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This report is the outcome of three conferences involving scientists, science educators and teachers. Recommendations are addressed to teachers of science courses and professional courses for elementary school teachers. Two standards are stated, one relating to facilities and materials in teacher education institutions, the other to individualizing instruction. Guidelines are given, followed by objectives stated as desired terminal behaviors. Areas considered are attitudes towards science, processes of science, scientific knowledge, continuous learning, instructional management, relations with children, relations with school and community, and team teaching. A model program is outlined for experiences with children and schools. Questions follow each standard and guideline for use by evaluators of teacher education programs. A statement on the liberal education of the teacher emphasizes co-curricular activities. The report concludes with a call to action, suggestions for development and demonstration projects, and suggested questions for research. (EB)

PRESERVICE SCIENCE EDUCATION OF ELEMENTARY SCHOOL TEACHERS

Preliminary Report

Standards and Guidelines

and

Recommendations for Research and Development

A report of the project on the

Preservice Science Education of Elementary Teachers

sponsored by the

AAAS Commission on Science Education

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CONTENTS

FOREWORD

This report suggests ways in which preservice science education might be improved to bring about more effective science teaching in elementary schools. The purpose of the report is to stimulate discussion and study of preservice education. The AAAS Commission on Science Education hopes that the report will be discussed frequently and critically by groups of scientists, teacher educators, and elementary school teachers and administrators. It is further hoped that these discussions will yield constructive criticisms and suggestions that can be used to revise and strengthen the report in another year.

If the report stimulates discussion, prompts teacher education institutions to give serious attention to updating their preservice programs in science for elementary teachers, and even more importantly, to initiate research and development projects from which better answers to relevant and important questions can be found, the preservice project will have served its purpose.

In its initial planning the Commission requested support for a six-month planning period to be followed by the organization of a cooperative project in four centers in which samples of materials of the kinds described in the report would be written and tried. When it was learned that funds would not be available for the developmental work, the Commission decided to go ahead with the planning period with the hope that others would be persuaded to embark on the urgent development and research.

The AAAS Commission on Science Education is well aware of the complexities involved in the preservice education of elementary teachers. Elementary school teachers constitute the largest professional group in the United States. Each year 85,000 elementary teachers are graduated from more than 1,200 institutions of higher education. These teachers are expected to teach language arts, social studies, mathematics, health, fine arts, and physical education in addition to science. Their task is complicated by the fact that recent curriculum projects in mathematics, science, and other areas have redefined what should be taught in elementary schools. While science in elementary schools has been completely changed, most science courses for teachers at the college level have changed little or not at all.[1] Herein lies the pinch of the educational shoe.

Prospective elementary teachers should be prepared to teach new programs in science that are being developed; they should be prepared to continue their study of science after graduation in order to adjust to a changing curriculum. It is often suggested that they should study science in the way that they are expected to teach science to children, but at an adult learning level. Present preservice education programs do not prepare teachers in these ways and improvements are urgently needed.

In 1963, *Guidelines for Science and Mathematics in the Preparation Program*

[1] There are exceptions. See for example Physical Science for Non-Science Students (PSNS) developed by a group working at RPI. The materials are published by John Wiley.

of Elementary School Teachers was prepared by a joint project of AAAS and the National Association of State Directors of Teacher Education and Certification. The NASDTEC-AAAS Guidelines were widely distributed and have brought about improvements in the preservice programs in science and mathematics for elementary teachers. They continue to be of importance. However, the Guidelines appeared before the development of the new elementary science programs and their recommendations are expressed in terms of course titles, which are always subject to misinterpretation. This report provides recommendations for pre-service education of elementary teachers, which take into account recent developments in science and in education, and attempts to define what elementary teachers should be able to do.

Two educational innovations of the past year give promise of having a major influence in the improvement of the preservice education of elementary teachers: the new *Standards and Evaluative Criteria for the Accreditation of Teacher Education,* which has been prepared for use by the National Council for Accreditation of Teacher Education, and the Model Programs developed by nine universities under contract with the U. S. Office of Education. These materials have greatly influenced the thinking which led to this report, and they contribute in a significant way to its timeliness. It is reasonable to expect that this report will be useful to NCATE evaluation teams, and will strengthen the science components of Model Projects as they are put into practice.

The recommendations of this report grew out of a series of three conferences in which over sixty leaders in American education participated. They are bold and perhaps idealistic. For this there is no apology—bold action is needed.

The report is the product of the hard work of the participants in the three conferences; their names are listed in the Appendix. Special credit must be extended to the members of the Commission's Committee on Teacher Education: Deborah Partridge Wolfe, Queens College of the City University of New York, Chairman; Hubert N. Alyea, Princeton University; Addison E. Lee, The University of Texas at Austin; Wendell H. Pierce, Education Commission of the States; and William W. Rubey, University of California at Los Angeles and Rice University.

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AAAS Commission on Science Education

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1

WHERE ARE WE GOING, HOW SHALL WE GET THERE, HOW WILL WE KNOW WE'VE ARRIVED?

