of study. "The children really enjoyed this unit on lines and surfaces. They were eager and anxious to start. Effects carried over to creative art work." "The children noticed the geometric shapes in objects besides animals." *Science—A Process Approach* "correlated very well with social studies units on maps and globes, and strengthened our study of parallels and meridians." There were also occasional reports to the contrary. "The children have not pointed out any place to use our new science knowledge in the math program." "These children have had the 'new math' all through elementary school and I see no effects of using two [experimental programs] at the same time."

It was also noted earlier that the teachers reported that the science program reinforced the mathematics previously studied in mathematics classes. It might be inferred from this comment that the pupils were more able to use their mathematical skills as needed in their study of science, although this is not explicitly stated. The intent of the teachers referring to reinforcement would depend upon what the teachers considered to be the objectives of their mathematics program. In any case, the fact that some teachers felt there was "reinforcement" suggests that the study of science and of mathematics in the elementary school can be related.

Supplementary to the Science-Mathematics Study, John R. Kolb, candidate for the Ph.D degree in education at the University of Maryland, conducted an investigation of the effect on science of reorder-



Sample Items from the Mathematics Test

(The teacher reads the statement in bold face twice, and then allows time for a response.)

61. **Put your finger on the picture of the rabbit.** (Wait until you can see that all children have identified the appropriate row.) **Find the table of data about varieties of chocolates and numbers of each variety next to the picture of the rabbit. In this row, mark with an "A" the graph that best represents the data that is presented in the table.**

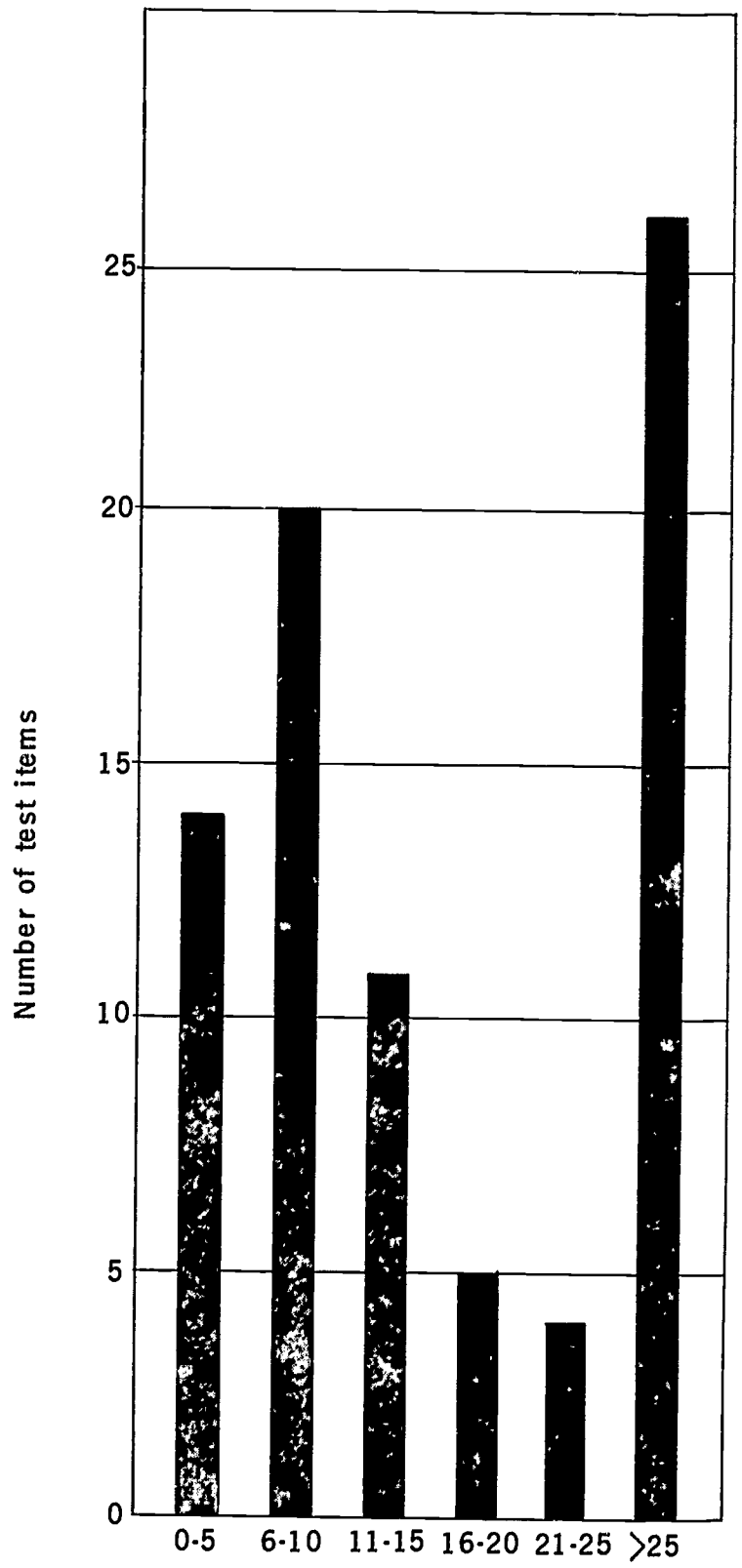
76. **Put your finger on the picture of the flower.** (Wait until you can see that all children have identified the appropriate row.) **Find the picture of the various shapes next to the picture of the flower. In this row, mark with an "A" the probability of selecting a triangle if the shapes were placed in a box and you were to draw one shape out of the box.**

