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IDENTIFIERS	*Science Curriculum Improvement Study

ABSTRACT

This report deals with the developmental history of the Science Curriculum Improvement Study (SCIS). Description of the project and its origins as well as summative evaluation are briefly discussed. Diffusion of the project and subsequent adoption are also treated and its future potential evaluated. (CP)

PRODUCT DEVELOPMENT REPORT NO. 4

SCIENCE CURRICULUM IMPROVEMENT STUDY

DEVELOPED BY THE SCIENCE CURRICULUM IMPROVEMENT STUDY PROJECT
UNIVERSITY OF CALIFORNIA, BERKELEY

November, 1971

Contract No. OEC-0-70-4892

AMERICAN INSTITUTES FOR RESEARCH
Post Office Box 1113 / Palo Alto, California 94302

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Daniel W. Kratochvil
Jack J. Crawford

American Institutes for Research
in the Behavioral Sciences

Palo Alto, California

November, 1971

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Office of Program Planning and Evaluation

PREFACE

This product development report is one of 21 such reports, each dealing with the developmental history of a recent educational product. A list of the 21 products, and the agencies responsible for their development, is contained in Appendix A to this report. The study, of which this report is a component, was supported by U.S. Office of Education Contract No. OEC-0-70-4892, entitled "The Evaluation of the Impact of Educational Research and Development Products." The overall project was designed to examine the process of development of "successful educational products."

(This report represents a relatively unique attempt to document what occurred in the development of a recent educational product that appears to have potential impact.) The report is based upon published materials, documents in the files of the developing agency, and interviews with staff who were involved in the development of the product. A draft of each study was reviewed by the developer's staff. Generally, their suggestions for revisions were incorporated into the text; however, complete responsibility for interpretations concerning any facet of development, evaluation, and diffusion rests with the authors of this report.

Although awareness of the full impact of the study requires reading both the individual product development reports and the separate final report, each study may be read individually. For a quick overview of essential events in the product history, the reader is referred to those sections of the report containing the flow chart and the critical decision record.

The final report contains: a complete discussion of the procedures and the selection criteria used to identify exemplary educational products; generalizations drawn from the 21 product development case studies; a comparison of these generalizations with hypotheses currently existing in the literature regarding the processes of innovation and change; and the identification of some proposed data sources through which the U.S. Office of Education could monitor the impact of developing products. The final report also includes a detailed outline of the search procedures and the information sought for each case report.

Permanent project staff consisted of Calvin E. Wright, Principal Investigator; Jack J. Crawford, Project Director; Daniel W. Kratochvil, Research Scientist; and Carolyn A. Morrow, Administrative Assistant. In addition, other staff who assisted in the preparation of individual product reports are identified on the appropriate title pages. The Project Monitor was Dr. Alice Y. Scates of the USOE Office of Program Planning and Evaluation.

Sincere gratitude is extended to those overburdened staff members of the 21 product development studies who courteously and freely gave their time so that we might present a detailed and relatively accurate picture of the events in the development of some exemplary educational research and development products. If we have chronicled a just and moderately complete account of the birth of these products and the hard work that spawned them, credit lies with those staff members of each product development team who ransacked memory and files to recreate history.

TABLE OF CONTENTS

LIST OF FIGURES

PRODUCT DESCRIPTION

Product Characteristics

Name

Science Curriculum Improvement Study.

Developer

Science Curriculum Improvement Study Project, headquartered at the University of California, Berkeley.

Distributor

Commercial publisher involvement began in 1965 when D. C. Heath contracted to publish the preliminary editions of the SCIS program; American Science and Engineering, Inc., was the apparatus manufacturer selected. In 1968, D. C. Heath decided they no longer wished to publish the SCIS materials. In 1969 Rand McNally contracted to publish the final editions. All final editions will be published by 1972, after which Rand McNally will retain exclusive rights to publish the SCIS materials for five years. Then, the entire program becomes public domain.

Focus

The focus of the SCIS program is on developing a framework of fundamental scientific concepts that are related to the student's own experience with natural phenomena. The attainment of this functional framework so that it provides a basis for assimilating further information is referred to as "scientific literacy."

Grade Level

Grades one through six (1-6).

Target Population

The target population consists of all students capable of learning in typical classroom settings in grades one through six. Because the program is designed to foster experiences and the total involvement of students, it has some claim to be appropriate for the disadvantaged student.

Rationale for Product

Long Range Goals of Product

By 1972, the developers of the SCIS program plan to have readied for adoption the final editions of 12 science units, six units for a physical science sequence and six for life sciences. At present, approximately one-half of these units are available in final editions. Three additional project goals include:

1. The development of evaluation supplements for each of the 12 units. These supplements are being designed to assist teachers in evaluating the performance of students.

2. The development of optional units which may be used as remedial/enrichment, or simply as the basis for a more extensive program.

3. The diffusion of the SCIS program. SCIS staff plan to support the future diffusion activities of the commercial publisher.

Objectives of Product

The general learning goal is the attainment of "scientific literacy," i.e., learning the abstract, conceptual structure of sciences, and being able to interpret this new information as though the student himself had discovered it. Objectives include performance of the processes of scientific investigation and observation and data recording skills.

The general affective goals are the development of an inquiry and evaluative attitude about science and the development of independent thinking.

Each of the 12 units is diveded into parts. For example, the unit on Organisms is divided into six parts. For each part, the teacher's guide lists learning objectives. Such objectives are not presented in any of the student materials. Typical objectives in a teacher's guide include:

1. "To understand the term habitat and to use it to refer to a place where an organism lives."

2. "To draw conclusions from group data."

3. "To collectively propose and test hypotheses about the changes in the material on the aquarium bottom."

4. "To recognize and describe birth, reproduction, death, feeding, growing, and other events occuring in aquaria."

Strict behavior specificity was neither intended by the developers, nor achieved.

Philosophy and Theories Supporting Product

The developers of SCIS drew primarily from the works of Piaget and Bruner. The influence of the former is evident in both the sequence of activities across units, e.g., from grades 1-6, and the teaching/learning cycle recommended within units.

The SCIS staff reviewed three positions on learning as relevant to the development of their product. They interpreted these three as:

1. "Learning-by equilibration" theory, associated with Jean Piaget, views the individual using mental operations within a self-sustaining feedback loop (equilibrium) as he acts on his environment and receives stimuli in return. When the feedback loop is disturbed by events that don't fit the scheme (disequilibrium), changes in the mental operations ultimately lead to more powerful mental operations that can cope successfully with a larger class of events (equilibrium).

2. "Learning-by-discovery" theory which implies that the capability of the learner is latent within him. Given a sufficiently rich environment, the learner will discover the properties of objects, conditions under which phenomena take place, and general principles relating the isolated incidents and observations in his experiments and investigations. On the basis of this theory, SCIS developers felt that an educational program must give the student opportunities to express latent tendencies, but should not provide any input that might inhibit or redirect his natural inclinations.

3. "Learning-by-conditioning" theory which views the learner's behavior as a response to a well-planned stimulus. With repetition, practice and suitable reinforcement, the learner will exhibit the desired behavior. Within this theory, SCIS developers perceived no room for spontaneous or creative expressions by the student, and that outcomes of educational value had to reflect the inputs accumulated during the teaching program.

The developers distinguished between two aspects of the program: the experiential (i.e., student experience with a wide variety of phenomena, including their acting on the materials involved) and the conceptual (i.e., introduction of the student to approaches which scientists find useful in thinking about the phenomena they study.

On the basis of the three positions regarding learning and development, and in light of the distinctions between the experiential and conceptual aspects of the program, SCIS arrived at a prescription for designing instructional units.

The developers of SCIS conceived a teaching/learning cycle with three phases: (1) exploration, referring to self-directed, unstructured investigation; (2) invention, referring to the introduction of a new integrating concept by teacher or by learner, a concept previously invented by a scientist; and (3) discovery, referring to applications of the same new concept in a variety of situations, partly self-directed, partly guided. Exploration, which allows the learner to impose his ideas and preconceptions on the subject matter to be investigated, is in accord with "learning-by-discovery" and "learning-by-equilibration." The student may come up with a successful new idea or may become confused. Invention is in accord with the "learning-by-equilibration" theory; introduction of a new idea suggests a way for the learner to resolve his disequilibrium. Discovery is in accord with "learning-by-equilibration" and with "learning-by-conditioning." Through repetition and practice of largely self-directed activities the learner resolves his disequilibrium by interacting with the experimental materials and by establishing a new feedback pattern for his actions and observations.

In order to reach the objective of scientific literacy, SCIS developers felt that the science curriculum had to provide students with experiences that are different from their usual ones. Furthermore, these experiences should be direct and concrete, not told by a teacher or read in a book. However, it was also apparent that there should be substantial guidance and discussion, and sufficient opportunity to relate the unusual experience to the more usual experience. In this way, the abstract concepts that are at the basis of the scientific point of view could be built up. As the children made further observations they would look at them more scientifically. The abstractions would form a link between their earlier experiences and later experiences, so that the children would bring their knowledge to bear in a systematic way.

Thus, a stress upon direct experience, upon the processes of science, and upon the concepts of science was indicated.

Description of Materials

Organization of Materials

The SCIS program consists of 12 units, six units for a physical science sequence, and six for a life science sequence. The unity of the physical science sequence derives from fundamental concepts of change and interaction. The six basic units--Material Objects, Interaction and Systems, Subsystems and Variables, Relative Position and Motion, Energy Sources, and Models: Electric and Magnetic Interactions--introduce and develop the four scientific and the four process-oriented concepts considered necessary for scientific literacy. The units in the life science sequence focus on organism-environment interactions. The six basic units--Organisms, Life Cycles, Populations, Environments, Communities, and Ecosystems--make use of the scientific and process-oriented concepts but add the special considerations appropriate to the study of life. The Ecosystems unit attempts a synthesis of the children's investigations in physical and life science. Figure 1 shows the six levels of the SCIS program along with the concepts introduced in each unit. Optional units are being planned to extend the basic sequences in physical and life science. Either the physical or life science program may be used independently. Within a subject area program, the units are designed to be sequentially presented, not as independent modules or components. Each sequence of six units roughly corresponds to the 1-6 grade level sequence.

