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ABSTRACT

A rationale for the inclusion of "conceptual structure," "science processes," "the nature of science," and "the relationship of science to society" in an operational definition of science education is offered in the first chapter of the report prepared by a conference of State Science Supervisors. In addition, consideration of the nature of the learner is recognized as an important component of science curriculum theory. Later chapters consider possible organization of a science curriculum development effort at the state or local level; the coordination and articulation of the sciences with other areas of the general curriculum, in a unified science curriculum, between grade levels in a school, and within the classroom; and implementation of a science curriculum, including methods of overcoming some implementation deterrents, evaluation, and the establishment of a hierarchy of responsibility from funding scources, commercial suppliers and specialized curriculum projects through state and district supervisors, principals and teachers to the student. All chapters are written from the point of view of the responsibility of state science supervisor in curriculum development. (AL)

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The Science Curriculum & the States




SCIENCE CURRICULUM AND THE STATES

COUNCIL OF STATE SCIENCE SUPERVISORS

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INTRODUCTION

In 1963 the Council of State Science Supervisors was organized to strengthen the leadership role of individuals who have a primary responsibility for science education in the state educational agencies of the United States and its territories. Since its organization, the Council has, in cooperation with other agencies, held several conferences to consider problems related to the somewhat unique working situation of its membership. This publication is the product of one of these conferences held in St. Louis, Missouri, June 14-18, 1971. This conference was devoted to working sessions where 34 papers previously developed by Council members as a preconference report were refined to become the final statement.

The problems of science curriculum, the theory, the methods of development, the strategies for coordination and articulation, and the procedures for implementation all fall within the realm of responsibility of the state science consultant. To aid their colleagues working in similar situations, and to delineate guidelines for their own curriculum work, the Council members have contributed a large amount of time and effort to this publication.

The entire project, including the initial phases, the writing conference, and the publication was sponsored by the National Science Foundation under a grant made to the Council of State Science Supervisors, Inc. The Council is extremely grateful to the National Science Foundation for this support.

SCIENCE CURRICULUM THEORY

The theoretical background for the science curriculum as it is presented in the nation's schools has its roots in educational research and philosophy beginning in the late nineteenth century. Throughout its evolution there has been continual shifting in emphasis and design. No doubt this shifting will continue in the future, but at the present time, work with the curriculum begins with a currently acceptable operational definition.

An Operational Definition for Science Education

The principle goal of science education is to develop scientific literacy. This goal comes from three contributing factors: the information crisis caused by the accelerated accumulation of knowledge about natural phenomena; the recognition of the role of science processes in learning; and the cultural and social impact of science and related technology. The science curriculum must provide a strategy for including these aspects of science education in the learning experiences of students. A scientifically literate person is one who possesses an understanding of the conceptual structure and processes of science and who is able to apply this understanding to interpret information presented to him. His understanding will enable him to assess the role of science and its applications and limitations within society. If it is accepted that the principle purpose of science education is to develop scientific literacy in students, then an operational definition for science education becomes:

> Any series of related activities that develops an understanding of the conceptual structure and processes of science directed toward contributing to the student's ability to interpret scientific information and to enable him to understand the role of science and its applications and limitations within society.

The definition of science education identifies four major curricular areas to be dealt with: the conceptual structure of science; the processes of science as applied to learning; the nature of science; and the relationship of science to society. Although in a workable science curriculum these areas would be interrelated in all activities, it is possible to develop a rationale for each separately.

The Importance of Conceptual Structures in Science Education

Organizing subject matter around conceptual schemes can be traced back over forty years. In 1927 Gerald Craig published his content based science plan for the Horace Mann Elementary School. Five years later the *Thirty-first Yearbook of the National Society for the Study of Education* published in 1932 listed thirty-eight major generalizations of science intended to be guides for the selection of content by curriculum builders. These early attempts to generalize science content evolved through many efforts until 1964 when seven general conceptual schemes were developed by a committee of the National Science Teachers Association as principal organizers for the science curriculum. Since then a variety of science curriculum projects and curriculum development guides have adopted the notion of conceptual schemes as an organizing framework.

The movement toward the use of a conceptual structure has gained impetus as scientific knowledge has expanded exponentially with many once accepted facts being modified or discarded. In many science classrooms new knowledge has tended to appear as additional chapters in texts. A non-inclusive selection of the facts to be taught has been offered because of the impossibility of adequately covering all related material during the limited time available. The facts themselves have, for the most part, been considered to be immutable, and the impression has been left with students that once a new fact is entered in the scientific information bank it is to remain there unaltered throughout time. Experiences such as these have left many students with the attitude that science is a convergent process churning out new knowledge, compiling this knowledge unfalteringly, and presenting the knowledge to be accepted unquestioningly. This situation is the antithesis of the view of science that many scientists and science educators hold. They promote an education that will lead the student to have respect for existing scientific work while at the same time questioning present expert opinion and realizing the high probability that conclusions arrived at will be altered or modified in time. Such learning should provide the broad generalizations necessary to assimilate new observations into a systematic cognitive structure.

Conceptual schemes, concepts, principles, and facts constitute the building blocks of a conceptual structure. Conceptual schemes are made up of related concepts, concepts of related principles, and principles of a series of related elements or facts.

Paul Hurd, in developing a rationale for the NSTA publication, *Theory Into Action,* defined a conceptual scheme as a relationship between a number of concepts:

> It ties past experience to the present and serves as a guide for the comprehension and assimilation of new facts and concepts. It serves as a basis for prediction of what will happen in a new problem or situation.

The building unit of a conceptual scheme is the concept and inasmuch as this term is used so frequently by professionals and by lay people alike there is a need to describe and perhaps to define the functions assigned to it in a conceptual structure. A concept may be defined as an idea formed by mentally combining related characteristics or particulars: a construct. This definition implies that a concept involves a general characteristic which can be applied to a number of specific situations. In a learning situation the concept may be arrived at by studying a number of specific instances. A student may learn the concept "smooth," for example, by being exposed to a number of objects which manifest that characteristic. These objects might range from a billiard ball to a formica table top to a drinking glass. Once the concept is learned, it becomes applicable to a large number of specific stimuli. Teaching for concepts, then, may be assumed to provide greater efficiency of learning by switching from the attempt to learn large numbers of facts to the attempt to isolate the characteristics of those facts which may be applied generally to other specific instances. The value of the resulting capability of the learner was recognized by Gagné when he wrote in 1970:

> The effect of concept learning is to free the individual from control by specific stimuli. This kind of learning, then, is obviously of tremendous importance for most kinds of intellectual activity engaged in by the human individual.

In another step in the quasihierarchy of generalizations, one arrives at a conceptual scheme level. Again, according to Hurd:

> Within the sciences there are unifying conceptual schemes serving to integrate the knowledge of the field as well as to provide a focus for scientific investigation. . . . Not only do the schemes provide a means for organizing a course but they suggest how a student should pattern his learning.

It is apparently wasteful to teach facts divorced from meaningful concepts. When facts with meaning for the learner are tied into a logically related conceptual pattern, retention is improved and insight is more likely to occur. An understanding of the conceptual structure helps the student select what is pertinent in the new situation.

Paul Brandwein wrote in 1965:

> Facts change with great rapidity, but the concept--a statement of relationships, a configuration or patterning of facts--remains somewhat stable over a few decades. Concepts offer us hope that we may have good--if temporary--moorings, or foundations, for building a curriculum. Without an ordering in conceptual schemes the curriculum becomes a potpourri; revisions are at the mercy of an ever-changing technology even as the conceptual schemes remain fairly stable.
>
> We suggest then that the curriculum seek its substance, its base, in conceptual schemes. We hasten to repeat that these conceptual schemes are floorings for the curriculum and guides for the teacher, not the invincible knowns of (the subject). The teacher does not cover them, but children uncover them through experience and investigation.

At another point in the same reference, Brandwein writes:

> A curriculum structure based upon conceptual schemes is practical and, from the viewpoint of economy of time, eminently desirable. Hypothetically, if such a framework for curriculum structure were adopted, some youngsters (perhaps 20 percent) could conceivably be doing 10th-grade work in the 8th grade; others would no doubt need ten or more grades to accomplish the same work. In short, such a framework permits the flow of students rapidly or slowly up and down the conceptual ladder. Yet, they can communicate with each other for they are working within the area of the same conceptual scheme.

The movement toward conceptual structures is important in that it attempts to channel instruction from an arbitrary selection of information to an organization based on broad conceptual schemes. The resulting tendency is to improve the efficiency of instruction by stressing concepts and conceptual schemes rather than ever increasing masses of unrelated information. Using concepts as organizers opens the way for an increased understanding of the learning process which is not solely oriented toward the cognitive dimension.

As a caution, it is important to keep in mind that the theoretical value of concept teaching is yet to be verified. Much research is still needed to form a sound empirical foundation for the acceptance of a program based on concept learning and conceptual structures. Belanger, in the October, 1969, edition of the *Review of Educational Research,* refers to Wallace who in his book, *Concept Growth and Education of the Child* (1965) reviewed British, French, and American literature on concept learning and concluded:

> It is a sad commentary on the effectiveness of our methods of enquiry that after some eighty years of psychological investigation and a discontinuous history of laboratory xperiments, our funds of accepted knowledge on the subject of conceptualization comprises so little of consequence that it is hardly worth compiling.

Regardless of this observation, until new research can conclusively evaluate teaching for conceptualization, the fact that a conceptual structure provides criteria for selection or exclusion of learning activities justifies consideration of such a structure in developing a sequential science curriculum.

The Importance of Process in the Science Curriculum

Science education, as part of the general curriculum, has always included some laboratory activities and direct experience. However, the purpose of such experience in the school program has tended to be to reinforce previous learning of facts and principles rather than to provide a base for learning. Many educators have questioned the value of this kind of experience, and often research studies directed at both elementary and secondary science education have failed to show that there is any significant advantage in achievement regardless of a variety of strategies used in employing the laboratory in teaching science. These results tended to put science educators, who intuitively felt that there is value in direct experience in a laboratory, on the defensive. They pointed out that the achievement being measured in such studies relates only to science information and that there is a probable discrepancy between this concept of achievement and the actual positive effects of laboratory activity. Although a long time in coming, a reassessment of science education goals followed that has finally resulted in a growing emphasis on science processes as being of an importance comparable to science concepts.

This new emphasis comes from the observation that science is not just a series of concepts and generalizations which organize discrete facts and principles. Educators now recognize that science is also a process, a mode of inquiry, and a point of view. To provide a comprehensive education in science, this process must become a major aspect of the science education program and must be reflected in instructional planning and evaluation. This decision on the part of science educators is reflected in the 1968 *Sixth Report of the International Clearinghouse on Science and Mathematics Curricular Development*, where it is observed that every curriculum project in the secondary schools which was supported by funds from the National Science Foundation listed laboratory investigations as a method of instruction and further identified process acquisition as a course objective. In the elementary curriculum projects, the emphasis on process has been even greater. *Science--A Process Approach* developed under the auspices of the American Association for the Advancement of Science has, no doubt, led the field in developing the behavioral processes according to the recommendation of Robert Gagne. Although given a somewhat smaller emphasis, process has been included as an important aspect of science as well as a teaching and learning method in all other major elementary science curriculum projects that have produced materials in the last decade.

It has been demonstrated through numerous pilot projects and extensive feedback from experimental classes that children at all levels in school programs have been successful in achieving the behaviors and related understandings that have been specified as process objectives by curriculum designers. However, the bulk of the research done in recent years relating process learning to achievement has failed to show that competencies in the identified processes contribute significantly to achievement within the cognitive conceptual structure of science even though in many studies there seemed to be a positive affective value change toward process oriented science.