ing mathematics topics.* He attempted to determine whether an instructional sequence in mathematics, based on a hierarchy of mathematical tasks assumed necessary for selected quantitative science behaviors, would facilitate the acquisition of the quantitative science behaviors more than an instructional sequence in mathematics not directly related to the science behaviors. His experimental subjects were 275 fifth-grade pupils in eight classes in School District 49, Overland Park, Kansas. Children in each class were randomly assigned to Groups A and B. Group A continued the mathematics sequence in their textbook. Group B received instruction in a mathematics sequence based on the hierarchy. The study occupied four school weeks. Kolb concluded that the instructional sequence in mathematics related to the science exercises facilitated the acquisition of the quantitative science behaviors for the experimental materials and the population used in his study. He further concluded that the results can be interpreted as providing suggestions for a way of relating mathematics instruction to science instruction without introducing science examples in the mathematics instruction.

Quantitative Results

The quantitative part of the study was based on four sets of test items covering topics included among the objectives of exercises in *Science—A Process Approach.* One set was administered to kindergarten pupils and first-graders, one set to second- and third-graders, a set to fourth-graders, and the last set to fifth- and sixth-graders. The same tests were used as pretests and posttests. The number of test results, i.e., the number of pupils who took both the pretest and the posttest, varied from 170 to 196 for the four sets of tests. This number was approximately equally distributed among the three groups (CSM, CS, CM) of children tested, with the smallest number of test results coming from the group (CS) not studying a contemporary mathematics program.

For each of the 80 test items the percentage of pupils that answered the test item correctly was



Maximum difference in percentage of pupils who responded correctly to a test item in the posttest, for the three groups of pupils.

Figure 1.

* Kolb, John R., "The Contributions of an Instructional Sequence in Mathematics Related to Quantitative Science Exercises in Grade Five." Unpublished Ph.D. dissertation, University of Maryland, 1967.

tabulated for both the pretest and the posttest. These percentages were tabulated for each of the three groups of pupils, CSM, CS, and CM. From this tabulation the differences among the three groups were examined for each test item; the maximum difference between any two of the groups on the posttest was tabulated. The distribution of test items according to the magnitude of these maximum differences in percentage is plotted in Figure 1.

Figure 1 shows that for almost a third (26) of the 80 test items the maximum difference in percentages between the groups of pupils was greater than 25 percent. This difference ranged from 26 percent to 89 percent. Thus for these 26 test items the difference in achievement between the groups of pupils was considerable.

However, examination of these 26 test items uncovered only four clusters of topically similar test items for which the difference in achievement followed a consistent pattern.