Format of Materials

The SCIS materials reach the classroom in the form of kits. The kits have been designed to simplify and make convenient the use, storage and reuse of the required equipment and supplies. Each kit is packaged for a teacher and 32 children and contains all of the materials needed except standard classroom supplies, such as crayons and scissors, and the freshwater organisms which are sent separately when requested by the teacher. For each unit, there is a teacher's guide, and in most cases a student manual. The teacher's guides include the following:

1. An explanation of the SCIS conceptual framework.

2. A program overview for the particular unit or sequence.

Figure 1

The Six Levels of the SCIS Program With Major Concepts Introduced in Each Unit

LIFE SCIENCE

Organisms

- organism
- birth
- death
- habitat
- food web
- detritus

Life Cycles

- growth
- development
- life cycle
- genetic identity
- biotic potential
- generation
- plant & animal
- metamorphosis

Populations

- population
- predator
- prey
- community
- plant eater
- animal eater
- food chain
- food web

Environments

- environment
- environmental factor
- range
- optimum range

Communities

- photosynthesis
- community
- food transfer
- producers
- consumers
- decomposers
- raw materials

Ecosystems

- ecosystem
- water cycle
- food-mineral cycle
- oxygen-carbon dioxide cycle
- pollutant

PHYSICAL SCIENCE

Material Objects

- object
- property
- material
- serial ordering
- change
- evidence

Interaction & Systems

- interaction
- evidence of interaction
- system
- interaction-at-a distance

Subsystems & Variables

- subsystem
- evaporation
- histogram
- solution
- variable

Relative Position & Motion

- reference object
- relative position
- relative motion
- reference frame
- polar coordinates
- rectangular coordinates

Energy Sources

- energy transfer
- energy chain
- energy source
- energy receiver

Models: Electric and Magnetic Interactions

- scientific model
- magnetic field
- electricity

3. Clues for the teacher--explanation of the learning cycle, exploration/invention/discovery; how to implement the learning cycle; use of discussions, questions and feedback; the student manual; language development; and optional activities.

4. Design and use of the kit.

5. Major parts of the unit--series of chapters are combined to form parts of the unit. Preceding each series of chapters there is a list of objectives for that part of the unit, background information, an overview, and how the student manual can be used.

6. Chapters--for each chapter, learning objectives, teaching materials needed, advance preparation required, teaching suggestions, and optional activities are described or noted.

The student manual is one of the teaching aids and is not designed as a mainstay of the course. During some activities, the students record information about their experiments in their manual, for later discussion. The manual also contains some problems for the children to solve independently, and some for class discussion. Much of the manual would not be useful in the absence of the classroom activities. When a student manual is used, the objectives for using the manual are spelled out for the teacher in the teacher's guide.

A kit is portrayed in Figure 2. The front of each drawer of the kit is numbered. A diagram of a kit, listing the contents of each drawer, appears at the top of the box. The kit diagram is reproduced at the beginning of each chapter of the teacher's guide, associated with the list of teaching materials required for that chapter.

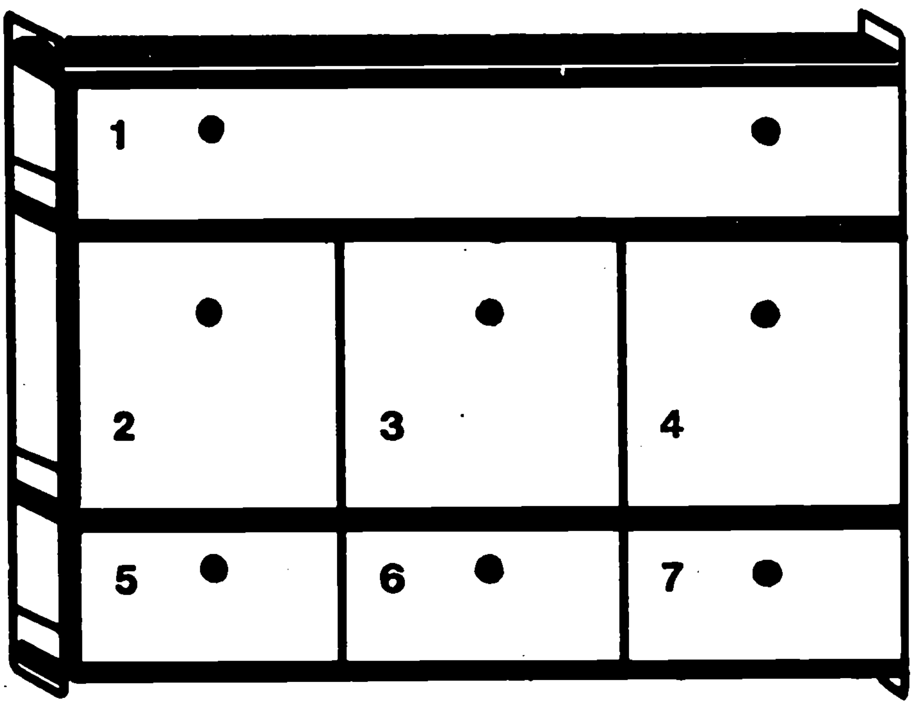
Content of Materials

Central to the SCIS program is the view that changes take place because objects interact in reproducible ways under similar conditions. In the SCIS program, "interaction" refers to relations among objects or organisms that do something to one another, thereby bringing about a change. Students can observe change and use it as evidence of interaction. As they advance from a dependence on concrete experiences to the ability to think abstractly, students identify the conditions under which interaction occurs and predict its outcome. The four major scientific concepts the SCIS program uses to elaborate the interaction viewpoint are matter, energy, organisms, and

Figure 2

Diagram of an Example Kit

Kit



Key

Drawer		Item Description & Quantity
1	Planter Materials	36 planter cups 36 planter bases 2 light sources 4 packages seeds 3 water sprinklers 16 paper plates 1 roll labels
2	Aquaria	6 one-gallon plastic containers
3	Aquaria	6 one-gallon plastic containers
4	Aquaria	6 one-gallon plastic containers
5	Aquaria Materials	1 bottle plant nutrient 2 dip nets (coarse & fine) 32 plastic tumblers 16 magnifiers 1 package fish food 2 living-material order forms (A & B) 16 medicine droppers
6	Filtering Materials	1 baster 1 roll labels 16 plastic funnels 1 package cotton balls
7	Small Containers	70 plastic bags 70 twistems 16 plastic tumblers 22 vials

Other Materials

Sand and Soil Box:

1 bag soil (12 lb)
2 bags white sand (16 lb/bag)

Shipment A:

10 male guppies
26 female guppies
18 pond snails
12 sprigs *Anacharis*
12 sprigs eelgrass
1 jar duckweed
1 jar *Chlamydomonas*

Shipment B:

3 jars *Daphnia* culture

ecosystem. Students' experiences and investigations in the physical science sequence are based on matter and energy; organism and ecosystem provide the framework of the life science sequence. In addition to these scientific concepts, four process-oriented concepts--property, reference frame, system, and model--are used. These, together with others that relate to specific units, are of the heart of the processes of observing, describing, comparing, clarifying, measuring, interpreting evidence, and experimenting.

Cost of Materials to User

Each unit, packaged in a kit for a typical classroom, costs between $150 and $200. The cost of a unit per pupil for the first year is approximately $5. This varies depending on whether the units are shared among teachers. In subsequent years, the cost per pupil decreases as the "permanent" parts of each unit can be reused.

Procedures for Using Product

Learner Activities

The SCIS program is designed to foster direct laboratory kinds of experiences. The elementary classroom actually becomes a laboratory. In their first explorations of a new concept, the students manipulate or observe selected materials, sometimes freely, sometimes under the guidance of the teacher. The student is confronted by the systems of objects he chooses, or which are chosen from the environment. He watches the objects and what happens to them. At this point, he does not know the instructional objective or the intended scientific concept. The observations are individual and are based on the student's direct experience with phenomena rather than on his reading about or talking about science. The student is intimately involved in the experience, and may or may not be able to report what he has observed. As the next step, the teacher introduces the scientific concept that describes or explains what the students have observed; this is called the "invention" lesson. Thus, the student is presented with a concept only after he has had some relevant experience on which his understanding of the concept can be based. The concept may be introduced through a lecture, a demonstration, or audiovisual presentations. Students answer or ask questions and discuss ways in which the concept relates to their own experience. Following the invention lesson, other experiences are provided that present further examples of the concept. These are called "discovery" lessons. Through this procedure, the child is expected to recognize the applications of the new concept to situations other than the initial example. The students observe, describe, and conduct experiments. They discuss their activities with peers and the teacher. Thus, the discovery experiences reinforce, refine, and enlarge upon the concept.

The units are designed so that students can complete one unit per semester, or two per school year, provided they spend at least 45 minutes per day, two days per week working on the units. Students participate in both group and individual activities. While the objectives are well specified in the teacher's guide for each student activity, these objectives are never presented to the student. SCIS developers were afraid that presenting the student with the objective would hinder the exploration and experiential aspects of learning; that students might learn the specific objective and, consequently, their learning would be limited. Students obtain feedback through group discussions and interactions with the teacher, e.g., when reviewing work in the student manual. Motivation is primarily intrinsic, e.g., working with live animals and real objects.

Teacher Activities

The SCIS classroom is considered a laboratory in which students can make discoveries and gain experience about natural phenomena. Consequently, the teacher is a leader whose job is not primarily to tell children about science or to listen to them while they read about science, but to observe and offer guidance to students while they are individually involved with science. The students work, and their observations and questions are used by the teacher for planning subsequent science activities. The teacher needs to be sensitive to where the student is and respond in a fashion that enables the student to move ahead. The teacher provides conceptual "inventions," but these are always followed by extensive opportunities for student centered "discovery" experiences.

The teacher's role differs, depending on which stage of the three phase teaching/learning cycle is emphasized. Exploration requires that the teacher remain in the background, observing and occasionaly answering questions. During invention, the teacher is more active. During discovery, the teacher's role is primarily to ask facilitating questions and to respond to student questions in ways that facilitate further inquiry.