In terms of science curriculum design, the recent development of substructures in process has had a great impact. Prior to the decade of the sixties, process was usually implied in laboratory activities, but the components of that process were not often identified and even less often used to establish learning objectives. Now, as is demonstrated by *A Guide to Science Curriculum Development* published by the Wisconsin Department of Public Instruction, it is considered feasible to plan a sequential process development beginning with the simplest process skills and systematically working toward increased sophistication within each major process. In such a structure, the major processes take on a characteristic similar to the more cognitive conceptual schemes, although the behavioral nature of process becomes an important difference in designing any attempt to assess student achievement.

Many science educators tend to feel a necessity to choose between a process emphasis or a conceptual emphasis in curriculum design. In some special situations this choice may be necessary, but for the best contribution from science education to general education it seems apparent that process should be the method by which students are led to concepts. This strategy depends upon an initial introduction to process and as soon as possible new process skills are applied to acquiring direct experiences which, according to a definition given earlier, provide the characteristics or particulars that can be assimilated into constructs or concepts. Early in science education, the processes and concepts attained are very simple, but once the mode is set and coordination between the conceptual and the process structures is established the curriculum becomes only a route to greater complexity.

Including the Nature of Science in the Science Curriculum

One of the most neglected elements in science teacher education is the definition of science itself. So often the prospective teacher, perhaps also prospective science consultant, is so immediately immersed in scientific content and scientific technology that he never asks, nor is told, why all these things of science have been classified together. It is small wonder, then, that the nature of science has had short shrift when these same teachers, a few years later with a few years experience in the classroom and in related responsibilities, turn to curriculum development and implementation. As with process, there has been an intuitive feeling that something usually referred to as the scientific method was significant in science education, but the emphasis was light, the interpretation faulty, and the application non-existent.

As with process, the decade of the sixties has been significant in bringing a better understanding of the nature of the scientific enterprise to science educators at all levels and a better perspective to the importance of the nature of science to science education as well as general education. To a large extent this result came from an effort to produce educational programs that would produce a "scientifically literate" public. The demand for such a program required scientists and science educators to become more introspective about the entire generalized process that is called science.

Henri Poincaré once said, "Science is built of facts as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house." What is missing, of course, is not only the structure but also the planning and activity that went into producing the final product. It is the planning and activity that actually reveal the nature of science, but because science is so diverse, it is not possible to describe by a simplistic series of confining steps as has traditionally been done in efforts to describe the scientific method.

In a bulletin entitled "Developments in Elementary School Science," produced by the American Association for the Advancement of Science Commission on Science Education, it is stated that:

> Science is an activity that goes on in the mind of man. It is a process by which man seeks to order nature and thus learn from it. In the process of seeking to understand, he continually reorganizes his observations forming concepts, principles, or laws which represent, in each case, a wealth of systemized knowledge all housed in small intellectual packages called constructs.

The Wisconsin publication, *A Guide to Science Curriculum Development,* has treated the nature of the scientific enterprise as one of four important aspects of the science curriculum. This is rationalized by stating:

> In order to understand and appreciate the conceptual structure of the products of science and the processes by which science concepts evolve, it is necessary for the science student to understand what a scientist is, what he does, what he believes, and how he conducts his investigations.

The Guide describes the nature of science in terms of the philosophy of science including assumptions and ethics and the actions of scientists which go beyond investigation to methods of classifying and correlating observations and establishing theoretical constructs.

The nature of science is complex but its inclusion in the science curriculum need not be. If the nature of science is, in fact, to be an integral part of an implemented science teaching program, teachers, and perhaps more importantly local and state science consultants, must incorporate the nature of science in their casual as well as formal plans for curriculum organization.

Relating Science to Society Through the Science Curriculum

In recent years, there has been a great deal of criticism of science on the part of non-scientists. Many articles say that science now tends to be characterized by arrogance, dominance, irresponsibility, and an excessive concentration on esoteric questions, almost equivalent to that of medieval scholasticism. Science has seemed to become a new mystery with a new priesthood and an occult doctrine understood by only a small and select group. It seems to some that there is now a need for general social control of science to ensure that it will really benefit mankind and help decrease the gap between science and other aspects of life.

The problem of relating science to society is quite apparent at the college level. Educators are beginning to wonder about the science curriculum for students who are not academically science-oriented. Dr. V. L. Parsegian has noted that science education for the non-science college student is getting widespread attraction. He realized that the non-science students need a course of study that differs from that followed by students pursuing a career in science. The Alfred P. Sloan Foundation, cognizant of these recent trends in education, recently awarded a $400,000 grant to Antioch College for the purpose of developing "improved ways of teaching science that will make it clear and interesting to non-science students." Also, a science program for non-science students has been in the process of development for the past three years at Rensselaer Polytechnic Institute. According to Dr. Parsegian, director of the RPI program, a non-science program is important because there is a complete lack of communication between the social and physical sciences.

According to Isidore Hudes and George Moriber in an article in the February, 1968, issue of *The Science Teacher,* the study of science for non-science majors must be justified by what science can contribute to the fulfillment of the basic purpose of a college education. The students should have science courses which contribute meaningfully to these goals. Our problem is concerned with extending scientific literacy to non-science students. If it is true in the modern world that science speaks to all men, then it is the duty and responsibility of educators to see that we prepare men to understand the language of science.

Hudes and Moriber continue to say that education is a lifelong process, and a person whose special interests lie in the humanities and the arts should, as a student, get sufficiently involved in science to be able to read about scientific developments with a fair degree of understanding and judgment. To accomplish this, there must be developed an appreciation of science and its knowledge in the world that is comparable to the appreciation and understanding of music, art, and literature that is expected of any educated person.

Overall, there is a need for science education to help all people--scientific and nonscientific, college and noncollege, American and non-American--to be aware of the impact that science has had upon the world culture. They will also benefit from the knowledge that science as an intellectual activity is constantly interacting with aesthetic and philosophical development, with political and economic goals, and with the worldwide sociological security.

In the summer of 1970, President Nixon sent Congress an unprecedented report warning of possible "ecological disaster." In his message forwarding the report by the White House Council on Environmental Quality, Nixon said:

> We must seek nothing less than a basic reform in the way our society looks at problems and

> makes decisions. . . In dealing with the environment we must learn not how to master nature but how to master ourselves, our institutions, and our technology.
>
> I see implicit in these reports, in these statements, a clear mandate to the science teaching community to develop an informed citizenry. It is clearly the function of science teachers to make science and technology understandable to all people, not only in the facts and principles and concepts of science but in the broader sense of its being a potent force affecting the very quality of life and living.

The educational philosophy of "science as a career" that has been prevalent in many of the curriculum reforms of the late fifties and the sixties has ignored the importance of science in the general education of all people. It is apparent that if science education is to serve its total function, the relationship between science and society must become an integral and pervasive part of the science curriculum.

The Place of Science Education in General Education

Many curriculum writers have considered science to be unique because of its association with technology and subsequent application to economics and family living. This limited utilitarian view of science has tended to place it apart from other academic disciplines, especially the humanities, with a resulting limit to the contribution science can offer to a general humanizing education. In addition, such a view has tended to result in a strong content emphasis that allows the discipline to dictate curriculum organization instead of consideration for the nature of the learner.

The more contemporary view of science is in terms of broad conceptual schemes that are often transferable to other disciplines, learning processes that are no more unique to the natural sciences than to the social sciences, and a cultural approach to the nature of science and its relationship to society. This view tends to soften science and put it in a realm comparable to other creative endeavors of mankind.

The changing concept of science education is parallel to changes in other disciplines that are responses to similar concerns for relevance where it has been noted that information alone makes little contribution to intellectual freedom and that learning the birthplace of Rubens or the date of the Battle of Hastings has little to do with providing a humanizing experience to students.

It may be presumptuous to say that science education has led the way to inquiry-oriented learning since this technique has been employed since the time of John Dewey by perceptive teachers in every kind of classroom and in every discipline, but the fact that natural science provides concrete, non-statistical phenomena as a context for inquiry places science in a position of considerable importance in general education. This contribution to the major commonality among disciplines is still expanding in elementary and secondary science programs, and no doubt a corresponding effect in other curricular areas will continue to be noted.

Other than the process contribution to general education, it is important to consider the role of science as a major intellectual achievement of the human mind. Since many consider one objective of general education to be conveying the amassed cultural achievements to succeeding generations, there is little doubt science must be included. However, one must keep in mind that the knowledge product of science is no more significant as a cultural achievement than is the development of the process by which the knowledge was derived. It is through this process that creativity and the resulting intellectual excitement are possible. Educators should understand this process, for too few have understood it in the past, and convey its importance as a source of satisfaction to the human mind just as they attempt to convey the importance of creativity in the arts and humanities. Albert Einstein once said:

> . . . one of the strongest motives that lead people to give their lives to art and science is the urge to flee from everyday life, with its drab and deadly dullness, and thus to unshackle the chains of one's own transient desires, which supplant one another in an interminable succession so long as the mind is fixed on the horizon of daily environment.

This thinking, like the theories of special relativity, are worth passing on.

Consideration of the Nature of the Learner in Science Curriculum

How one learns science is an interesting and provocative problem. The range of intellectual development is great--moving by a gradual transition from the concrete to the abstract. To transcend this change through science education, a program must provide the learner experiences in manipulating objects and systems. In the beginning, the individual learns to control his muscles and gains the ability to manipulate concrete objects. His thinking is dependent on direct experience. In the later years, the learner achieves a degree of mastery of mind. He is able to focus his thoughts consciously and to manipulate abstract relationships without constant reference to specific examples.

At the highest level of student involvement the individual is confronted by systems of objects. He watches the ob[illegible] and what happens to them. The observations are indivi[illegible] and are based on the learner's direct experiences. In a science program this level of involvement is important but not a panacea which solves all the problems of science curriculum development. In addition, the learner needs guidance in his development and must be able to relate to the overall developing structure of the program.

All children in a classroom need to be involved in the important aspects of basic science. While systematically using the processes of science, the beginner should acquire fundamental concepts which are basic to science. As the learner progresses in science, he will encounter these concepts with more and more frequency and in ever more complex applications.

The adoption of the "involvement" philosophy for science learning makes impossible the separation of process goals, cognitive goals, and affective goals. These three fundamentals of a science program are completely interwoven and intermingled. However, to make consistent curriculum decisions feasible, it is important to consider the Piagetian notion that development precedes learning and that structure in the sense of advance organizers as presented by David Ausubel provides a base for learning. A curriculum structured on concepts and processes with increasing sophistication and abstraction leading to pervading affective values and appreciations for the nature of science and its impact on society is consistent with modern learning theory.

SCIENCE CURRICULUM DEVELOPMENT

The Range of Science Curriculum Development Activities

A fundamental role of the state science supervisor is to improve science instruction at the local level. This improvement can, in part, be best accomplished by providing the necessary leadership in designing strategies for the many aspects necessary in the development of a science curriculum. No one state science supervisor could be expected to be an expert in each of the content areas that must be considered in the development of a science curriculum. A skillful supervisor can identify individuals with expertise in the wide range of activities that must be conducted and can develop the organization and operational strategy that will work toward successful curriculum development.

The range of activities in the design for science curriculum development may vary depending on the extensiveness of the project; however, the following organization constitutes a useful scheme for curriculum development that may be adopted as a whole or in part.