These clusters involved competencies with graphs, probability, the metric system, and ordinal numbers. Table 1 summarizes the ranges of the percentage of pupils who correctly answered test items (posttest results) for these four clusters.

TABLE 1

	CSM	CS	CM
Graphs (five test items)	10-32*	42-96*	12-27*
Probability (four test items)	12-38	52-75	5-27
Metric System (four test items)	76-96	78-93	3-17
Ordinals (four test items)	57-89	58-91	22-54

* Ranges for four of the five test items. In the fifth item the CSM and CM groups did considerably better, but still not nearly as well as the CS group.

The CS group of fifth- and sixth-grade pupils was the only group that could (1) match bar graphs and point graphs with given tables of data, and (2) interpret a bar graph. About 90 percent of the pupils in this group achieved these skills for four of the five items concerned with graphs, compared with about 20-25 percent of each of the other two groups of pupils—CSM and CM.

There were similar results for the cluster of test items concerned with probability. The fifth- and sixth-graders in group CS demonstrated greater achievement than the other groups. One-half to three-fourths of the group answered the probability test items correctly, representing more than twice as many as in the other two groups.

The tasks in the four test items on the metric system involved identifying the greatest length or area, and the least volume or force. The tasks required conversions within the metric system of units. Two of the three groups of fourth-grade pupils demonstrated their ability to do these tasks—CSM and CS. In these groups 76 to 96 percent of the pupils were able to perform these tasks, in contrast to only 3 to 17 percent of the CM group.

The fourth cluster of tasks involved the ordinal position of illustrated objects. These tasks were part of the test given to kindergarten and first-grade pupils. Of the CSM and CS groups 57-91 percent were able to perform these tasks, roughly twice as many pupils as for the CM group.

There was another single test item that only the CSM and CS groups could do. It involved finding the mean of five numerals. No other test item was concerned with this task. Compared with the CM group, about twice as many fourth-grade pupils in these two groups could find the mean.

All of these data are based on the posttest results. The pretest results, in general, were lower—often considerably lower. For any given test item on the pretest the results were about the same for each group of students. However, there was a fair amount of variation from item to item on the pretest.

The results for the tasks associated with the metric system and finding the mean were not unexpected. These competencies are peculiar to *Science—A Process Approach*. It is expected that pupils not taking *Science—A Process Approach* (the CM group) are not as likely to acquire these competencies in the elementary grades.

However, the results for the tasks associated with graphs and probability were not expected. These results suggest that children taking *Science—A Process Approach* and noncontemporary mathematics (CS group) acquire these competencies to a much greater degree than the other two groups of children (CM and CSM). Perhaps in the samples of children tested, the CS pupils had more experience (more time, greater depth) with the exercises concerned with graphs and probability in *Science—A*

Process Approach than the CSM pupils. This possible explanation cannot be checked, for no relevant feedback data on this point were collected as a part of the quantitative study.

In comparisons of the groups, the limitations of the study must be kept in mind. First of all, the tests were not administered to a group that had neither contemporary science nor contemporary mathematics, as would have been desirable. The children tested were in different school systems and no attempt was made to match the children in the groups, other than in the Kolb study. The test items were selected from skills that are developed in *Science—A Process Approach.* In view of these limitations the group comparisons are interesting, and they suggest a need for more carefully designed investigations.

Conclusion

The study has given encouragement that, in schools where good supervision is available, the simultaneous use of two new programs presents no special problems either to teachers or pupils. The absence of complaint from the teachers about the amount of preparation necessary is significant. The frequency with which teachers reported that the programs supported each other is surprising, in view of the fact that there was no cooperative planning in the preparation of the curriculums used. But how much better might the mutual support be with cooperative planning?

The principal negative feedback (the teachers recognize clearly that their science and mathematics programs are not nearly as well-coordinated as they could be), while expected, is possibly the most significant part of the results. This feedback calls for coordination, both planned and practiced, of new programs in elementary mathematics and new programs in elementary science.

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AAAS Commission on Science Education
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