Although SCIS does not specify that teachers have a science major or graduate degree preparation, the proposed teacher role in the three phase strategy requires skills other than traditional ones. To teach the SCIS programs effectively, the developers recommend that the teacher should have the confidence to venture into new areas and to try new approaches with children; the teacher should have sufficient background understanding of science and the SCIS program to move with students along divergent, as contrasted to the more usual, paths; and should have the sensitivity and insight to recognize the possible importance of various responses to students. A strong emphasis upon in-service training has been maintained by the developers who have established a training program at SCIS headquarters in Berkeley. The present publishers, Rand McNally, are planning an in-service training program. Previous in-service training programs, such as SCIS Awareness Conferences, Cooperative College-School Science Programs, and Summer Leadership Training Programs, have been designed and made available through either the publishers, developers, or colleges. Training prerequisites to installation are discussed later in this report under Installation Procedures.

Provisions for Parent/Community Involvement

No specific provisions for parent/community involvement have been made. However, SCIS differs from conventional science programs in goals, student activities, classroom noise level, and deportment to such an extent that parent/community information is recommended.

Special Physical Facilities or Equipment

No special facilities or equipment other than that provided are required for utilizing the program. While a well equipped laboratory room would be advantageous, all that is required is a room with an electrical outlet and a sink. Some space may be needed for storing the unit kits.

Recommended Assessment Techniques for User

Presently the teacher's guide is the only recommended source for assessment procedures. As noted earlier, this guide provides cues for the teacher for all phases of the science program, including evaluation and feedback to the student. Evaluation supplements for each unit, the development of which began in the spring of 1971, are scheduled to be completed in 1972. Activities in the evaluation supplements will be similar to those currently contained in the units.

At present, the teacher has four sources for assessment:

1. Observation of student activities, e.g., the student's performance, responses to questioning, handling equipment, etc.

2. Review of written work prescribed in the student manual.

3. Use of the review exercises as assessments.

4. Re-stating objectives from the teacher's guide into questions for assessment.

ORIGINS

Key Personnel

Robert Karplus, a professor of physics at the University of California, Berkeley since 1958, originated and continues to direct the project. Karplus has been the driving force behind SCIS from its beginning in 1958. Herbert Thier, an experienced educational administrator and an early experimenter with the SCIS science program, has been the assistant director of the project since 1963. Chester A. Lawson, who left his post as research professor of natural science at Michigan State University in 1965 to construct the SCIS life science program, is director of development in the life sciences for SCIS.

In addition, many science educators, curriculum specialists, and teachers have contributed to the actual writing of the units and have participated in tryouts and implementation of the units in the classrooms.

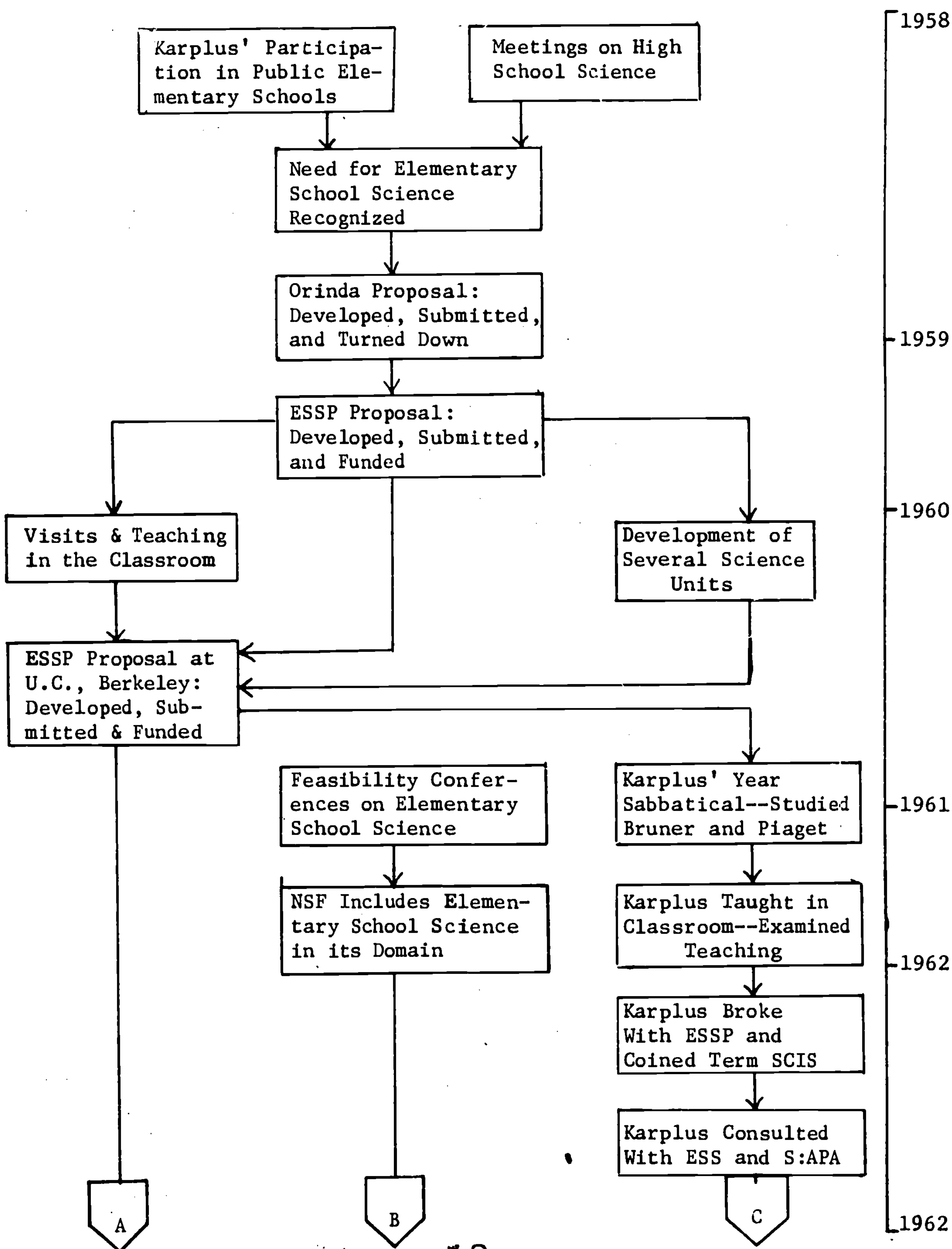
Sources and Evolution of Ideas*

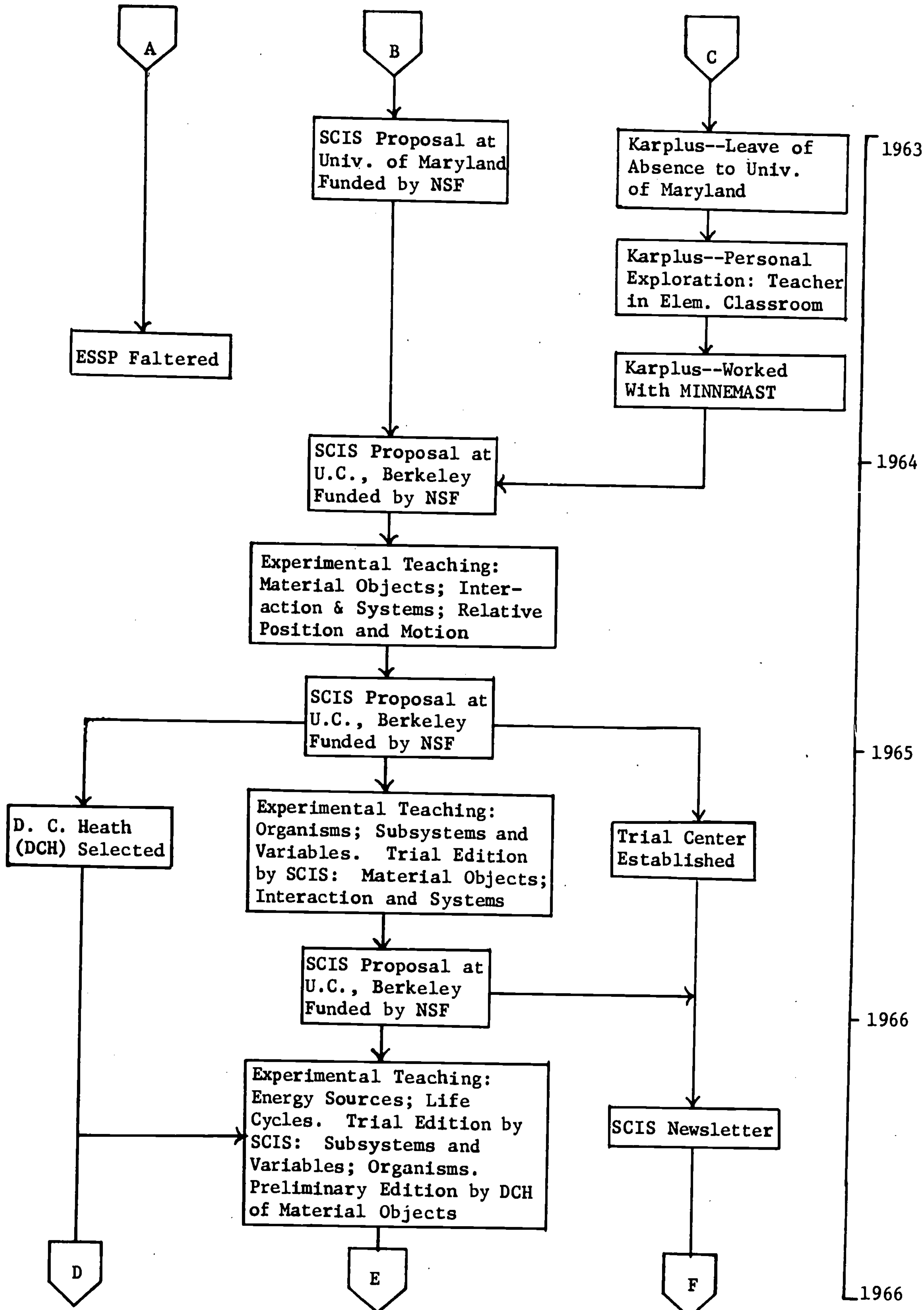
In the late 1950's, following the beginning of the General Education Movement and the Sputnik furor, meetings were held across the nation to discuss the adequacy of teaching science in high schools. Robert Karplus, Professor of Physics at the University of California at Berkeley, attended some of these meetings. He was impressed by the complaints made by the high school teachers who attended the meetings. These science teachers