Steering Committee

The state science supervisor is often in a position to observe problems and needs in the science curriculum. It is imperative that he identify insightful individuals from a cross section of educators and involved laymen and form them into a steering committee which would ascertain the origin, nature, or definitive characteristic of the problem and suggest solutions. This group might be composed of classroom teachers, department chairmen, administrators, college staff, industrial experts, parents, students, and people from other units of the state department of education. It is through this group's planning that the activities of all other subcommittees should be directed.

Writing Subcommittee

The writing subcommittee should be a rather small group of people identified by the steering committee as having the necessary skill to convert the recommendation of the steering committee into a working document. The writing subcommittee must continuously keep in perspective all aspects of curriculum development such as educational psychology, theory, research, articulation and coordination, implementation, and resources. After the initial draft, subcommittee members must be prepared to add, remove, and alter the document as the feedback is received from trial classrooms.

Supplemental Materials Subcommittee

The supplemental materials subcommittee should provide the various activities and resources that will assist classroom teachers in the implementation of the writers' document. This group may give special assignments to members in order to pursue the varied areas within this responsibility such as instructional media, supplemental reading, field trips, students labs, and demonstrations. Because of the magnitude of this group's responsibility, it may he composed of many people, and it may continue functioning as new resources are discovered.

Inservice Training Subcommittee

The classroom teacher must understand and accept the basic rationale of the resulting curriculum if implementation is to be successful. The inservice training group might be composed of various members from the writing and supplemental materials subcommittees. This subcommittee has the responsibility of relating to the teachers of the trial classrooms and later to teachers not involved in the experimental phases of the program. They must communicate the philosophy and intent of the document and the use of the supplemental materials to those who will be implementing the plan in the classroom.

Trial Classrooms

Before the curriculum can be finalized, the efforts put forth by the writing subcommittee and the supplemental materials subcommittee must be tested in the classrooms of a wide cross section of the population for which the program is designed. This should be done by teachers of varied experiences teaching under adverse as well as ideal conditions. The trial teachers may well include members of the various subcommittees but should also include additional teachers who have been exposed only to the inservice training portion of the program. It is the responsibility of these teachers to teach the program using the philosophy by which it was designed and to provide the necessary feedback to the various subcommittees so the overall program can be reworked if necessary.

Evaluation Subcommittee

The responsibility of the evaluation subcommittee is to design various effective evaluation devices that will be applied to the trial classrooms in order to produce statistical evidence of the successes and shortcomings of the program. The feedback from this subcommittee's work will dictate many of the activities of the other subcommittees after the initial curriculum design has been produced.

Research Subcommittee

The function of the research subcommittee should be wide in range and may touch upon the efforts of all other subcommittees. The activities might range from testing new laboratory materials to investigating the effects of individualization of learning as a method of instruction. Its specific role is to remain continuously abreast of educational research and attempt to incorporate its successful findings into the project.

The state science supervisor occupies a key position in organizing and directing the range of activities in the development of a local, state, or national science curriculum. From his position the supervisor is often able to acquire the necesssary financial resources to conduct the activities of a curriculum project, to arrange for appropriate meetings, and to identify steering committee members and subcommittee leadership. With this model for organizing a wide range of activities, the state science supervisor can coordinate the efforts of a large number of experts in the task of science curriculum development.

Involving Teachers in Science Curriculum Development

Since curriculum development is a long-range, continuing process, many of the key people involved must be practitioners whose careers are devoted to implementation. The task is too involved to be accomplished completely by the outside consultant, professor, or part-time worker.

The student, as always, must be the focal point of any curriculum, and the teacher provides the situation that encourages student learning. Since all teachers have a great stake in the development of better curricula, a logical approach to improving the science curriculum is to involve teachers in its development. Such involvement has the assumed advantage of reducing the gap between curriculum theory and practice. Regardless of the level at which curriculum is being developed there are always ways in which teachers may become involved. It is important to remember that, although teachers may not have the depth in curriculum theory that many consultants at state and local levels possess, they do have the advantage of recent and direct experience in the classrooms which they can apply to curriculum work. While teachers need not necessarily be involved in every level of curriculum development it is essential that they completely understand and accept the curriculum design if they are to be successful in teaching it. Thus, it is important to implementation that teachers be involved in the initial phases of developing the curriculum model as well as in the writing phase. No doubt the greatest teacher involvement comes in the trial classroom and evaluation stages where quantitative data as well as subjective judgments must be collected and fed back to the writing and supplemental materials subcommittees for revision. It should also be noted that in small scale curriculum projects at the local level teacher involvement in all phases of the development insures success at the implementation stage. A new curriculum is not something that can be installed completely at any given time, but rather, it is to be gradually put into effect as decisions are made regarding staff and resources. These decisions should involve teachers to the fullest extent possible. It is also important to realize that after the original curriculum has been implemented there will be constant adaptation and evolution of the overall program which will be accomplished almost entirely by teacher feedback and team planning.

Teachers may improve their proficiency for curriculum development by attending curriculum development meetings and conferences at the local, state, and national levels conducted by various professional organizations. Visiting other schools where innovative materials and teaching methods are being used is also a valid way to help teachers to improve their ability to interact with others on curriculum problems. Considerations for the extra effort put forth by these professionally-minded teachers might be extra salary, special status as a master teacher with supervisor responsibilities or chairmanship, or expense money to defray the costs of travel and attendance at meetings.

There seems to be adequate evidence to support the basic premise that teachers like to become involved in goal setting, decision making, and activity planning, all of which are components of curriculum development. Leaders in curriculum development who capitalize on this fact by providing situations that allow teachers to become involved are utilizing one of the most important resources available to them.

Involving the Community, Including Parents and Students, in Science Curriculum Development

Much has been written about the need for community involvement in all phases of curriculum development. Considerably less has appeared explaining how this involvement might be accomplished. However, there are ways in which the state science supervisor can involve students, parents, and the non-educational community in curriculum development and implementation.

Under normal circumstances, the state science supervisor does not have access to school age students. Hence some technique must be devised by the state science supervisor to permit him access to students in the curriculum target group. With the cooperation of a university, students from the associated university laboratory school may serve as the curriculum trial group or validators. Most frequently, however, there will not be university involvement, and students from a local school system will have to be obtained. The state science supervisor in these situations can be effectively involved with parents and students only through cooperation with a local science supervisor or administrator. It is the local person who will make first contacts with students and their parents and who will make primary selection of students and parents who are to work toward the goals suggested by the state science supervisor. In the same sense it is likely to be the facilities of the local school where contact with parents and students will take place. The local supervisor's cooperation will be necessary in scheduling the use of the local school for curriculum development activities.

There are two ways in which parents and students may be involved in curriculum development. In the first kind of situation, they may initiate curriculum change as in a community with a specialized industry such as aerospace technology where families may want aerospace science courses in the schools. In such a situation, the parents could probably offer valuable suggestions for curriculum content, materials, and possibly even methodology. In the second type of situation, initiation of the curriculum change would come from someone other than parents, perhaps teachers or the supervisor. It is important where the initial ideas are not theirs, that parents be informed of the nature of experimental materials and methodology with which their children are to be involved. They and the students can be involved throughout the development of the curriculum, participating in the validation of the program which must take place continuously throughout the entire project. Parents may also be involved in decision making when the decision is to choose either an established science curriculum or a new curriculum plan. In some states, parents may serve on textbook adoption committees or on science curriculum advisory committees.

Probably the most frequent involvement of the non-educational community with the state science supervisor in matters of curriculum development and implementation occurs when business, government, or private agencies have a curriculum bias for which it has developed materials and wishes them made available in the schools. It becomes the responsibility for the state science supervisor, with the aid of local specialists, to judge the potential educational value of these materials. Examples of this sort include the "science kits" available from a major communications utility, filmstrips and study guides from the petroleum industry, and motion picture films from a multitude of businesses. Whether the state supervisor favorably or unfavorably recommends the offered materials, he faces a dilemma. If he decides the industry has produced a valuable educational tool, he must promote the curriculum in the schools in such a manner as to enhance the materials without showing favoritism to one competitor in an industry over another. If he decides unfavorably, he has to seek methods discouraging the materials without offending the goodwill of the business or agency making the materials available to schools.

A less likely situation in which the state science supervisor wishes to involve a business or private agency is that in which the supervisor desires assistance in developing a program he has chosen. The measure of cooperation to be expected by the agency is almost directly proportional to the popularity of the cause taken by the developing curriculum program. At the time of the 1959 impact of the Russian "Sputnik," government and business groups were eager to assist with both talent and money to improve science education. At the present time, however, the same groups are willing to help with environmental science education but may be deaf, for example, to the problem of diminishing physics enrollment in secondary schools.

At the state level, curriculum development assistance is readily available from agencies of state government other than the state education agency. Most branches of state government have an office of information. The director of each of these offices is usually eager to provide technical assistance and information pertinent to his agency which will become part of a school program.

The nature of the curriculum being developed or implemented affects the extent to which the several aspects of the community may be involved. For instance, work on an environmental curriculum will probably involve segments of the community different from those involved in "pure" science. Elementary curriculum needs differ from those of the secondary curriculum, and the nature of a classroom instructional television curriculum differs from that of an inservice science curriculum for teachers.

The process of curriculum development includes decision making. It is universally axiomatic that those people affected by decision making should be permitted a voice in the decision-making process. Schools at all levels are people's business. Involving a variety of people in making decisions enhances the success of the choices.

The Role of the Local Administrator in Science Curriculum Development

The science curriculum should effectively serve the entire range of students from those who end their formal science study early to those who continue and become professional scientists and engineers. To achieve this end, those with responsibility for the science curriculum in each school district must inform the administrators of the present state of science education within the district and enlist their aid in planning for continual improvement and increased comprehensiveness of the science instructional program. However, since many administrators possess neither extensive science backgrounds nor positive attitudes toward science, deliberate planning in the approach may be necessary. In such cases the services of the state science supervisor can be valuable.

Although any change in curriculum or in teaching materials or method is usually viewed critically by both teachers and administrators, the rate of change in instructional procedures is dependent upon the amount of administrative support for such change. If the various administrators have current knowledge of the science program and know the direction of desired change, they are more likely to add their individual support. They also will be able to make efficient use of available staff, facilities, and funds for science. The specific techniques for involving the state science supervisor with administrators in the coordination of the science curriculum within a district will vary. However, a general pattern of procedures consists of personal conversations between the individual administrators and the state science supervisor, and more formal discussions of planned change during administrative meetings. Any necessary "selling" of the science program to build positive attitudes should be carried out by the science supervisor during the informal conversations with the individual administrators. Such conversations must stress the fundamental idea that the cooperation and assistance of all personnel is needed for effective implementation of a new science instructional program on a district-wide basis.

Items in administrative newsletters or other internal communications should give credit to individual administrators who have supported specific changes. This technique is of particular importance in a large district where activities of individuals may not be generally known. Usually the contributor is pleased to see his name in the administrative newsletter, and recognition of such activity tends to promote further cooperative efforts from him as well as his colleagues.

Annually the state science supervisor should communicate the "state of science" to the state's district administrators. This report could be followed up by discussions of any given district's plans for change in the science instructional program. In these initial discussions, each district administrator should be free and, in fact, encouraged to contribute his ideas for improvement and to be an active member of the planning group or steering committee.

The Role of Local Science Consultants in Curriculum Development

The basic function of the local science consultant is the improvement of the teaching-learning situation in his special field. This improvement can best take place when consultation is done as a cooperative process carried on in a climate of mutual understanding and respect among administrators, teachers, students, and the community.