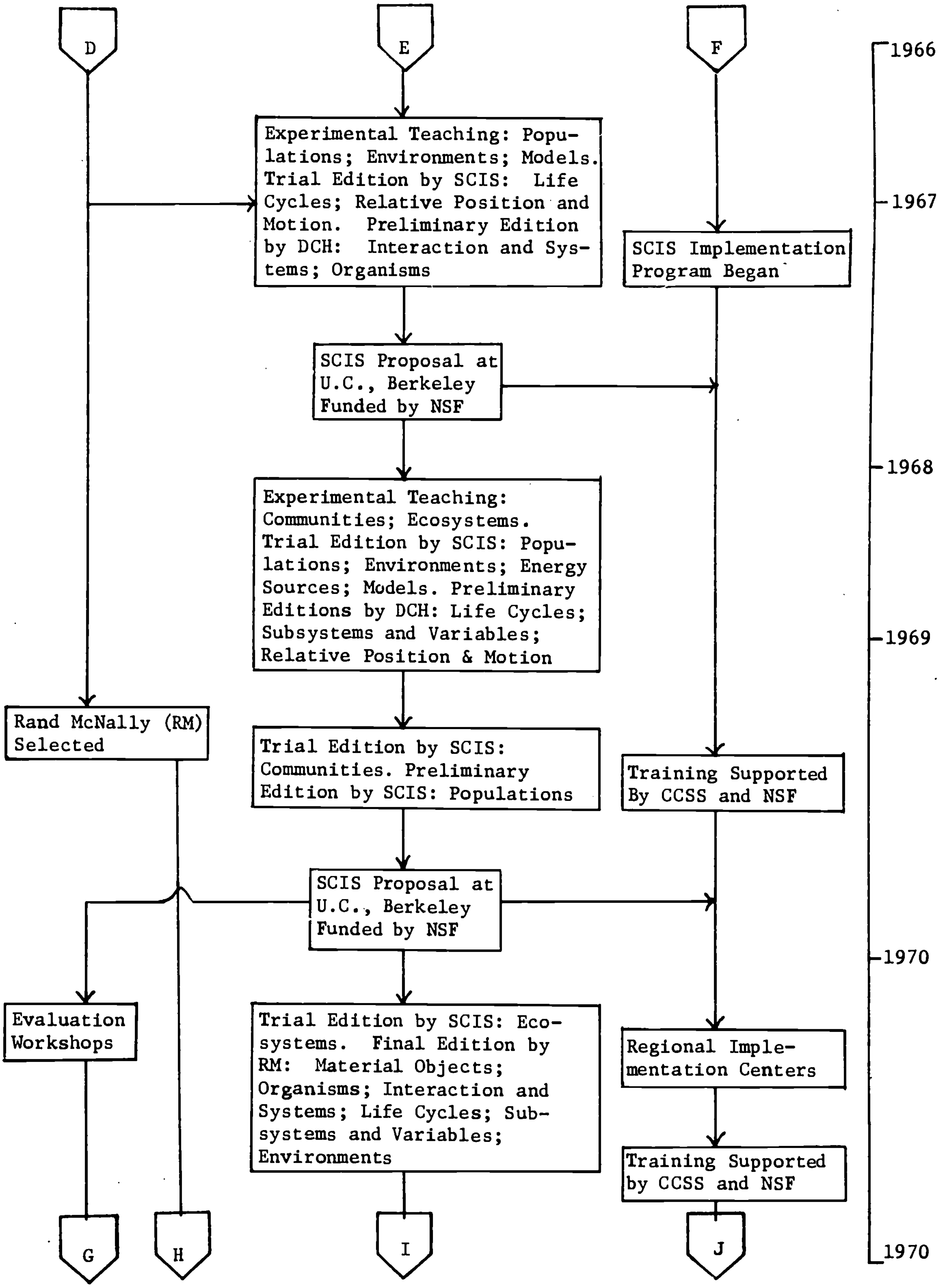
*See Figure 3 for a diagram of the major events in the history of the product.

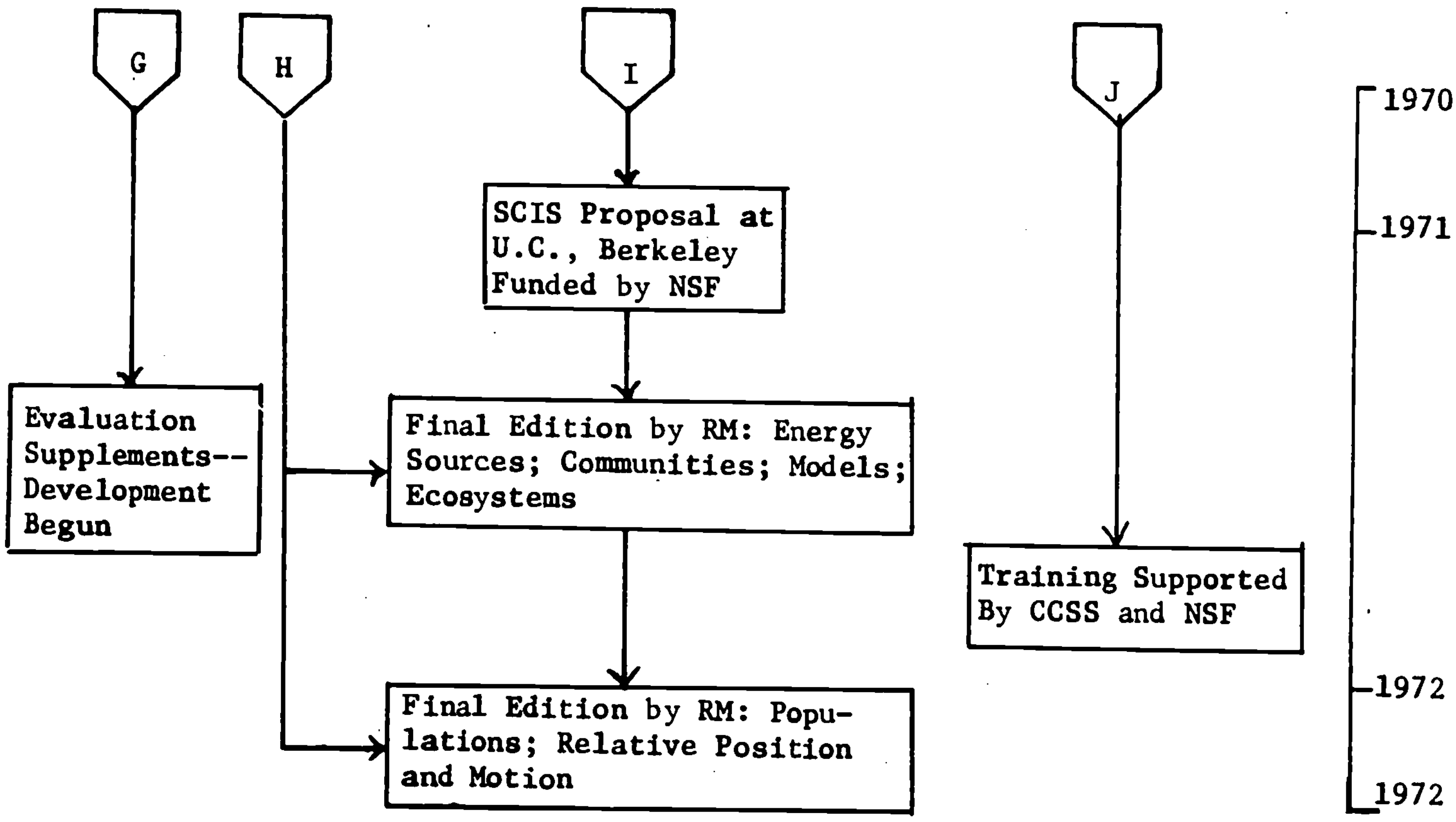
Figure 3

Major Event Flow Chart




A
B
C
SCIS Proposal at Univ. of Maryland Funded by NSF
Karplus--Leave of Absence to Univ. of Maryland
1963
Karplus--Personal Exploration: Teacher in Elem. Classroom
ESSP Faltered
Karplus--Worked With MINNEMAST
SCIS Proposal at U.C., Berkeley Funded by NSF
1964
Experimental Teaching: Material Objects; Interaction & Systems; Relative Position and Motion
SCIS Proposal at U.C., Berkeley Funded by NSF
1965
D. C. Heath (DCH) Selected
Experimental Teaching: Organisms; Subsystems and Variables. Trial Edition by SCIS: Material Objects; Interaction and Systems
Trial Center Established
SCIS Proposal at U.C., Berkeley Funded by NSF
1966
Experimental Teaching: Energy Sources; Life Cycles. Trial Edition by SCIS: Subsystems and Variables; Organisms. Preliminary Edition by DCH of Material Objects
SCIS Newsletter
D
E
F
1966


D
E
F
1966
Experimental Teaching: Populations; Environments; Models. Trial Edition by SCIS: Life Cycles; Relative Position and Motion. Preliminary Edition by DCH: Interaction and Systems; Organisms
1967
SCIS Implementation Program Began
SCIS Proposal at U.C., Berkeley Funded by NSF
1968
Experimental Teaching: Communities; Ecosystems. Trial Edition by SCIS: Populations; Environments; Energy Sources; Models. Preliminary Editions by DCH: Life Cycles; Subsystems and Variables; Relative Position & Motion
1969
Rand McNally (RM) Selected
Trial Edition by SCIS: Communities. Preliminary Edition by SCIS: Populations
Training Supported By CCSS and NSF
SCIS Proposal at U.C., Berkeley Funded by NSF
1970
Evaluation Workshops
Trial Edition by SCIS: Ecosystems. Final Edition by RM: Material Objects; Organisms; Interaction and Systems; Life Cycles; Subsystems and Variables; Environments
Regional Implementation Centers
Training Supported by CCSS and NSF
G
H
I
J
1970


G
H
I
J
1970
SCIS Proposal at U.C., Berkeley Funded by NSF
1971
Evaluation Supplements--Development Begun
Final Edition by RM: Energy Sources; Communities; Models; Ecosystems
Training Supported By CCSS and NSF
1972
Final Edition by RM: Populations; Relative Position and Motion
1972

were irritated and perplexed by how unprepared in science students were when they entered high school. The meetings were held to discuss new high school science programs, but at the time, Karplus was wondering how valuable such programs would be if students continued to be so ill-prepared when they reached high school. He felt that if previous instruction was that deficient, a one- or two-year high school course would not be a remedy.

At this time, Karplus was becoming reacquainted with the public schools. Two of his children were in the early grades of elementary school where teachers and students were desperate for someone to help in the teaching of science. Karplus was invited to participate in "show and tell" sessions at the elementary school attended by his children. This experience was enjoyable for Karplus, and presumably the students.

After hearing the high school teachers' reflections on inadequate preparation of students and having personally taught in elementary school classrooms, Karplus concluded that there was a need for the improvement of science instruction at the elementary level. Consequently, in the summer of 1958, Karplus and a group of U.C. scientists and educators submitted a proposal, "A Proposal for Research and Action in the Field of Elementary School Science Teaching in the Orinda Union School District," to the National Science Foundation. The Orinda Union School District is located near the University of California at Berkeley. Total funds requested for the period of April 1959 through June 1962, were $150,000. Karplus proposed to do the following: (1) to experiment with content, methods and materials for elementary school science with the aim of establishing a comprehensive curriculum; (2) to develop in-service training programs for Orinda teachers; and (3) to identify gifted students. The project was not funded. NSF felt, at the time, that its contribution needed to take the form of a national effort developed by the scientific community to improve the curriculum and programs, like summer institutes sponsored by colleges and universities to give teachers more knowledge of science. Since discussions which eventuated in a basic curriculum study were in progress, NSF felt it would be wise to wait until a comprehensive program had been formulated before small-scale variants like Karplus' should be considered. Furthermore, NSF up to this time had given grants only to universities and could not give money to elementary schools.

In the spring of 1959 Karplus, et al., prepared and submitted another proposal to NSF. This time the proposal was submitted through the University of California at Berkeley, rather than through a school district. The project, "Proposal for a Study of Course Content Improvement in Elementary School Science," was to be conducted from July 1959 through June 1960, with total funds of $43,000. During the first year, the principal investigators proposed to initiate the experimental development of a science curriculum for grades 1-8, emphasizing an understanding of a small number of important ideas underlying natural phenomena which could be studied by appropriately graded observational and analytical activities. More specifically, they proposed to construct a conceptual framework for the science curriculum, to prepare sample teaching units, to conduct an evaluation of the effectiveness of the materials, and to adopt the materials for use in training teachers. The project was funded: the first money NSF contributed to elementary school education. Up to that time, the U.S. Office of Education had provided the monies for elementary school education. By this time, such science education developments as the School Mathematics Study Group (SMSG), Biological Sciences Curriculum Study (BSCS), Physical Science Study Committee (PSSC), and Chemistry Study (CHEM), all funded by NSF, were proceeding at the secondary level.

During the 1959-60 school year, Karplus was a full time professor at the University of California at Berkeley. All of his work on the Elementary School Science Program (ESSP) was done during spare time. This was the case for all of the principal investigators of ESSP. Karplus believed that personal contact in the classroom might be helpful, a minority view, and actually visited classrooms during the 1959-60 school year. In fact, Karplus taught regularly in the elementary classroom and explored, through his teaching, what children were able to do. Several of the investigators, including Karplus, developed science units, but Karplus was the only one who persistently used classroom experience as the basis for product development. After his experience with developing units and teaching in the classroom, Karplus concluded that personal experience in the classroom was not only desirable, but mandatory for anyone to develop an effective science unit. Teachers could report some aspects of instruction, but frequently they were oblivious to many of the critical scientific procedures or concepts.

In the spring of 1960, Karplus extensively discussed his interest in, and ideas about, elementary school science with J. B. Conant. He especially emphasized his beliefs that developers must spend time in the classroom to check out their ideas, and his beliefs about students becoming scientifically literate. Conant was at that time tuning in to the social and economic issues concerning education in the slums and the cities. Karplus was informed that his efforts were idealistic and might only hinder the handling of the more critical social and economic matters. In short, Conant felt that Karplus' plan for elementary school science might be destructive or, at best, a waste of time. Karplus, who was not aware of national school needs, had hoped that Conant would view the elementary educational needs at the national level just as he had perceived them at his local level. Karplus was disappointed in Conant's reaction, but was stubborn and continued his own direction.

In June 1960, Karplus left for a long planned sabbatical at the University of Vienna. This interval and separation from the day-to-day pressures at the University of California enabled him to review the first year's experience and to reformulate his thinking about science education. He was also able to read articles and books by Bruner and Piaget. At this time, the American Association for the Advancement of Science, with the support of NSF, sponsored feasibility conferences of scientists, teachers, school administrators, and psychologists to determine whether the nation should undertake a concerted effort of curriculum improvement in elementary school science. During these conferences, it was concluded that instruction in science should be a regular part of the curriculum from kindergarten through the ninth grade, that a major effort should be undertaken, and that this effort should involve improving both course materials and classroom teaching. Plans were made to develop two or three major science programs in the United States.

The ESSP, meanwhile, continued in Berkeley under the interim direction of Karplus' colleagues and subject to certain understandings between NSF, the Chancellor of the University, and Karplus. However, before Karplus' return to Berkeley in the fall of 1961, the direction of the project was altered without his knowledge. The project began to pursue a course which Karplus considered unpromising and even threatened to prevent him from continuing according to his own ideas. Karplus' colleagues felt that personal classroom participation by product developers was neither essential nor desirable. Furthermore, ESSP was now aiming toward a less structured approach than Karplus believed optimal.

A proposal had been funded for the 1961-62 school year to continue the work of ESSP. However, upon returning to Berkeley in the fall of 1961, and discovering the change in direction taken by the project, Karplus felt he should start his own independent activities. He again practiced teaching in the classroom and formulated his ideas about two phases of the learning cycle that he was to discuss later, "discovery" and "invention." He now used audio and video equipment to help him examine his teaching more closely than he had previously. By the winter of 1962, Karplus had completely dissociated himself from the ESSP and had formed a new group called the Science Curriculum Improvement Study (SCIS). It was clear to him at this point that his colleagues wanted nothing to do with his ideas on instructional development. Karplus considered leaving the University.

In the fall of 1961, NSF had officially included elementary science in the domain of its responsibility. By the summer of 1962, the Elementary Science Study (ESS) and Science: A Process Approach (S: APA) had been granted substantial NSF funds; these were two of the three major science programs planned during the feasibility conferences. During the summer of 1962, Karplus served as a consultant for ESS and S: APA and was able to observe the directions these projects were taking and to try out some of his own ideas.

Recognizing the need to reinforce the separate identity of the SCIS group, Karplus took a leave of absence from the University of California and placed the SCIS headquarters at the University of Maryland where he was visiting professor during 1962-63. When planning for this leave of absence, Karplus submitted a proposal to NSF to continue his work while at the University of Maryland. In the fall of 1962, the grant from NSF came through. This was the first time that any of Karplus' salary was paid by a grant; up to this time, he had been a full time professor who kept the elementary science curriculum work alive by overtime efforts. Karplus used the year at the University of Maryland for more exploration and teaching of young children in the public schools. SCIS was still a primitive operation. No units or products were being planned or developed. Only a few people, including Herbert Thier who began working with Karplus in 1963, were involved with SCIS.

In the winter of 1963, MINNEMAST was funded by NSF and became the third major elementary school science program. Karplus was invited to become the director of science for the summer of 1963 with MINNEMAST. During this time, he was able to further develop and try out his ideas. The stop at MINNEMAST was made on his return to the University of California at Berkeley. Karplus had concluded that he could not remain at the University of Maryland, even though welcome, as he could not develop a unique science project there, since S: APA was being developed in the same area. At this time ESSP at Berkeley was faltering and presented no obstacles to SCIS.

After making the decision to return to Berkeley, Karplus and his staff developed a proposal to continue his work on SCIS. When he returned to Berkeley in the fall of 1963, the grant from NSF was approved. Thus, Karplus could continue his work, but he was now at a critical decision point. NSF had been supporting his exploratory work for four years and now wanted him to either plan on phasing out his exploratory work and expect no more funds, or put SCIS on a larger scale with a more permanent footing and with clearly specified plans to produce materials. No units or materials had been produced since those originally developed in 1959. It was now becoming apparent that further development required children in the program for more than one year. The sequential objectives required the involvement of second grade students who had completed the first unit of SCIS, etc. This would require materials that other teachers could use; Karplus and staff could not teach all students.

Funding for Product Development

All support for the SCIS science program was obtained from NSF. When the 12 units are completed in 1972, the total funds allocated since 1962, when SCIS was established, will equal approximately $4 million.

Funds were acquired from NSF through a series of proposals; each succeeding proposal was designed to continue the work initiated or completed in the previous project. Thus far, proposals were funded in 1963, 1964, 1965, 1966, 1967, 1969, and 1971.

Expenditures of these funds can be analyzed in either of the following ways:

1.	Overhead	25%	$1,000,000
	Personnel	55%	2,200,000
	Supplies/travel	20%	800,000
2.	Development	80%	3,200,000
	Evaluation	5%	200,000
	Diffusion	15%	600,000

The above figures were obtained from the development group.

PRODUCT DEVELOPMENT

Management and Organization

The Science Curriculum Improvement Study is headquartered at the Lawrence Hall of Science, University of California, Berkeley. Although a large part of the University's resources are devoted to scientific research, many individual faculty members have demonstrated their deep interest in improving the public understanding of science. For example, former Chancellor Glenn T. Seaborg and Professor George Pimentel participated in the CHEM Study, Professors Harvey White and John Kelley have conducted programs such as "Continental Classroom," Professor Richard Powell developed a classroom television series "What's the Matter" for the upper elementary grades, and Professor White is director of the Lawrence Hall of Science. These and other faculty members have assisted the Science Curriculum Improvement Study in the past and continue to furnish counsel as members of an Advisory Board.

To supplement the resources of the University of California at Berkeley, trial centers affilitated with other institutions were organized. The center at Teachers College, Columbia University, has played a significant role in developing in-service education for teachers. Other trial centers include: Michigan State University; University of California at Los Angeles; University of Hawaii; and University of Oklahoma. The centers operate their own programs, but submit reports containing subjective teacher and student feedback on the SCIS materials.