Consulting is a service activity in which the role of the consultant is to support and assist more than to administer. The consultant's responsibility is both to program and to staff where he provides expertise in science education. He engages in a wide variety of activities by providing help to individual teachers and groups of teachers to improve required teaching skills; assuming a leadership role in curriculum development and revision in his field of specialization; cooperating with other departments in the development of coordinated general educational programs; informing teachers of opportunities through which they can grow in professional competence; engaging in projects and activities directed toward improving the educational program, both system-wide and in individual schools; and working with community groups and with other school systems on educational projects. The consultant needs to be acquainted with the findings of research in his own field and the relation of that research to other fields. At the same time, he functions as a member of an educational team by working with principals, teachers, counselors, central office administrators, and community leaders in a continuous effort to improve the quality of the learning experiences provided for the children of the community.

The local science consultant has a special responsibility in curriculum development. The following procedures are important in fulfilling that role:

Surveys are periodically done to provide basic data concerning needs of teachers and students. The surveys may involve questionnaires, interviews, or reviews of existing records. These data are used as a basis for beginning curriculum projects.

Contacts are developed with federal and state agencies, foundations, and industries to determine the likelihood of procurement of funds to carry out proposed curriculum projects. If the indications are favorable, proposals are written for approval and submitted to the most promising source.

Contact is maintained with professional societies, agencies, academic institutions, and national groups as a reservoir for resource people and pertinent materials.

Master teachers are identified to assist where special knowledge is required.

Pertinent data is disseminated to teachers and administrators through such channels as newsletters, bulletins, multi-media presentations, meetings, conferences, memoranda, and reports.

New programs are tried out on a pilot basis.

Consideration is given to coordination of the curriculum with the facilities and equipment.

The underlying aspects of safety as they apply to the program are considered.

This extensive background to curriculum development will be modified according to the characteristics of the district or districts involved. In many cases the preliminary functions can be accomplished in cooperation with other local consultants, with consultants from regional education agencies, or with the state science supervisor. Because of the nature of his office and responsibility, the state science supervisor has a very direct interest in such activities and will lend whatever assistance possible to the local science consultant.

The local science consultant accepts the leadership role in the actual curriculum development work. It is his responsibility to appoint the steering committee and the various subcommittees that have been discussed earlier. This, of course, is best accomplished after school administrators have been involved in the initial selection. Once the personnel have been assigned it is the consultant's job to acquaint them with the project goals and the strategies that will be employed to attain those goals. In this initial phase the state science supervisor can perform a real service by conferring with the local consultant and by meeting with the assigned staff to lend support to the credibility of the project. This support is also important in contacts with admini. . .s since it is of paramount importance that the introduction of change in the science education program be accompanied by the understanding and acceptance of the administrators who are responsible for the decision to adopt such changes.

Once the project is initiated, the consultant must continue to coordinate efforts of the subcommittees, to make special assignments, and to set deadlines. Throughout the development, success will depend upon his leadership. The amount of time that can be given to the project by the state science supervisor at this stage will be necessarily limited, but his continued interest, support, and occasional direct involvement will add assurance that the final product will be accepted and implemented.

In most cases the chief handicap hampering the consultant's successful implementation of new programs is that teachers are inadequately prepared to present new materials using new approaches. Most secondary school teachers of science seem adequately prepared to teach the typical science sequence for the traditional college entrance program. However, many of the secondary teachers are not prepared in the philosophy, knowledge, or skills required to be successful in teaching a process-oriented curriculum involving methods and materials that require less teacher domination and more student responsibility. The situation of the teacher in the elementary grades is often much worse. In both science and mathematics the average elementary teacher has received much less instruction than in language arts and social studies. Thus, it follows that the consultant's job does not end when the curriculum materials are finalized but carries on into inservice education.

State Involvement in Local Science Curriculum Development

The state department of education can become involved in curriculum development by providing leadership to local school systems. Basic to providing effective leadership is an awareness and an understanding of local needs. It is important that those in leadership positions, such as the state science supervisor, understand local attitudes, local leadership potential for curriculum development, implementation, and the needs of students involved. To adequately provide curriculum leadership at the state level, the state science supervisor must fully understand and appreciate the spectrum of science education practices in his state, the rate of adoption and adaptation of major national curriculum projects, the role of administrators, consultants, teachers, and students in development and implementation of curriculum projects, and the appropriate procedures for initiating new science curriculum projects. These capabilities lead the state supervisor to perform a variety of services at the local and regional level. Among these are:

Assisting local systems in diagnosis of present programs to establish needs and priorities.

Assisting local school districts in establishing a committee system for developing and implementing curriculum change.

Establishing state science advisory groups to produce guidelines for curriculum work at the local level.

Establishing communication and working relationships with local science consultants.

Bringing national viewpoints and trends in science education to local groups. This can be accomplished through newsletters or by visits to local school systems.

Leadership activities of a science supervisor require an understanding of established policies and protocol as well as the legal considerations which determine the activities and responsibilities of state departments of education. State departments of education (and by implication state science supervisors) are constrained in their actions toward local schools by a variety of means: the state laws relegating curriculum development responsibilities to school districts; the vast number of schools within a state; the time and resources available to the office; the degree of willingness of various schools to enlist the support of state science advisors; the state department of education policies. Within all of these constraints, the state science supervisor must exercise discretion in his efforts to encourage weaker schools to analyze their resources with a view toward preparing a program which will raise their science instruction to a higher level and to guide schools with strong science programs into well-planned experiments to discover more effective ways of handling various aspects of the curriculum. In short, the state science supervisor will need to weigh alternatives and proceed to assist schools, whether they have a weak or strong science program, in the manner he views best for science education in his state as a whole.

The state science supervisor will actually help the local districts choose among three options that are available to systems engaged in science curriculum development: adoption of existing programs; adaptation of existing programs; or creation of new programs. In the adoption of an existing program, it is particularly important that schools be made aware of the need for inservice preparation to use new programs. Practice in the use of the materials and thorough examination of course content, sequence, rationale, and teaching strategies should be suggested. Further, most available programs should be examined before deciding on a single program.

Adaptation of an existing program allows schools to utilize multiple programs, drawing upon the best of each to complete the science program desired by that school system. Coordination of each segment of the program is a major problem in this instance, however. Typically, programs are adapted over periods of time through use and alteration. In all of these instances familiarity with the program and some practice of the activities is essential. Virtually all programs, even though adopted, will require some adaptation to avoid duplication and overlapping and to integrate them into a sequential K-12 program.

A large number of today's school science programs are variations on science textbook materials. While creation of a new program is a desirable goal, in reality it is a difficult task and one for which many local school systems are ill equipped. Few local school systems are capable of marshalling the personnel and time required for such a procedure. It is important that a school system realize that the success of creating a new program is directly proportional to the allocation of the resources of personnel and time.

The state science supervisor is obligated to counsel school systems about the various constraints which operate during the curriculum development. Subsequently, he then needs to suggest the nature of the commitment that accompanies any curriculum choice made by local schools. In particular, he may suggest sources of funding available to schools involved in work of this kind. Also, a list of qualified resource personnel to assist the schools should be made known to the districts and, where requested, aid should be given in acquiring services of needed individuals. Cooperative work with such resource people is integral to the science supervisor's functions.

Adapting Existing Curriculum Resources to the Local Science Curriculum

Every local school district has a responsibility for curriculum development. In addition, each state department of education is involved in curriculum, at least to the extent that recommendations or guidelines are made available to the public school districts. However, even at the state level, and certainly at the local level, the limited amount of professional time and limited financial resources make the development of a complete sequential curriculum with all the related classroom activities, materials, and equipment a virtual impossibility. In most disciplines this difficulty has resulted in dependence on commercial interests to develop printed materials which have had a topical organization that for the most part provided the needed curriculum structure. This was the case in science education until a sudden interest at the federal level made it possible for universities and other interested non-profit organizations to obtain sufficient grant money to undertake massive curriculum development projects that were carried to the point of developing special student equipment to accomplish the goals of the program. As a result, a local district contemplating a possible new science curriculum does not have to face the impossibility of beginning from ground level; rather, an array of ready-made curricular materials is now available (including much improved products from the commercial interests that have had to compete with the federally funded efforts) that can be adopted as a whole or used in part as building blocks that can be fitted into a locally developed plan. It is this latter plan that presents the greatest difficulty in terms of actually establishing the program although either approach will present the same sort of implementation problems.

When the local district attempts to develop its own strategy it is almost certain to find something less than a perfect fit between that plan and the existing materials. The alternatives are to make compromises or adapt the available resources to the plan. Since few seem to favor the rigidity of a state or national curriculum, adaptation of national projects to suit local needs becomes a very important process. In this process the skill and knowledge of a state science supervisor can be of great value to the local district since he is in a position to know the curriculum projects in great detail and will be able to give advice that will make changes possible without losing the essential purpose and philosophy that have been carefully built upon the program by the original project committee or authors.

Related to this activity is the necessity for local curriculum leaders and teachers to have access to information about the entire range of science curriculum resources so that they may make wise decisions in their selections and subsequent purchases. To meet this need, the state science supervisor becomes a disseminator of information through sending newsletters, speaking at local inservice sessions, conducting local and statewide conferences, and making information kits, films, brochures, and other materials available through his office.

COORDINATING AND ARTICULATING THE SCIENCE CURRICULUM

Coordinating the Science Curriculum Among Administrative Units Within School Districts

The state science supervisor has a significant role to play in the articulation of the science curriculum at both local and state levels. Basically, the science curriculum should be a locally chosen one, one that is desired by the school staff, the students, and the community. It should, however, be derived from a local study of needs and interests of the school on one hand, and a survey of possible new and widely accepted science programs that are recommended as an improvement to the total curriculum on the other hand. The state science supervisor is in a position to assist with such studies and to make recommendations.

In many communities there are dual districts in which the administrative units are completely different for the high school and the elementary school. It has often been the case that the science supervisor finds little communication between the two districts about their science programs. The role of the supervisor then becomes much more complex. It is immediately recognized that the whole pattern of curriculum study and program planning in these districts needs to be changed if the science program is to be improved in its ability to prepare students more adequately for more productive and satisfying lives.

The state science supervisor, however, unlike the district supervisor, does not hold a key position in the school organization. Therefore, the state science supervisor may find it more difficult to suggest change since one of the districts within the community may not have requested his help in any way. The well-prepared, energetic, and tactful supervisor may still be unable to bring about the vertical articulation he considers essential in a particular community.

Of course, the lack of vertical articulation does not always come about because the administrative units are in two different school districts. It can also come about between two different administrative units in the same district where there is no articulation. On the surface this appears to be lack of interest and dedication on the parts of science teachers, department heads, counselors, and administrators. The truth often is, however, that many of these people have never thought of their responsibilities as involving investigation and comparison of programs in more than one building, even in their own district. To those involved in working with teachers and administrators in groups, it seems completely unrealistic that one teacher or administrator could implement a science course of study without looking at the whole picture of the child's science education.

Concern for a continuous and sequential science program spurs the conscientious science supervisor to try harder to assist the school in its curriculum coordination. Often it is difficult to get started at all. Even if one has been asked for help by one administrative unit, the other unit may not at first be receptive to any assistance. In this case, success is dependent upon the confidence placed in the state supervisor by the central administrative staff and, in particular, by the district administrator. Should work begin with one unit, it is often necessary to seek this central support in order to gain the cooperation necessary to establish district-wide articulation. When it is necessary to seek such support, the supervisor's reputation, based on his proven professional judgment, knowledge of content in the sciences, current knowledge of curricular materials in science and methods in science teaching, current knowledge about children and how they learn, and overall leadership ability, is of great importance.

When the science supervisor outlines ideas for coordination, he should try to show each administrative unit concerned that there is a reason for the suggested changes. The administrator has the right to expect him to have clearly stated justification for each suggestion that he makes.

In districts that are not large enough to have a science consultant, the curriculum decisions in science usually become the responsibility of a general curriculum specialist or selected administrator. These people promote new methodology and instructional media, set up various kinds of inservice programs, and contribute to the improvement of teaching in many ways, but their functions rarely include study and implementation or development of a district-wide science curriculum. As a result, the science program often "grows like Topsy"--a course added here this year and another next year.

The state science supervisor is able to help only when the district curriculum leaders are willing to accept outside assistance. Although curriculum supervisors often have little special subject area preparation, they must assume the function of setting up the curriculum in all areas. Since school staffs generally include teachers of high intellectual capacity and performance, highly trained in the science field, the wise generalist in science curriculum work will take advantage of the expertise of the specialized staff members. Because the state science specialist is usually known by these staff members through various professional contacts, it is common that they will seek his inclusion in the study of the district-wide program. However, until he establishes rapport with the curriculum leaders there is little chance that he will be able to play a strategic role in the development of the science curriculum. The state science supervisor, once he becomes established as a significant advisory member of a local curriculum group, should encourage the district to strengthen the role of department chairmen and to charge principals and assistant principals with the responsibility of being "administrative representatives" to system-wide curriculum study committees and to science curriculum meetings of various kinds.

The state science supervisor must be able to work with the other teachers and administrative staff to coordinate the science program, not only among various buildings or classrooms teaching at the same level, but from one grade level to another and from one administrative unit to another. The state science supervisor has the advantage of his position. Although he may be expected to leave decisions to the local administrative unit, he has some advantage in the fact that he is from the state office, especially if he has been in his present position for some time and has been visiting schools the major part of his time.

At this time, when science and the teaching of science is being constantly evaluated, reformed, and changed, it should be easier for the state science supervisor to help bring about desired coordination and articulation between administrative units. The mere fact that all administrators should be aware of this need for change should, in itself, be a catalyst, but the state science supervisor, if time permits, can be a sharp stimulant when interest lags, even if it is only by an occasional phone call. Only by a reasonable amount of care about student educational needs, and a lot of hard work and hope, can a person in the unique position of a state science supervisor bring about articulation and coordination between or among administrative units.

Coordinating the Science Curriculum With Other Areas of the General Curriculum

Coordinating the science curriculum with other areas of the general curriculum presents a variety of problems such as the interaction of pure science with technology and its effects and the differences that exist between science courses restricted to science concepts and those with a more humanistic orientation. Attempts at coordination raise questions as to what extent a course should be quantitative as opposed to descriptive and questions about science class activities which are strictly science centered as opposed to those which sometime stray from the "straight and narrow" course. Similarly, teachers and students of other subject areas will consider how and to what extent learnings in science are appropriate in their courses.

The view of the Council of State Science Supervisors on coordinating the science curriculum with other areas of the general curriculum has been expressed in a position paper included in a publication entitled *This We Believe:*

> Identification of the social and cultural implications of science is an essential part of the science curriculum. . . . This pervasive influence touches upon aesthetic and humanistic values as well as upon the economic and political climate. The relationship between science and technology and between technology and society is a complex interaction creating an increasing need for scientific literacy.

From this statement one infers the importance of coordinating the science curriculum with the general curriculum.

A study of any phase of curriculum should take into account the basic needs of children as found in *Curriculum Development for Elementary Schools in a Changing Society* by Muriel Crosby. She specifically identifies the need for belonging, for affection and love, for at least a minimum of economic security, for recognition and respect, for achievement, for understanding the world around them, for freedom of excessive feelings of guilt, and for freedom from excessive feelings of fear. Above all, an effort to interrelate instruction in the disciplines should consider such student needs.

The science curriculum is somewhat unique in the contribution it can make to other fields of the general curriculum, because the nature of science and the scientific process are transferable to all fields of learning. Some characteristics of the scientific process applicable to other fields are open mindedness--willingness to accept new facts and to change ideas in the face of new information; critical thinking--relating facts in decision making, distinguishing between fact and fiction or between observable facts and supposition, suspended judgment; intellectual honesty--reporting and recording accurately and objectively, without bias; problem solving--recognition of problems, fact gathering, and establishing hypotheses. The science teacher has the opportunity to teach these intellectual techniques related to natural phenomena in such a way that the student can see the application of them to other school and life situations. Elements of science such as these have helped science to gain the respect of teachers of all disciplines. The science supervisor or the science teacher can assist others in establishing curricula in other fields which will help pupils acquire and apply the elements of science to the general curriculum.

A second means of extending science into the general curriculum is through the medium of literature. Such books as Miss Carson's *The Sea Around Us,* Pettit's *The Web of Nature,* or biographies of some of the great scientists such as Agassiz, Jenner, Edison, Bell, Salk, and Einstein, constitute excellent reading material for literature classes. Such books are appropriate as supplementary curriculum material for either science or literature classes.

Coordination with other areas of the curriculum is augmented when the science curriculum is seen from the viewpoint of community related activities. The writing of news articles for the press, science club activities, the use of resource persons, science fair activities, and field trips are all activities which involve economics, accounting, social relationships, communications, etc. Wholesome community involvement will aid in creating a favorable image of science and will aid in combating unfavorable impressions of science which have developed recently. Most recently, the problems of environmental education have provided a means and a reason to bring science into an interdisciplinary approach to understanding and solving community problems.

Science and mathematics seem inseparably bound. Mathematics has been referred to as a pure science, and therefore, a member of the family of sciences. Science and mathematics are frequently in the same department and teachers meet together. Both science and mathematics programs are enhanced when teachers of both fields recognize the contribution which each discipline makes to the other. This communication can benefit both departments whereby the mathematics program will provide the mathematics knowledge and skills required for a particular study in the sciences and the sciences provide the opportunity to derive and apply mathematical concepts in relation to concrete phenomena. Mathematics and science instruction best complement one another when the science and mathematics teachers work cooperatively in curriculum planning.

Where emphasis is being given to quantitative aspects of science as is commonly done in physics, trigonometric functions, logarithms, mathematical equations, and even simple calculus may be required. Needs in mathematics may be partially met through classes organized specifically to obtain the mathematical skills and knowledge essential for certain science activities. Conversely, certain aspects of science instruction such as concurrent forces or alternating current theory appropriately contribute to attaining mathematical goals.

Art is easily recognized as the creative result of the effort of a skilled artist. Science is not as easily recognized as the creative effort of scientists. Yet scholars recognize the product of science to be purely creative and at a degree comparable to the greatest works of art. Similarly, the beauty of the organization in the universe as viewed by the scientist is comparable to the more easily recognized beauty of formal art. The emphasis on creativity and the intellectual joy that can be derived from appreciation of fine works are obvious links between science and the arts that can contribute to coordinating the two disciplines.

At a less involved level the skills of the artist find their usefulness in science classes in preparing diagrams, sketches, exhibits, models, and pictures. Graphic ability can be a useful tool to the science teacher in communicating information related to science concepts while making use of students who have interest and ability in this kind of expression. Such activity can motivate students who may otherwise have lacked confidence in the science classroom. Dramatic and literary skills may also be related to science activities.

Social studies, like science, is the study of existing phenomena although the statistical nature of social phenomena makes their study more abstract than the natural sciences. Because of this similarity the two areas can actually be considered as a continuum going from the most concrete physical concepts through the biological and anthropological concepts to the most abstract historical concepts. The true link between all of these areas in planning curriculum is a generalized approach to gaining and applying information about phenomena--the processes of science or, if preferred, the processes of learning. Recognition of these two curriculum features--the concrete-to-abstract continuum and the process commonality--makes the coordination of the teaching of science and social studies relatively easy provided that the traditional barriers can be broken down by the consultant.

Often, the problem approach to learning lends itself to a coordinated curriculum. The problem of cleaning up a polluted swamp at the edge of a city involves many activities from government, economy, health, science, and engineering. Similarly, solving a real problem at the local school site may involve many people whose occupations are not easily classified. A problem approach is valuable because of its proximity to real life situations in which people are less concerned with categorizing the information needed to solve the problem and process takes on a new importance. When the curriculum provides only pure science there is danger of isolating science in ivory towers. Pure science will appeal to the science oriented, but the majority of students will attach the greatest value to science as it relates to them and their communities.

An article in the *Mississippi Education Advance*, a publication of the Mississippi Education Association, entitled "Every High School Teacher A Reading Teacher" states:

> Quite often math and science teachers are aware of only a limited number of the many reading study skills in their subjects. Success in concept acquisition, however, is directly related to the quality of reading-study skills. Such skills in math and science include: use of research methods and library resources necessary to scientific inquiry; the ability to distinguish between fact and opinion in evaluating research material; an understanding of specialized presentations of materials such as technical symbols, graphs, scales, formulas, equations; the ability to distinguish between relevant and irrelevant facts; facility in translating a word statement into an equation; and skill in following a sequence of directions or different operations.

The more obvious relationships of vocabulary and sentence construction are taken for granted. The value of communication which has been identified as a major process of science must, in theory and practice, be recognized by science curriculum makers and practitioners. Proficiency in this process, therefore, becomes an objective of both science and language arts and, as such, it forms the basis for coordination between the two disciplines.

There are many opportunities for coordination with other subject areas such as industrial arts, health and safety, physical education, agriculture, home economics, business education. This coordination will be done through design by curriculum makers who use imagination. However, good science teachers will use correlations with other fields as means of reinforcement or extension of science concepts and not as a means of departure from science. In *Creative Teaching in the Elementary School* Shumsky comments:

> Stendler warns that the integrative approach may lead to diminution of science concepts. The emphasis may be on health rules (how to brush teeth) or on safety (how to ride bikes) rather than on the science aspect. This is perhaps one of the major reasons for the reluctance on the part of many science specialists, including textbook writers, to move toward integration of science and other subjects.

The key to coordination seems to lie in the contribution science can make to a humanizing general education both through conceptual learning and process learning. The opportunity for coordination is found in commonality of major conceptual schemes such as universal change, interaction and organization, and in the processes of science which, when applied in other areas, become simply processes of learning.

Coordinating the Various Science Areas in a Unified Science Curriculum

Since science education began in the American schools a century ago, educators in positions of responsibility have attempted to provide a coordinated structure for the program. Unfortunately, science evolved as a set of subdisciplines and scientists representing each subdiscipline have consciously or subconsciously tended to promote their own special interest as being more important than others. The result in school programs has been a corresponding separation of the science curriculum into subdisciplines.

The present sequence of science subdisciplines can be traced to the NEA committee on college entrance requirements at the turn of the century. Despite several efforts to develop a general curriculum which did result in biology and general science, the science program evolved to the present as independent science areas. The placement of these subdisciplinary curricula into the instructional program has been the result of the independent prestige of each science area and assumed difficulty of comprehension of each area by the student. Rapidly expanding knowledge in the field of research has exposed much of the overlap which exists among the several subdisciplines.

Most scientists in fields of biological science now recognize the need for some expertise in chemistry. Physicists and chemists share many commonalities in research. Therefore, it follows that to avoid overlap and to provide the most meaningful educational sequences in these and other science areas, some degree of coordination is required. The most frequent effort at coordination has come in the form of state and local curriculum guides. Such guides, when intended to give structure to the total science program, can be useful in eliminating excessive repetition among the several subdiscipline courses. By defining the scope and sequence of each individual course some continuity can be imposed upon the educational program.