Staff at the project headquarters includes: the director, the assistant director, the Director of Life Sciences, a coordinator, physicists, botanists, chemists; biologists; specialist teachers, research psychologists, laboratory assistants, production staff, research assistants, and secretaries. Additional staff have been appointed at the trial centers and numerous consultants have been appointed at the trial centers and numerous consultants have contributed to the development of the SCIS program.

Original Development Plan

As originally proposed in the early 1960's, the SCIS program was a small scale project designed to explore a novel approach to the teaching of elementary school science. The major objective of the program was to help students develop "scientific literacy." Any large scale reorganization of elementary science was to be guided by three considerations: (1) the conceptual hierarchy or structure of science; (2) the maturity of the students; and (3) the students' existing concepts of natural phenomena. The project was to be an exploratory investigation in which ideas about desirable science education could be tested through experimental teaching in the classroom.

Then, the SCIS project moved from an exploratory investigation to product development. These characteristics of the SCIS project now formed a basis for the development plan. Senior scientists, personally committed to curriculum experimentation and materials production, were giving leadership to the project. A conceptual structure of science was providing the framework of the curriculum plan. The new materials were being tried in schools with teachers and children who were to participate in the development year after year.

While it was anticipated that the exact nature of the units would evolve slowly, the original development plan did specify that work on units would progress roughly as follows:

1. Preparation of a teaching plan and design of experiments.
2. Exploratory teaching by SCIS staff members.
3. Completion of unit, including student manuals and apparatus.
4. Classroom trial of unit by SCIS staff and by regular teachers in local area laboratory schools (1 to 2 years).
5. Revision of the unit in light of experience.
6. Preliminary commercial publication.
7. Classroom trial in several centers across the United States (2 to 3 years).
8. Revision and final commercial publication.

Modifications of Original Development Plan

The original development plan was followed closely. The original objectives of the project and the basis for organizing and developing the science curriculum remained constant. However, some modifications were made. First, the exact nature of the units constantly changed as concepts were added, modified, or dropped, and as the intellectual achievements of the students became more clear. Thus, the curriculum structure evolved; and more specific questions, such as "How many units to develop?" or "How should the units be sequenced?" were answered as development progressed. Whether to include a life science program was not actually answered until the summer of 1965. The developers had originally considered the possibility of developing only physical science units. The last five units developed were developed on a much tighter schedule than originally planned. For these units, there were no preliminary editions and consequently the amount of time spent on tryouts was substantially reduced.

Actual Procedures for Product Development

Development

The development of science units was begun in the fall of 1963 and will be completed in the spring of 1972. The science program was subdivided into units; however, each unit could not be developed in isolation from the others because of the units' strong interdependence at the conceptual level. This conceptual interdependence has been noted as one of the distinguishing characteristics of the SCIS program, and has been thought to be its most significant contribution to the intellectual growth of the pupils. Interdependence of units necessitated complicated, lengthy, and formal trial procedures which depended on the availability at each grade level of pupils who had experience with the SCIS program in earlier grades.

Ideas and suggestions for unit topics and for instructional methods usually originated through staff discussions and through conferences and contacts with teachers and scientists. After discussion and analysis, approved ideas and suggestions were turned into units through the following process, as described by SCIS:

1. The SCIS staff prepared draft versions of several lessons--including design of a teaching plan, materials, and equipment for a unit based on the initial idea or suggestion.

2. The draft lessons underwent exploratory teaching at several schools in the Berkeley area.

3. On the basis of feedback from at least one year of exploratory teaching, the SCIS staff prepared a complete version (trial edition) of a unit, including teacher's guide, student manuals, teaching materials, and equipment kits.

4. Regular elementary school teachers conducted classroom trials of the unit in four Berkeley area schools for one to two years.

5. The SCIS staff reconsidered the unit as a whole on the basis of feedback from the first classroom trial on the usability of the unit and its materials. If necessary, the unit was revised and subjected to some additional exploratory teaching by SCIS staff.

6. Under the close supervision of SCIS staff, regular elementary school teachers in Berkeley then conducted a second classroom trial of the unit for another one to two years.

7. The unit was again revised by SCIS staff into a preliminary edition for commercial publication.

8. Classroom testing of the preliminary edition of the unit was again conducted in the Berkeley schools and also in five university trial centers for two to three more years. These centers are located at Michigan State University, Columbia University, University of California at Los Angeles, University of Hawaii, and the University of Oklahoma.

9. The unit was again revised by SCIS staff into a final edition. A 9-12 month period was typically required by the commercial publisher to prepare the final edition for publication.

Of the 12 units which will be completed in final edition by 1972, seven, when completed, will have gone through all of the above phases of development. The last five units were developed on a much tighter schedule. For these units there were no preliminary editions and, consequently, the amount of time spent trying them out in the classroom was reduced. The reason for speeding up unit development was primarily financial. The money for curriculum development, especially for science, was becoming less plentiful, and a more rigid time schedule for SCIS production resulted.

In most cases, the trial and revision procedures were quite time-consuming. For example, the first grade program had to be reviewed in light of the work done by the first-graders when they came to second or third grade, or even later. Classroom trials were also conducted for more than one year between revisions. This was thought necessary because, during the first year, the ideas and procedures of a unit were so novel to many teachers that their reactions were not indicative of actual difficulties in pedagogical design. Only with repetition, was it felt that teachers were able to plan instruction satisfactorily because then they knew what range of behaviors to expect from the pupils. Frequently, the feedback from one unit suggested changes in several other units, as well as changed in the unit under examination.

Many units (i.e., more than 12) were initiated. In some cases a unit (e.g., Populations and Communities) later became two units (e.g., Population, Communities). Sometimes a unit was developed (e.g., Recycling of Material) but lost its identity when it became part of another unit (e.g., Energy Sources). In some cases two units were developed for two groups of concepts, and then the concepts were switched from one group to the other; this was the case for Interaction and Systems and Subsystems and Variables. While a few of the original units were simply dropped, most of them eventually fed into one of the 12 units to be completed in 1972.

Karplus had always planned on developing physical science units, but was not always certain that SCIS would also develop life science units. Karplus and his staff then recognized that the SCIS program would be at a very serious disadvantage when competing for the market in public schools if a life science program was not included. In 1964, the decision to include a life science program was made, but until 1965 leadership to develop the program could not be found. In 1965 the first efforts to develop a life science program that would parallel the physical science program were begun--six years after the initiation of the physical science program.

The following is a summary outline indicating when four major phases (i.e., early experimental teaching, trial edition, preliminary edition, and final edition) for each of the 12 units took place. Additional exploratory teaching by project staff members took place in connection with the preparation of each subsequent edition and revision of the units.

1. Material Objects

Early experimental teaching: 1962-1963.

Trial editions published: November, 1963; September, 1964; August, 1965.

Preliminary edition published: June, 1966.

Final edition published: March, 1970.

2. Organisms

Early experimental teaching: 1964-1966.

Trial edition published: September, 1966.

Preliminary edition published: June, 1968.

Final edition published: May, 1970.

3. Interaction and Systems

Early experimental teaching: 1961-1963.

Trial editions published: October, 1963; March, 1966.

Preliminary edition published: July, 1967.

Final edition published: May, 1970.

4. Life Cycles

Early experimental teaching: 1965-1967.

Trial edition published: September, 1967.

Preliminary edition published: 1968.

Final edition published: November, 1970.

5. Subsystems and Variables

Early experimental teaching: 1964.

Trial editions published: September, 1964; February, 1966.

Preliminary edition published: 1968.

Final edition published: October, 1970.

6. Populations

Early experimental teaching: 1966-1967.

Trial edition published: March, 1968.

Preliminary edition published: 1969.

Final edition published: Planned July, 1972.

7. Relative Position and Motion

Early experimental teaching: 1961-1964.

Trial editions published: January, 1964; November, 1966; September, 1967.

Preliminary editions published: 1968, 1969.

Final edition published: Planned May, 1972.

8. Environments

   Early experimental teaching: 1967-1968.

   Trial edition published: September, 1968.

   Preliminary edition published: None.

   Final edition published: November, 1970.

9. Energy Sources

   Early experimental teaching: 1962-1964.

   Trial editions published: January, 1965; September, 1966; September, 1967; February, 1968; September, 1969.

   Preliminary edition published: None.

   Final edition published: June, 1971.

10. Communities

   Early experimental teaching: 1967-1969.

   Trial edition published: October, 1969.

   Preliminary edition published: None.

   Final edition published: July, 1971.

11. Models

   Early experimental teaching: 1966-1968.

   Trial edition published: September, 1968.

   Preliminary edition published: None.

   Final edition published: August, 1971.

12. Ecosystems

   Early experimental teaching: 1968-1969.

   Trial edition published: February, 1970.

   Preliminary edition published: None.

   Final edition published: August, 1971.

Formative Evaluation

Ideas for each unit first were discussed by the development staff. Then, through extensive formative evaluation procedures, these ideas were translated into the activities, materials, and equipment for the units. The formative evaluation activities for each unit, as suggested above, typically moved from discussion and testing of the exploratory version to classroom trial, revision, and retrial of the trail edition in the Berkeley, California, public schools, through the use of the preliminary edition in schools affiliated with the SCIS trial centers at five universities. These formative evaluation activities typically covered a period of about five or six years. Although many units are now available commercially, SCIS continues to gather additional feedback from the trial centers.

The information collected during the formative evaluation activities was derived from three main sources and was retrieved in several different ways. The main sources of information were the SCIS staff, teachers, and students. The information was retrieved through SCIS staff teaching and observing, from reports and conferences with coordinators of the trial centers, from written teacher reports, and from recorded student comments.

This information helped to determine which unit activities were interesting to students, which were appropriate to the students' level, which were relevant to the principles being taught, and which were producing the intended learning outcomes. On the basis of this feedback, the materials and equipment were revised and redesigned. Some units were completely or partially rejected, while others were integrated into other units.

To determine the extent to which students in trial classes understood the key concepts in a unit, special assessment measures for each unit were developed. Usually, individual oral tests were used at the lower grade levels, and paper and pencil tests were generally reserved for the upper elementary grades. Individual testing enabled the tester to probe the student to determine his capabilities. Control measures used on written tests were either of the pre-post sort or of an internal consistency sort, using data from all classes working with a unit to determine the relative performance of students.