Problem areas include the inability to reach a consensus among the several subdisciplines as to their individual responsibilities. It is difficult to reach a decision as to what is properly the domain of a subdivision and which should be excluded from all others. Each subdiscipline may be proposed as the educational capstone, and it is difficult for curriculum workers at any level to solve this problem because individuals tend to be prejudiced toward certain subdisciplines.

A positive step can be taken when the science program is envisioned as a whole. Compromise of arbitrary positions can lead to the development of a viable science instructional program while still providing for those interested in becoming physicists, chemists, engineers, or microbiologists. Traditionally, the general education phase has consisted of a survey of the subdisciplines of science with the assumption that a science oriented student could choose his vocational interest from this exposure. Another assumption was that the non-science oriented student would develop from such surveys an appreciation of the work of the scientific community. This dual function of general science courses has tended to make them dysfunctional with a scope too limited for vocational pursuits and too academic for those seeking the contribution science can make to general education. Under these conditions general, or unified, science has tended to degenerate into a modified history course stressing verbal skills.

The two primary aspects of the science discipline are its process structure (mode of inquiry) and conceptual structure (substantive content). While it is still possible to classify the subdisciplines on the basis of substantive content, the inquiry modes of the natural sciences are approximately congruent. The development of a hierarchy of investigative skills related to a generalized conceptual structure can provide the skeletal structure for a unified science curriculum. As has been pointed out earlier, the rationale for using processes and conceptual schemes as curriculum organizers is very well established, and certainly these two aspects of science make it possible for the curriculum designer to relate the subdisciplines into a unified program.

Even though the desirability of a unified science curriculum has been recognized in many schools for some time, the actual implementation of such a curriculum, with a few notable exceptions, has received little serious effort by science teachers. This has been due in part because there is a concern that students who move from one school district to another may not be able to continue in a unified science program; because many parents do not want their children to enroll in unified science courses when they are concerned about College Board scores; and because there is a lack of suggested procedures for implementing unified science courses.

Increased use of technological aids, greater emphasis on individualized instruction, and more help by paraprofessionals and specialists from the community with professional guidance from competent teachers should help to compensate for the limited number of teachers who possess both the ability and motivation to work in a unified program with students ranging widely in ability and interest. State science supervisors should be prepared to suggest procedures for implementing a unified science curriculum in the schools of their state, and an effort should be made to encourage as many schools as possible to participate in this endeavor in order to reduce the scheduling problems when students move from one school district to another. State science supervisors should also work closely with colleges and universities in their states in order to promote the development of unified science courses at the teacher preparation level. The introduction of unified science courses at the college level should help to increase the acceptance of the concept at the high school level. In addition, state science supervisors should develop guidelines for programs which will work within the prevailing limitations imposed by the nature of teachers, of student bodies, and of school facilities when promoting the development of a unified science curriculum.

Whether a unified science curriculum can be successfully introduced into the high school program will depend in large part on meeting the following conditions:

> The subject matter must be selected very carefully. Determine the objectives in each of the separate science areas and then use the overlapping objectives as a guide for determining content to be included in the unified curriculum. Both process and conceptual objectives should be selected.
>
> The basic approach to a unified science curriculum is to select a few significant conceptual schemes to serve as a structural framework. The use of conceptual schemes that reveal unifying relations and deeper insights is good strategy for dealing with students of heterogenous background. The slow learners do not get lost since they can concentrate on a few essential ideas, while the exceptionally able students maintain their interest as they learn to see the interrelationships of the schemes in diverse science disciplines.
>
> A hierarchy of process accomplishments developed from identified major science processes should be developed concurrently with the conceptual structure.
>
> The unified curriculum should provide for effective cooperation between "teachers" and "learners" and should produce meaningful feedback from students and teachers to those professionals who are responsible for curriculum development.
>
> The unified science curriculum must acquire the reputation for being intellectually honest as well as exciting to the students and to the teachers. If this is the case, the curriculum will appeal to the students and attract exceptionally capable teachers.

Whether as ordinary citizens or in positions of leadership, our present school population will be called upon to make decisions in the future which will significantly affect the quality of life in our society. The present practice of keeping the various science areas separate and distinct from each other has not yet succeeded in producing a society with a reasonable familiarity with science. A different approach is needed and one possible course of action is the development of a unified science curriculum.

Coordinating the Science Curriculum Among Grade Levels Within Schools

As a state supervisor contemplates a curriculum in science, he should not consider structuring a curriculum that would suit the needs of all the schools of the state, nor should he consider a specific program for each teacher or student. The best a supervisor can do is plan a general program for the state and expect each district to add details to suit its own characteristics. When completed the curriculum should still be general enough to allow each teacher to accept the responsibility for fitting the curriculum to the individual needs of the students.

It is important that students become involved in a variety of science areas. Just as it is impractical for a mathematics student to work only addition and subtraction, a science student should not be limited to just the study of plants and animals. He should also be exposed to physical science and earth science as well as specialities within these broad areas. In any one year a certain area may be emphasized more than another, but science should be diversified.

After a school system has developed a science program and the administrators and teachers are agreed that this is the program for them, the process of coordinating the curriculum begins. It is sheer folly to hand teachers new teaching materials and tell them to start using them without extensive preparation. Many elementary teachers have not had a well organized summer institute nor extensive training in science in their undergraduate training. Some group planning or workshop meetings are necessary to coordinate a program within a school. There are many instances when group discussions and working together are beneficial, but it is also true that all teachers do not require the same program and same help because of their grade level, their teaching experience, and their science background. Teachers should have individually prescribed instruction related to the new curriculum based on diagnosed needs.

The most important activity related to coordination of a curriculum among grade levels within a given school is team planning. This activity can be carried out on a regular basis with a local science consultant or, where consultant time is too limited to make it possible for him to work regularly with each school, one person in the school may function as department head to lead the planning sessions. In elementary schools a unit plan has emerged that allows for a teacher leader for each group of teachers who carries planning and coordination problems to conferences with other leaders and the building principal. This hierarchy of responsibility serves well to establish coordinated programs within the school structure.

The state science supervisor may act as a consultant but in most cases coordination of the science curriculum within a school is ordinarily a local responsibility. Teachers must be provided flexibility in time, in content, in method, and in their use of equipment; a teacher should not have to be on a certain project or a certain page in a book at a certain time. However, the curriculum must provide sufficient structure so that all areas are taught and a teacher in the fourth grade, for example, does not do the same thing as was done in third grade. In general, there must be structure for sequence, content, and activities. Teachers should know what other teachers are doing, what the students have been exposed to, and what the students will accomplish in future science courses. They should also be aware of the progress students are making toward the program objectives.

The ultimate function of supervision is to provide the best possible conditions for teaching and learning by coordinating the total science program for the students' benefit. The teachers are the core to an effective science program, but the administration must be helpful and familiar with the teachers' work.

Science teachers need encouragement in using effective modern methods in teaching. They need the freedom to experiment with new ideas, they need an acquaintance with nationwide experimental programs, and they need provisions for keeping up with science itself. They also need to associate with professional workers in their field on a national, state, regional, and local level in order to be aware of their degree of success in fulfilling their responsibility in the total science education experience of the students.

Strategies for Interrelating Science Classroom Activities

Since curriculum is both content and process, it consists of classroom activities as well as topics and understandings. It is, therefore, necessary to properly relate classroom activities if the curriculum is to be most effective. Every teacher has at his disposal a multiplicity of choices of activites all of which are potential parts of the curriculum. The activities actually chosen and implemented are dictated by many factors peculiar to the local situation. Those activities chosen should complement one another in developing the concepts or main ideas. The strategies for interrelating science classroom activities may take several forms.

Steps in the development of a concept may involve both the students and the teacher in the processes of preparation, motivation, presentation, association, application, and evaluation. Certain activities lend themselves better to a particular process than to others. For example, the introduction of a major idea may be made by the use of a carefully selected film primarily for the purpose of motivation and preparation of the students for that which is to follow. On the other hand, the film may not be suitable at the application or evaluation stage.

If activities are those which are ordinarily accorded to the scientific process, the introduction may begin with the recognition of a problem by either an observation of existing conditions or posing problems vicariously. Other elements or steps in the scientific process such as the gathering of facts and analysis of data require different types of classroom activities such as reading, observing, computing, and questioning. Classroom activities should be provided which will do two things in particular: develop the idea as far as advisable and exemplify a scientific process during the course of development. The strategy, then, should be one of selecting activities for developing specific parts of the idea or particular goals of instruction and fundamental elements of the scientific process.

As a general rule, a principle of science does not exist in a vacuum but is related to other scientific phenomena and manifests itself in many ways embracing most of the subdisciplines of science. The curriculum should be so designed that it draws on the previous experiences of the student and relates to his life situations. Since a student thinks in terms of his past experiences, it is necessary to assist at least the average student by reminding him of the manifestation of the principle in other situations with which he is familiar and to aid him in hypothesizing how the principle would apply in some new situation.

Correlation is especially necessary when the subdisciplines are treated separately. In a unified course, the problem may become one of application rather than correlation in considering particular cases of the same principle. For instance, the inverse square law is a good example of a principle applicable to many situations of physical science and to some cases of biological science.

It is just as important to correlate new techniques with previously learned techniques which are within the skills and knowledge of the student. For instance, where the essential task becomes that of identifying forms or shapes of bacteria, it must be assumed that one is already acquainted with the techniques of operating the microscope and handling cultures.

In any case of curriculum development, the science supervisor should emphasize flexibility and adaptability to the local situation. An ideal approach is to establish a curriculum and then secure the teaching staff, equipment, supplies, and administrative support for that curriculum. However, this may not be practical and one must think in realistic terms for a particular situation. There may be a problem of staff unwilling or unable to adapt to the new curriculum. There may also be the problem of obtaining sufficient materials or equipment to carry out desired activities. Many times, too, classroom activities are limited by nature of administrative assignment of teaching space, scheduling, and programming. The state supervisor may be able to expedite accessibility of materials and suggest scheduling which will achieve maximum utilization of the science facilities.

Department planning or inservice training can help alleviate some of the problems which otherwise would restrict activities and impose a limitation on the curriculum. The sharing of ideas, the sharing of equipment and materials, and proper programming and scheduling will help in establishing a course of study that is to some extent coordinated within the school system. A syllabus developed by the local science staff will afford much help in interrelating science classroom activities in a school system.

Several situations affecting the interrelating of science classroom activities must be considered. There is an availability of materials at one season and a paucity of materials at other times of the year. Also, the availability of resource persons and resource centers in one area and absence in another is an implication for the curriculum. The fact that one school is rural and another urban markedly affects the type of program which can be offered.

In planning science activities, the amount of time given to class or laboratory work has a bearing on the activities or curriculum. Efforts should be made to encourage the providing of at least one double period per week which would permit comprehensive laboratory activity. Field trips to nearby sites can be informative and interesting to students, also.

IMPLEMENTING THE SCIENCE CURRICULUM

Deterrents to Curriculum Implementation and Strategies for Overcoming Them

Although many new science curricula have become available in the past decade on both the elementary and secondary level, their impact upon the majority of schools has been relatively small. Undoubtedly there are many reasons which account for this lack of change in the classrooms. Although school systems have differing problems relating to the implementation of major curriculum change, there are certain deterrents which can be identified as operating in a large number of instances. Some of the deterrents to curriculum implementation are administratively oriented. Although the district superintendent is the person who has the legal status to make curriculum decisions, certain constraints upon his time may result in a decision to accept or reject a certain curriculum project without his direct involvement. In addition, the initial cost of implementing a new curriculum project may be such that administrators see it as not being economically feasible. Certain curriculum projects fail at the outset because of a lack of administrative support usually due to a lack of understanding of the project or to a failure of those favoring the change to show that the positive effects will outweigh the cost.

Other deterrents are teacher oriented. The teachers may lack in-depth knowledge as to what the new curriculum attempts to accomplish. There may also be teacher apathy to change based mostly on the failure to perceive a clear cut reason for change. The teachers may oppose the objectives and methodology and lack the process skills which are necessary for the new curriculum. In addition, they may also lack exposure to exemplary models so they can acquire a better understanding of the innovation, or they may lack the opportunity to be involved in the decision-making process of curriculum change. The school system may not have an active curriculum committee composed of both teachers and administrators, and it may be unwilling to provide additional compensation or released time needed to properly implement curriculum change. There may also be a lack of appropriate inservice training in regard to the new curriculum or a lack of consultant assistance in the implementation of a new curriculum. Finally, curriculum change may be deterred by the subject matter centered orientation commonly found among some school teachers, by the inadequacy of teacher institutions in producing teachers knowledgeable in certain teaching skills, or by the common concern for student performance on standardized tests as a result of curriculum changes that have an emphasis different from the kind of achievement measured by the tests.

Some strategies to overcome deterrents to curriculum implementation can be quite successful in eliminating most of the major problems involved with the introduction of extensive curriculum change. A school must not be handed a ready-made curriculum but rather, if implementation is to be successful, must develop its own curriculum from existing curriculum resources adapted to the local needs. Following the development stages, the task remains to construct a strategy for curriculum installation, complete with distinct components and approximate implementation dates and to follow the strategy from the start without resorting to a "we'll work it all out as we go along" approach. One should begin an extensive curriculum installation only after specific written agreements clearly describing participant roles and responsibilities are accepted by all collaborators. One should verify that teachers scheduled for involvement in a curriculum installation effort did personally volunteer or agree to participate. Curriculum developers must examine closely the existing curriculum as this will constitute the base from which the new program must develop. They will probably find it necessary to provide an intensive inservice workshop in the innovative curriculum for participating teachers and administrators and provide participating teachers with live or filmed models of the instructional methodology as prescribed by the developers of the new curricula.

The state science supervisor should employ a structured, classroom-based, task-oriented type of consultant service available to cooperating teachers, and select other consultants who know the curriculum including its software, hardware, and psychological undergirdings, and who can actually teach it to children. The state science supervisor should recommend that schools make formal provision for periodic, planned faculty assessment of curriculum implementation and resulting student achievement. He, of course, must work closely with the local science specialist in the planning, selecting, preparing, implementing, and evaluating phases of curriculum installation. Together they must make sure that the actual utilization of an innovative curriculum takes place in every classroom. Prior to final implementation, efforts must be made to insure that the philosophy and objectives of the new curriculum are understood by school board members, parents, and students. Finally, procedures to implement the new curriculum must not begin until all the required curriculum guides, other materials, equipment, and facilities are available.

Designating A Hierarchy of Responsibility to Individuals Involved in Curriculum Implementation

The development of a hierarchy of responsibility of individuals involved in the implementation of a curriculum once the curriculum has been designed or selected is obviously a very important phase of curriculum change. These individuals or groups of individuals may be from the local district or they may represent other agencies such as other school systems, universities, the state department of education, commercial suppliers, curriculum groups, and funding sources.

Locally, the school board has the responsibility to verify the educational soundness of the proposed change by consultation with administrative staff and the local science consultant and to fund the proposed change at a level that will insure a reasonable chance of success. To meet this responsibility effectively the board members must recognize that progress is the result of trying something different and that although new approaches will not always prove effective, without these efforts, improvement of the educational process would be extremely slow.

The local superintendent will make the final decision on the approach, content, methodology, and budget for the proposed programs. He will ascertain the possible effects of the proposed change upon other facets of the educational program and upon facilities and other resources within the school district. He will also verify that the involvement of his staff in the curriculum effort is parallel to their capabilities and positions.

The local principal is responsible for consulting with the superintendent and for understanding and accepting the superintendent's decisions regarding approach, methodology, and budget for the proposed program. The principal will recognize the possible effects of the proposed change upon other areas of the specific school's program and physical structures, and he will anticipate the major outcomes and side effects that will result from trying new and innovative programs. He must maintain a climate for change within his faculty, exhibit confidence in the ability of his faculty and support their efforts, keep the public and parents informed as to the expectations, progress, and outcomes of the curriculum change, and share information gained as a result of the implementation process with interested educators and community.

The local science consultant is responsible for developing a rationale for curriculum change from the science educator's viewpoint and for making that position clear to the administration. He needs to determine the practicality of obtaining suitable teacher training and to arrange the experiences required to update teacher methodology and understanding of subject matter. He must establish a cooperative relationship between himself and the pilot teachers and provide information concerning curriculum decisions to the entire staff. He must secure feedback from pilot teachers, use it to revise the curriculum during the implementation process, and provide for evaluation of the changes. Overall, he will be responsible for encouraging those involved in the implementation process when difficulties arise, keeping the administration informed of current progress, and coordinating all efforts related to the implementation process.

After having an opportunity to express his opinions and desires, the teacher must accept the administrative decisions that will determine the nature of the curriculum. He must conscientiously make every reasonable effort to successfully implement the new program, and he must become fully involved in the inservice opportunities provided. This will require that most teachers make some compromises in order to make possible a coordinated curriculum effort. The teacher is also responsible for actively participating in the "feedback" system to facilitate the solution of problems and to provide for sharing of better implementation ideas.

If there are local paraprofessionals, it is their responsibility to support the teacher in implementation procedures by assisting in preparation for classroom activities and by relieving the teacher of mechanical duties that may otherwise, because of a heavy work load, inhibit the classroom implementation phase. The paraprofessionals involved should take their direction from the classroom teachers.

The students, too, have responsibilities to the program. They need to maintain an open mind regarding a new program until they have experienced a reasonable cross-section of the activities. It may be noted that lack of responsible action by students is seldom an inhibitor in curriculum change. They welcome innovation, especially in science when the change includes increasing their responsibility to learn within a structure that reduces teacher dominance.

In terms of the responsibility of the public in general, parents represent the major group involved. They need to help their child, where necessary, cope with changes encountered at school. They should recognize that school programs are dynamic and that changes are necessary to keep pace with the characteristics of each new era. They must recognize that improvements in our educational system cost money and may result in increased taxes, but that increased taxes do not necessarily mean decreased efficiency in spending. If parents have concern about curriculum changes, they should share this concern with the school administration and with school board members. They should never abdicate their responsibility to have a voice in school affairs, but they should also be responsible to understand the conditions of these affairs and to recognize that education is a complex operation requiring the expertise of trained specialists.

Two different university groups must share in the responsibility for curriculum implementation--the department of education (curriculum and instruction including science education) and the science departments. The department of education may also establish rules and regulations regarding off-campus instruction with maximum flexibility in order to allow the development of inservice training programs tailored to meet the individual needs of each school district and program. Those faculty members working directly with science education must have the experience and knowledge necessary to provide inservice training in both methodology and subject content related to the new program. If such capability is not available from the existing faculty, the university should be prepared to secure experienced instructors from outside sources (possible adjunct professors). In the specific science areas, content of science courses offered should be adjusted to meet the needs of the teachers and the programs that might be expected to be implemented. These departments should also obtain qualified instructors with knowledge of the nature of the trends in science education in the pre-college levels.

The state legislature has tremendous responsibility in the area of curriculum change. First, it must recognize, as must school boards and administrators, that improvements in our educational system will require increased state and local financial support. The legislature must also consider current educational trends and their affect upon education in their state and recognize the role of state government in implementing desirable changes. And of course, like all groups involved, the legislature must recognize that children represent one of the state's primary resources and that funds properly spent on their education represent a wise investment.

In the state department of education the science supervisor will, of course, have a leadership responsibility in the implementation of science curricula. It is his task to advise local school districts on procedures involved in program implementation, aid them in developing a plan that fits their situation, and help in the search for funding sources. He will also make recommendations concerning the solution of human, materials, and facilities problems resulting from the implementation efforts. In many cases his recommendations provide credibility to prior statements of need made locally. He may also assist local school districts in obtaining resource persons to staff inservice programs, assist universities in the development of relevant inservice programs, facilitate the solution of any constraints that might exist at the state or local level, encourage school districts to investigate other successful projects, establish lines of communication between all districts involved in similar implementation efforts, serve where necessary as a clearinghouse for information, and assist in developing evaluation procedures. Other people in the state department of education may help by establishing rules and regulations that reflect current trends in education and that allow the flexibility required to promote educational change.

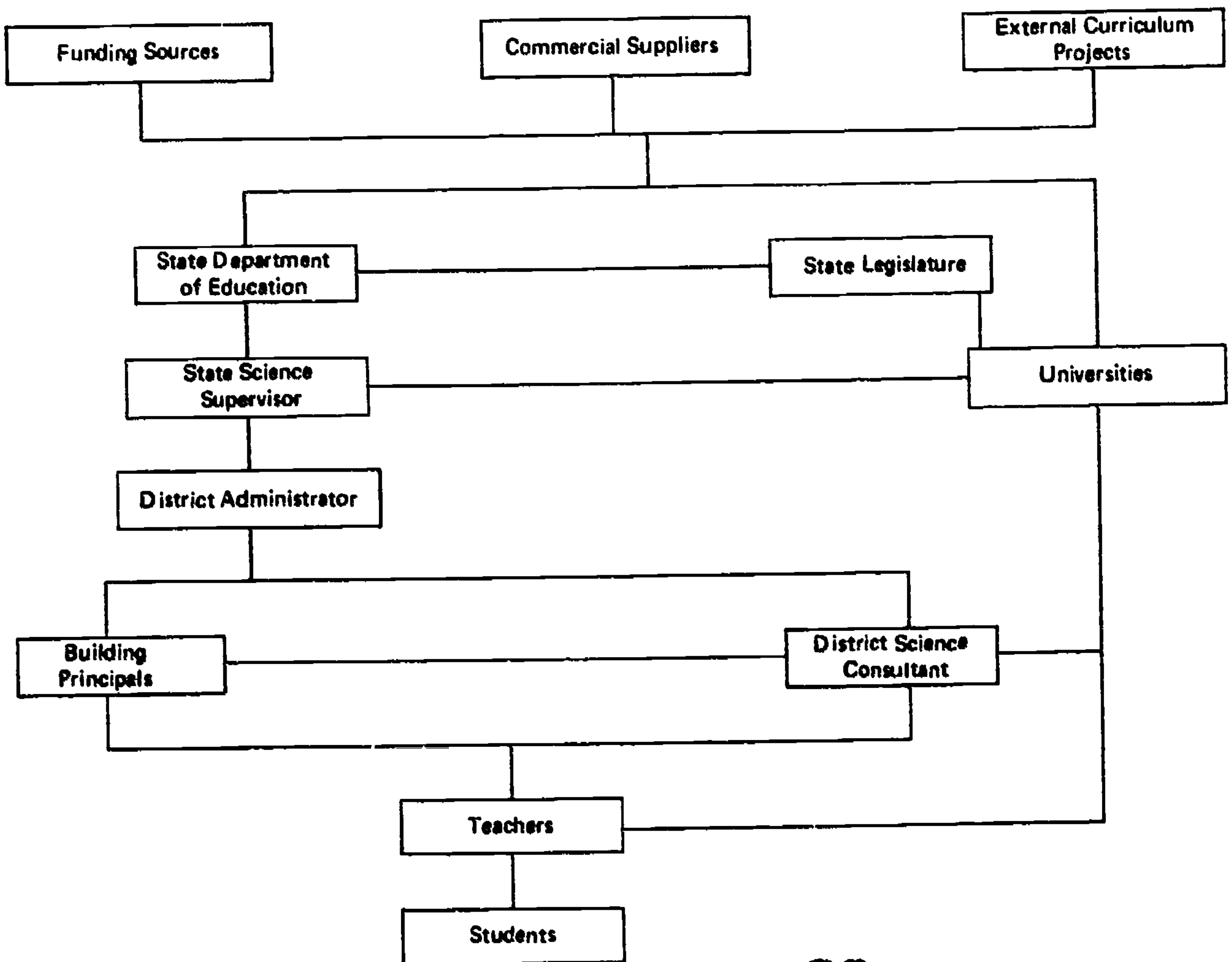
Commercial suppliers are responsible in that they must cooperate with school districts and universities in delivery of all program materials as specified and accurately describe all commercial aspects of their programs as they relate to the implementation process.