SUMMATIVE EVALUATION

From 1959 through December, 1970, only formative evaluation, designed to determine the appropriateness of the science materials, was conducted. While the development staff frequently visited the classroom to see if students could use and learn from the materials, there was no formal evaluation conducted to compare the SCIS program with other science programs or to determine formally and exactly how well students were learning. Most of the development staff could see the progress students were making and felt that the students especially enjoyed the program; however, these perceptions were documented only for purposes of developing the units and to devise a more effective program, and not for summative evaluation.

An evaluation workshop was conducted in the spring of 1970, during which various feedback activities were compared and a multiphasic approach to evaluation was designed to focus on: content and process gain; intellectual developmental stages; interests and attitudes; and teacher self-images in SCIS instruction. The reason for initiating this formal evaluation was primarily based on feedback coming from the field; this information indicated that more structured support for teacher administered evaluation might be desirable.

In the spring of 1971, the development of evaluation supplements began. Their major purpose will be to serve the teacher if she needs external assistance to evaluate the performance of students. Activities in the evaluation supplements will be very similar to those already in the units. Activities are being chosen which SCIS believes should cause children to manifest the desirable outcomes or behaviors. The basic difference between these SCIS instruments and the evaluation instruments developed by other curriculum projects is that SCIS employs a multiphasic evaluation approach which directs the teacher and others to look at the classroom environment from the children's viewpoint.

A supplement will be developed for each unit. The production schedule for these supplements is indefinite at this time. The supplements will be published by Rand McNally. At that time, they may be used by independent evaluators for summative evaluation purposes. However, SCIS personnel are not developing them for such evaluation efforts; from their point of view, they are designed to serve individual teachers.

In short, SCIS has not and does not plan to conduct a large-scale long term summative evaluation program. However, several small-scale studies have been conducted by both SCIS and non-SCIS individuals. A study by Haan (1968) showed that first grade children who had one semester's experience with the SCIS unit increased their beliefs in self-determination as contrasted with a control group. The results indicated that children in the experimental group made attitudinal shifts toward conceiving of themselves as able to determine their own fate. A later study by the same investigator (Haan, 1968) yielded similar findings for second and fourth grade children. In a study (Allen, 1967) comparing the classificatory ability of 190 children in grades 2 through 4, Allen found that there were no significant differences between the experimental group that had at least two years experience with SCIS materials and the control group that lacked such experience. Neuman (1969) attempted to measure intellectual growth of first grade children utilizing the Material Objects unit. He found that the SCIS group scored significantly higher on a posttest. Rowe (1969) described a study conducted with eight SCIS and eight non-SCIS second-graders. After they examined two different systems (i.e., aquarium and an SCIS whirlybird) through observations, the examiners disagreed with all statements made by these students. Six of the SCIS students argued their point of view, but only one from the non-SCIS group even attempted a second experiment to support his argument.

DIFFUSION

Agency Participation

Most of the actual diffusion activities were initially conducted by SCIS staff. Such activities focused on the development of Trial Centers and an implementation program, the selection of publishers, and the publication and presentation of articles, reports, and newsletters. Commercial publishers started playing a role in diffusion in 1965 when D. C. Heath was selected to publish the preliminary editions of SCIS; American Science and Engineering, Inc., was the apparatus manufacturer selected. In 1969, D. C. Heath decided not to bid on the final editions of the SCIS materials, and Rand McNally was selected to publish all of the final editions. All final editions will be published by them by 1972, after which they have exclusive rights to publish the materials for five years. Then the entire program goes into the public domain. Rand McNally has pledged that it will support teacher training, provided they can realize sufficient profit. Consequently, the diffusion and implementation activities are uncertain once SCIS terminates its participation in 1972.

Diffusion Strategy

The following is a generalized account of the approach being taken by SCIS in implementing the science program throughout the United States. Through reading the literature, convention presentations, recommendations of neighboring school systems, interest in implementing the program in a given community evolves. Then, based on discussions with members of the program development team and/or the commercial distributors of the program, an overall plan for the long term implementation of the program is designed. Such a plan typically includes the following characteristics:

1. A commitment to take responsibility for general administration by one or more leadership individuals who will obtain the necessary funds, make provisions for the necessary training, and identify themselves with the program, is obtained.

2. A pilot run of the program in the school system is then made to determine whether to proceed to the large-scale implementation.

3. A selection is made of key individuals from the local school system to carry on the leadership of the teacher education activities. These individuals are the key to the success of the whole approach. They need to understand the philosophy and operation of the new program, and to obtain this understanding in a planned leadership training workshop carried out by members of the program development team or other individuals who have had direct and continuing experience with the program. Presently, such individuals are brought to Berkeley or to one of the recently established regional SCIS implementation centers and for a period of a week to two weeks become a part of the operation of the project. Discussions with staff members, visits to classrooms, and training on specific techniques for working with teachers in the local school district are included.

4. These teacher trainees then return to the local school districts and begin the task of training local teachers so that the pilot or full-scale implementation of SCIS can take place.

Actual Diffusion Efforts

During the first two years of intensive development, exploratory teaching and the trial of SCIS materials took place in schools in the Berkeley area. In 1965, nationwide trial centers were needed to determine if the materials being developed were suitable for other parts of the country and not just uniquely appropriate for Berkeley schools where close supervision by the development staff was available if needed. Trial centers were established in New York at Teachers College, in Los Angeles at UCLA, at the University of Hawaii, and in East Lansing at Michigan State University. These centers have been supported jointly by SCIS, the local university, and the local community. This joint cooperation and support made it possible to enlarge and diversify the trial of SCIS materials without increasing the financial commitment. Very close liaison has been maintained with the centers; while center directors ran the center programs and reported only periodically to SCIS, SCIS maintained control over the type and extent of implementation that occurred through these centers. Thus, there still were no major implementation efforts; the trial of materials was merely expanded to schools nationwide.

In the spring of 1967, SCIS developers were forced to consider the problem of national dissemination. SCIS was receiving numerous requests from people to establish trial centers in their area; over 50 requests were received. However, in most cases SCIS would have to conduct the work of the centers if they were established and this was not feasible. Rather than expanding the number of centers, SCIS decided to set up an implementation program based on an internalization approach and the multiplier effect. On the basis of the internalization approach, individuals from the school system that was adopting SCIS were directly involved in a leadership role before full-scale implementation took place; this early and direct involvement was designed to encourage the local school district to take on the primary responsibility for organizing and following through the implementation of SCIS. Once these science educators were trained (at the SCIS headquarters in Berkeley) they returned to their local districts and trained more people, and hence by means of the multiplier effect, completed the final implementation step suggested by the SCIS diffusion strategy.

NSF, in the late 1960's, funded numerous two-week conferences held during the summer at local colleges. These Cooperative College Schools Science Conferences were designed to train teachers to conduct SCIS classrooms. Another dissemination activity involved the publication by SCIS of a newsletter which presently is published quarterly and reaches about 25,000 readers.

In summary, SCIS first tried out materials in the local Berkeley school area; then centers were established across the country, but implementation was still closely monitored from Berkeley. Then the SCIS implementation program was initiated with local school personnel and university science educators being trained, at Berkeley and later at other regional implementation centers, to go back to their own districts and institutions and to function independently of SCIS.

Product Characteristics and Other Factors Affecting Diffusion

The SCIS program is not a neatly wrapped package. Optional units are being planned to extend the basic sequences. The basic sequences do provide elementary school students with a fundamental science program that can be acquired in units and that is compatible with most school practices. Implementation of either all or a part of the SCIS curriculum does not depend on any particular form of school organization--such as team teaching, nongraded system, or modular scheduling. Self-contained classrooms can be used.

Because the program evolved through extensive exploration and experimentation with students, the basic units can serve as a core program that can be both added to by the user and adapted to individual student, classroom, or school needs. The start-up costs of about $5 per student per year would not be a significant obstacle for English or reading programs, but might be for science programs, which typically fall lower on the hierarchy of importance in elementary school curricula. Materials management problems may affect diffusion. Many school districts are not prepared to handle and to organize all of the materials (especially the live plants and animals) as they are often needed and used in more than a single classroom. Also critical and needing attention is teacher training; teachers need to get over the materials management hurdle and to learn to help students explore, investigate and discover. The need for teacher training at this level may affect how quickly the program is adopted.

ADOPTION

Extent of Product Use

The SCIS program presently is being used to some extent in almost all states. Approximately one million students in about 25,000 classrooms are now using the program. These students are from all socioeconomic levels and from both rural and urban school districts. The program, in either the preliminary or final edition form, has been in use for about three years, and the complete program will be available for use in final editions in 1972. As the diffusion activities increased over the last three years, potential adopters have increasingly initiated contacts with either the SCIS staff or the commercial publisher.

Installation Procedures

No special physical arrangements, equipment, or classroom organization procedures are necessary for installing the SCIS program. While SCIS developers indicate that teachers do not need a particular educational specialty or graduate level preparation in physical science in order to teach the SCIS elementary science curriculum, they do emphatically state that the teacher needs to change his or her traditional view of the teacher's role in the classroom. What is needed, according to SCIS are teachers who can (Hutchins, 1970):

> "contribute . . . ideas, see new possibilities, and are sensitive to the comments and reactions of children." The SCIS teacher must be able: 1) to accept children's active, direct participation in and analysis of their own science experiences; 2) to function more often as observer and guide than as demonstrator and lecturer; 3) to operate in a classroom situation where the noise level is often high and the student activity great; 4) to accept a diversity of responses from children; and 5) to assess what students say and do for evidence of their understanding of what is being studied. In addition to this overall change in his role, an SCIS teacher needs training in the three-step instructional strategy [p. 29].

Arrangements for in-service training can be negotiated with the publisher or can be obtained from people who have participated in the SCIS implementation program. A school can also develop its own staff expertise on SCIS by sending a representative to SCIS headquarters to participate in the implementation program. Another alternative is the teacher education program developed for SCIS by Dr. Jacobson of Teachers College, Columbia University. This program is designed for use in pre-service and in-service institutes and workshops. It offers a framework within which teachers can begin to develop skills and techniques and also learn different uses for SCIS materials and equipment.

The SCIS Elementary Science Sourcebook is the mainstay of the teacher education program. This sourcebook has served as a course manual which explains the psychological and educational foundations of the SCIS curriculum by explaining the curriculum's conceptual structure, by defining specific unit concepts, and by discussing teaching techniques. Included in this sourcebook is a bibliography of books, articles, films, and recordings useful for teacher education purposes.