External curriculum projects, such as those that have existed on a national level, must make every reasonable effort to refine their programs before they are released for general use. They should share information on curriculum innovations that have achieved considerable success as well as those that have proven to be potential problem situations. Also, they should make every effort to insure a reliable source of unique equipment, or kits, to interested school districts and to cooperate with the educational community in the establishment of a core of trained inservice workshop instructors familiar with all phases of the program as it relates to the classroom.

Finally, funding sources are required to insure that initiated curriculum projects will continue through adequate dissemination, implementation, and evaluation phases to demonstrate their actual value to education. In most national programs it has been necessary to fund regional institutes to provide a core of experienced teachers to carry the innovations into the local school districts.

The following diagram summarizes these responsibilities and establishes a hierarchy that demonstrates the interrelationships between the individuals and groups that become involved:

A HIERARCHY OF RESPONSIBILITY IN SCIENCE CURRICULUM IMPLEMENTATION



Developing A Sequence of Activities for Curriculum Implementation

It is obvious that no single sequence of activities will fit all curriculum implementation efforts. On the contrary, the particular sequence of implementation activities chosen will depend upon various parameters including: the level at which the curriculum is to be implemented; the school districts commitment in time, philosophy, and dollars; assigned personnel, material resources, and facilities; the ability, willingness, and opportunity of those involved to fully participate; rules and attitudes, explicit or implied, which govern the actions of schools and communities regarding curriculum; the students to be served and what is known about them; and the present curriculum.

The role of the state science supervisor in any curriculum implementation is governed by a variety of constraints. What he does with regard to developing a sequence of activities for curriculum implementation will depend, for example, upon the stage at which he enters the implementation process, his rapport with personnel in the involved district or school, the time he is able to devote, and his own commitment to the philosophy of the proposed curriculum. The state science supervisor must be knowledgeable about recent science curriculum innovations and related problems at the national, state, and local levels to be effective in assisting schools in the process of implementing the curriculum that has been selected or developed.

Any activity designed by the state supervisor to facilitate or promote curriculum implementation will obviously involve people. It is important that the supervisor recognize the various roles these people are to play in each stage of implementation as well as appreciate their needs, desires, and abilities in light of the particular situation. Those who have been given the responsibility for implementing a curriculum should be encouraged to fully participate in the activities and their development. Among those to be considered as sharing the implementation responsibility are students, teachers, administrators and auxillary personnel, department heads, local supervisor, parents and other citizens, and college and university personnel. Among the organized groups to be considered are curriculum committees, citizen advisory groups, school boards, legislative bodies, and professional organizations.

Since philosophy (both individual and collective) determines, or at least influences, the nature of every transaction which takes place during such a human activity as curriculum implementation, the science supervisor should be aware of the various philosophies that pertain to the activities he will initiate or direct. It can be expected that the educational priorities of the individuals and represented groups involved in the project will be very diverse, and correspondingly, it can be expected that a dogmatic approach by the supervisor will result in a lack of interest and cooperation on the part of those he is trying to help. To be effective, the supervisor must be very clear concerning his own philosophies while at the same time being willing to consider the position of others. In the early stages of implementation, differences must be compromised to expedite the attainment of the overall curriculum goal.

The establishment and maintenance of any new curriculum will probably involve expenditures for facilities, materials, and personnel as well as expenditures for the initial activities directed at implementation. It is necessary to consider not only what the expenditures might be but also who is to pay the bill and what the possible alternatives for funding are. Some of the institutions or individuals that may be responsible for financing certain facets of curriculum implementation are the local school district, teachers involved in inservice courses, federal and state agencies, and commercial sources such as publishers of curriculum materials. The state science supervisor should offer leadership to assist implementers to determine costs that must be anticipated and to locate sources of funds from outside the district when it seems warranted. However, it should be realized that curriculum change is usually the responsibility of the school district, and, therefore, the district should expect to absorb the major part of the implementation costs.

There are a number of sequential phases to be considered in the process of curriculum implementation: Phase I--initiation of the idea to implement new curricula; Phase II--exploration of curriculum alternatives; Phase III--decision to implement; Phase IV--pre-installation training of personnel; Phase V--post-installation activities; and Phase VI--evaluation.

Phase I--Initiation of the Idea to Implement New Curricula

From the point of view of the state science supervisor, activities leading to local curriculum implementation most often begin before he is made aware of the possibility or necessity of changes in the curriculum. The initial idea to consider implementation of a new curriculum ideally comes from sources within the educational system in which the change is to take place. Although many of the factors which give rise to the consideration of curriculum changes within a system are completely removed from the influence of the state science supervisor, there remains much that the state supervisor can do to directly or indirectly motivate thinking about curriculum alternatives. He might, for example, speak to administrative and teacher groups at conventions and other meetings regarding potential curriculum alternatives or encourage participation of teachers and administrators in curriculum institutes. He might also conduct workshops, make specific suggestions to individual persons or districts, work through college personnel and local consultants, and make recommendations through newsletters and other indirect contacts.

Phase II--Exploration of Curriculum Alternatives

Once a local system has decided to change some facets of its science curriculum it is faced with exploring alternatives. The state science supervisor can assist in this phase by working with curriculum leaders and administrators to identify limitations, responsibilities, and resources. A variety of questions must be answered regarding the scope of the project, the prospect of local development versus adoption of existing curricula, financial sources, the strategy for implementation, and the involvement of staff. The state supervisor can provide information that will lead the district personnel to survey pertinent curricular materials, he can consider objectives for science education, and he can make contacts with resource people that can provide expertise not available from the district staff.

Phase III--Decision to Implement

While the decision to implement a specific curriculum rests with policy makers in the educational system to be affected, there are a number of activities the state supervisor can suggest to assist those who will make the commitment to implement. He can recommend that systems establish curriculum committees with representatives from all segments of the educational community to be served and further recommend that these committees be empowered to make commitments regarding curriculum within specified constraints. He can confer directly with policy making bodies about the merits of proposed curricular changes and encourage these bodies to adopt new curricula. In some states the state supervisor can also influence acceptance or rejection of legislation or educational policies established by state boards of education which may force policy makers at the local level to make decisions to implement new curricula.

Phase IV--Pre-Installation Training of Personnel

It has been pointed out that contemporary changes in the science curriculum involve much more than subject matter considerations. They involve how people learn science, how it is taught, to whom it is taught, and under what circumstances it is taught. Values, attitudes, and philosophies play a key role. Consequently, careful and thorough pre-installation training of staff members is critical. Related to this phase the state science supervisor may:

Advise the system of the importance of inservice training prior to actual teaching and of the need for teachers to develop a commitment to the philosophy, methods, and materials associated with the curriculum to be implemented.

Assist in the identification of individuals to be involved in the pre-installation training--teachers, para-professionals and teacher aides, administrators, local supervisors, and resource personnel.

Assist in the development of training activities designed to meet the needs of individuals involved in the installation.

Conduct workshops for teachers or for those who will themselves serve as consultants to teachers.

Provide through publications or other media examples of inservice training models to give guidance to local consultants.

Suggest the appointment of a local consultant to direct the initial implementation activities and to be responsible for maintaining the curriculum.

Suggest other consultants familiar with the philosophy, methods, and materials of the curriculum to be implemented who might assist in the training of local teachers.

Teacher training programs should provide science teachers with the capability to establish learning conditions conducive to meeting the goals of contemporary science education. Although preservice training should be designed to develop these competencies in teachers entering the profession, inservice training programs are often needed to produce necessary changes in the behavior of practicing teachers. A teacher training program, whether it be preservice or inservice, should be organized for the attainment of definite competencies that will make it possible for teachers to provide educational experiences with a balance between a conceptual structure, and a process structure within the context of the nature of science and the relationship of science to society. Such a teacher training program should result in a teaching-learning method that is dependent upon investigation related to direct experiences.

Phase V--Post-Installation Activities

Many new curricula, whether developed locally or on a larger scale, include radical departures from traditional teaching strategies and impose new roles upon administrators, teachers, students, and other members of the educational community. If the implementation of such curricula is to be relatively smooth and lasting, it must also include post-installation activities among its components. Such activities include:

Establishment of a staffed, on-site resource center to provide materials as they are needed and such other day-to-day assistance as is necessary.

Continuing inservice course work designed to supplement and enhance the curriculum implementation. This work may be conducted by experienced local teachers, college and university personnel, state or local science supervisors, or administrators.

Periodic meetings of involved teaching and administrative personnel to discuss mutual observations and to share ideas and concerns.

A regular program of maintenance of equipment and consumable supplies necessary to conduct the program.

Visitations by the state science supervisor and other consultants to evaluate the status of the implementation process and to make recommendations for further progress.

Phase VI--Evaluation

Presumably, a new curriculum is implemented to bring about a desirable educational change in the community the curriculum serves. In some cases, the new curriculum is designed to better realize the attainment of goals which the community already holds. In other cases, new goals are established. At any rate, evaluation enters into every phase of the implementation, and because it is so directly related to goals and to what finally happens in the classroom, it must be considered at the outset. There are a number of activities regarding evaluation that will promote the establishment of structures and policies to guide evaluation of the implementation process. These activities may originate locally or they may result from recommendations made by the state science supervisor. The evaluation procedures need not be extremely complex nor even entirely objective, but it is very important that a strategy be provided that will indicate to teachers and administrators the degree of success in reaching the educational goals that were established at the beginning of the curriculum project.

The implementation stage is the first real opportunity to evaluate a new curriculum. Of course, in earlier stages comparisons may be made to other materials and pilot programs may be used to provide feedback for revision, but the chance for a true test of workability comes at the time when there is a broad application of the curriculum in a variety of classrooms with a wide diversity of teachers and students.

The nature of the evaluation plan and the role of various people in administering it depends upon the scope of the curriculum effort. If the change is intended to be statewide or regional within the state, the state science supervisor will have a very direct role in the assessment. If the change is limited to a local school district or to a school within a district, the state supervisor may still be asked to participate on a consultative basis. Regardless of the level of involvement, the primary role of the consultant in assessing curriculum effectiveness is in establishing an evaluation strategy that allows for feedback throughout the early stages of implementation. Where early results are positive, the strategy must also provide for continuing evaluation as the curriculum evolves to conform to changing characteristics of the educational situation.

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