Through the SCIS implementation program interested individuals undertake a study-visit to SCIS headquarters where they receive information about the development and philosophy of the curriculum, observe classes, and examine SCIS units. They also discuss the content of the program, teaching styles, student differences, and the use of materials and equipment. Once these individuals complete the program they can assist others in learning about the SCIS program.

While the teacher guides and student manuals give specific objectives and tasks, the program does permit teachers to make modifications to meet the needs of her particular classroom. The program is sufficiently flexible to allow teachers to make their own creative inputs. Attempts to individualize the program have been considered, but have not been realized. The program presently is designed and organized for use in a traditional classroom.

FUTURE OF THE PRODUCT

By 1972, the developers of the SCIS program hope to have ready for adoption the final editions of the 12 science units, six for a physical science sequence and six for a life science sequence. Evaluation supplements to accompany each of these units are being developed; two of these supplements have already been completed, and the other ten should be completed by 1973. The development of optional units is now being considered; these units would be used to extend the present 12 unit program. A project to adopt the SCIS program for use by blind children is also under way. The SCIS staff plan to support the activities of the commercial publisher, who will have a five year contract as exclusive publisher of the program from 1972-1977.

The future of the SCIS program seems now to depend on: (1) whether or not school personnel are willing to spend more of their limited funds on elementary school science; and (2) whether or not the teachers who will use the program are effectively trained. The major impact of the program is expected to be in the traditional classroom.

CRITICAL DECISIONS

The following events are a fair approximation of those crucial decisions made during the 13-year history of the Science Curriculum Improvement Study. For each decision point, the following information is given: the decision required; the alternatives available; the alternative selected; the forces leading to the selection of a particular alternative; and the consequences resulting from that choice.

Although an attempt has been made to present the critical decisions or turning points in chronological order, it must be clearly pointed out that these decisions were not usually made at one point in time, nor did they necessarily lead to the next decision presented in sequence. Many critical decisions were made simultaneously, and required a lengthy period of time. Furthermore, many of the critical decisions led to consequences that affected all subsequent decision making processes.

Decision 1: To Focus on Elementary School Science

With the General Education Movement and the Sputnik furor in the late 1950's came an increased concern about high school science. Meetings were held across the United States to discuss new high school science programs that would better prepare students for the study of science in college. Karplus questioned, however, the value of new high school science programs if students were not prepared for them when entering high school. At that point, he recognized the need for improving science at the elementary level. On the basis of this recognition and his subsequent participation in public elementary schools, Karplus and his colleagues decided to focus on elementary school science. Later, the feasibility conferences, which were held in the early 1960's to discuss elementary school science programs, also pointed to this need in the elementary grades. Thus, Karplus had identified this need before it was voiced nationally, had conducted extensive exploratory work in the area, and was prepared to seek funding at the time NSF became ready to provide support.

Decision 2: To Conduct Exploratory Teaching

During the early phases of the elementary school science program at Berkeley, Karplus taught regularly in the classroom and explored through his own teaching what interested children and what they were able to do. Before this teaching experience, Karplus believed that personal contact in the classroom might be desirable. After this experience, Karplus concluded that personal experience in the classroom was not just desirable, but mandatory for product developers. The decision to conduct exploratory teaching had significant consequences which set the stage for using a multiple stage trial procedure in unit development, and led to the next critical decision.

Decision 3: To Break With the ESSP at Berkeley

While Karplus was on sabbatical at the University of Vienna, the direction of the ESSP at Berkeley was altered without his knowledge. The project began to pursue a course which Karplus considered unpromising. Karplus' colleagues felt his beliefs about personal classroom participation by the developer were, as Karplus had been told by Conant, a total waste of time. Furthermore, the project was shifting to a much less structured approach. Consequently, Karplus decided to break with ESSP and to start the Science Curriculum Improvement Study. It is doubtful if SCIS would have emerged with the same content or teaching/learning strategies had the break not occurred.

Decision 4: To Develop a Full Scale Program

In the fall of 1963 another grant was made by NSF to support SCIS. NSF had been supporting, for four years, exploratory work conducted by SCIS, and now they wanted either a plan for phasing out the exploratory work with no further funds, or a plan to enlarge SCIS with a more permanent footing and with definite obligations to produce materials. No units or materials had been produced since those roughly designed in 1959. Had the first NSF alternative been chosen, probably SCIS would have died or remained too small to have national significance.

Decision 5: To Use a Multiple Stage Trial Procedure

The early exploratory work indicated that personal, first-hand experience in the classroom would be an early phase of unit development. This exploratory work, along with the perceived interdependence of units on the conceptual level, also pointed to a several year trial period. Thus, previous critical decisions pertaining to what were considered mandatory steps in unit development and what was the conceptual basis for the science program led to a multiple stage trial procedure. The decision to use a multiple stage trial procedure permitted sufficient development and formative evaluation time to insure that units were appropriate for the particular grade levels, as well as being integrated with other units of grades 1-6.

Decision 6: To Impose a General Program Structure on Unit Development

When developing the units, the developers could have permitted the general program structure to evolve, or they could have imposed it from the start. They chose the latter alternative. SCIS developers decided that the overall program structure would be based on selected theories of how children learn, and on the structure of the subject area. While the relating of learning theories to teaching/learning strategies, i.e., exploration, invention, and discovery, took place as the exploratory work was being conducted, the general program structure was conceived before unit development began in 1963. Thus, the developers of each unit operated with fairly specific guidelines.

Decision 7: To Base the Specifics of Units on Student Experiences

While the developers allowed little "mutiny on the Bounty" (as they put it) with respect to program structure, they decided that the specifics of units had to be based on student experiences as perceived by the writers of each unit. Given the general outline and purpose of a unit, the questions asked, the interests expressed, and the abilities demonstrated by the students during exploratory or experimental teaching served as the basis for the specifics of the unit. For example, questions asked by the students about an aquarium were actually written into the unit on life cycles. When the developers found that students could understand "environments" before "communities," even though the reverse would logically be predicted, they put "environments" before "communities" in the life science sequence.

They had anticipated that in the earliest grades children would not be able to execute experiments well. The students proved them wrong, and experimentation was built into all units. This decision to base the specifics of units on student experiences helped to assure that the concepts discussed in a unit were at an appropriate level. It paved the way for developing the first phase of learning (i.e., exploration) in each unit. Exploration, as noted earlier, allows the learner to impose his ideas and preconceptions on subject matter to be investigated.

Decision 8: To Include a Life Science Program

The decision to include a life science program was not finalized until the summer of 1965. Karplus, a physicist, had directed the development of the first units which were all targeted for a physical science sequence. He never questioned whether or not SCIS would produce a physical science sequence, but he did consider not including a life science sequence. Two events made him decide in favor of including life science units. D. C. Heath, the first commercial publisher, pointed out that the SCIS program would be very seriously handicapped when competing for adoption in the public schools if it did not include a life science sequence. Also, while leadership for the life science program previously could not be found, Chester Lawsen, well known in life science education, became available to lead the development of the life science units. Deciding to include a life science program forced a reduction in the number of physical science units that could be developed, but did make the SCIS program a complete, competitive elementary science product.

Decision 9: To Develop an Implementation Program Based on the Multiplier Effect

In the spring of 1967, SCIS developers were forced to consider the problem of national dissemination. SCIS was receiving numerous requests from people to establish trial centers in their area. However, in most cases, SCIS would have had to conduct the work of the centers if they were established; this was not feasible. Consequently, rather than expanding the number of centers, SCIS decided to set up an implementation program based on an "internalization approach" and the multiplier effect. On the basis of the internalization approach, individuals from the school district that was adopting SCIS were directly involved in a leadership role before full-scale implementation took place. This early and direct involvement encouraged the local school district to accept primary responsibility for organizing and following through the implementation of SCIS. Once the science educators were trained (at SCIS headquarters in Berkeley), they returned to their local districts and trained other teachers, producing the multiplier effect. Thus, implementation was facilitated and the critical teacher training problem became manageable in a large-scale effort.

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APPENDIX A

LIST OF PRODUCTS AND DEVELOPERS

The following is a list of products for which Product Development Reports will be prepared.

1. Arithmetic Proficiency Training Program (APTP)
   Developer: Science Research Associates

2. CLG Drug Education Program
   Developer: Creative Learning Group
   Cambridge, Massachusetts

3. Cluster Concept Program
   Developer: Dr. Donald Maley and Dr. Walter Mietus
   University of Maryland

4. Developmental Economic Education Program (DEEP)
   Developer: Joint Council on Economic Education

5. DISTAR
   Developer: Siegfried Engelmann & Associates

6. Facilitating Inquiry in the Classroom
   Developer: Northwest Regional Educational Laboratory

7. First Year Communication Skills Program
   Developer: Southwest Regional Laboratory for Educational Research & Development

8. Frostig Perceptual-Motor Skills Program
   Developer: Dr. Marianne Frostig

9. Hawaii English Program
   Developer: Hawaii State Department of Education and the University of Hawaii

10. Holt Social Studies Curriculum
    Developer: Dr. Edwin Fenton
    Carnegie Education Center
    Carnegie-Mellon University

11. Individually Prescribed Instruction--Math
    Developer: Learning Research and Development Center, University of Pittsburgh

12. Intermediate Science Curriculum Study
    Developer: Florida State University
    Dr. Ernest Burkman

13. MATCH--Materials and Activities for Teachers and Children
    Developer: The Children's Museum
    Boston, Massachusetts

14. Project PLAN
Developer: Dr. John C. Flanagan and the
American Institutes for Research

15. Science: A Process Approach
Developer: American Association for the Advancement
of Science, Commission on Science Education

16. Science Curriculum Improvement Study
Developer: Dr. Robert Karplus, Director
University of California, Berkeley

17. Sesame Street
Developer: Children's Television Workshop

18. Sullivan Reading Program
Developer: Dr. M. L. Sullivan

19. Taba Curriculum Development Project
Developer: San Francisco State College

20. Talking Typewriter
Developer: Omar K. Moore and Responsive
Environments Corporation

21. Variable Modular Scheduling
Developer: Stanford University and
Educational Coordinates