There once was a teacher
Whose principal feature
Was hidden in quite an odd way.
Students by millions
Or possibly zillions
Surrounded him all of the day.

When finally seen
By his scholarly dean
And asked how he managed the deed,
He lifted three fingers
And said, "All you swingers
Need only to follow my lead.

"To rise from a zero
To Big Campus Hero,
To answer these questions you'll strive:
Where am I going,
How shall I get there, and
How will I know I've arrived?" [2]

Introduction

Robert Mager's delightful poem provides an outline for this report as well as for the entire process of teaching. For what *is* teaching other than answering the questions posed in the poem?

This report suggests where we should be going in the preservice preparation of elementary teachers to teach science. In doing this, the report describes the skills that teachers will need to teach modern science to children. How will we know we've arrived? That question is touched on too. The statements suggest what to look for as evidence that teachers have the skills that are called for.

Although the primary concern is with science teaching, it is impossible to look at the preparation needed for elementary teachers to teach science without considering other aspects of preservice teacher education. Considerations have ranged from elementary science to liberal education in college,

[2] Robert F. Mager, *Developing Attitude Toward Learning* (Palo Alto: Fearon Publishers, Inc., 1968) p. vii. Published with permission.

from attitudes to manipulative skills, from performance objectives and individualized instruction to the spirit of inquiry and being human. It is clear that the problem involves more than the revision of college science courses or reordering the professional education sequence.

These broad considerations arise, in part, from a note of general dissatisfaction with the school and society as a whole—it is not only that science is often badly taught; for many youngsters, the entire school experience is frustrating and limits their intellectual development.

These limitations are found in all teaching, not just the teaching of science. Witness the following quote from a recent review by Waetjen:

"Information which children placed in the [learning] situation was often ignored, overlooked, or not considered by the teacher. More importantly, the kinds of teacher responses which seek expansion and association of ideas, which ask for comparison and inference, and which relate to personal experience and opinion occurred rarely." [3]

To Whom Is the Report Addressed?

This report is addressed to those scientists who teach courses for elementary teachers. They must make the important decisions concerning the nature of science experiences for teachers. Are the science experiences that will be most valuable for future elementary teachers the same as those for future scientists, engineers, or even future lawyers? If not, what experiences do teachers need? These are the questions which must be answered. This report outlines many of the skills, attitudes, and competencies that the teacher will need to teach a modern course in science; the design of experiences which will lead to these skills and attitudes is largely left to college scientists.

This report is also addressed to professors of education since these individuals are generally held responsible for the teachers who are prepared by an institution. The professor of science education may find it necessary to teach the prospective teacher science that he did not learn in his science courses or which he has since forgotten. He may attempt to change unfavorable attitudes toward science and help the student develop skills of teaching science to young children. He must constantly be aware of the science experiences with children and schools that the preservice teachers have, and be prepared to supplement the experiences as needed.

The problems that teachers face in the transition from preservice experiences to full responsibility as a teacher in the classroom are well documented.[4] Much of what teachers learn about teaching in the preservice program is

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[3] Walter B. Waetjen, "Recent Analyses of Teaching," *Maryland ASCD Journal*. Vol. 3, No. 1 (Fall, 1968) p. 28.

[4] See *The Real World of the Beginning Teacher*. Report of the 1965 Conference of the National Commission on Teacher Education and Professional Standards, National Education Association (1966).

learned through experience with children in schools. There are many problems of providing feedback to colleges, planning better clinical experiences, and continuing education during early periods of service which concern school administrators, directors of teacher education and certification, or other staff members of state departments of public instruction as well as college personnel. School administrators will have a larger role in establishing the organization which will make possible a gradual induction into teaching and a continual rebirth of the practicing teacher. The recommendations in this report will be of concern to school administrators, teachers and state department of education personnel.

Members of evaluation teams for the National Council for Accreditation of Teacher Education should also find the report useful since it provides, standards and guidelines which may be useful in evaluating existing and future preparation programs.

Standards

In this chapter two standards to be applied to the teacher education institution and its program of preservice elementary teacher education are stated. They are followed by questions that might be asked in judging the quality of the preservice program at a particular institution. These questions are intended for use by those evaluating the programs, including state departments of education and NCATE evaluation teams.

Guidelines

Chapters 2 and 3 are developed around guidelines. These are general statements which may be used by those taking a broad view of the preparation program. Guidelines must be general but, because they are, they are subject to various interpretations. Like the two standards stated in this chapter, they are followed by questions that might be asked in evaluating the preservice program.

To further clarify their intent, the guidelines are defined by behavioral objectives—specifications of what the future teacher should be able to do as a result of his college experiences. Some readers will think that a description of teaching in terms of behavioral specifications implies a mechanical performance by the teacher, that trivial behavior which is easily described is emphasized at the expense of creative performance which eludes definition, that flexibility on the part of the teacher and the pupil is precluded. Such objections suggest possibilities for abuse of behavioral objectives which can and should be avoided.

No error is made in setting forth clearly defined goals for ourselves or for others; the mistake is in setting trivial goals, in keeping the purpose secret from the student, in the failure to consider his goals. The lists of objectives describe competencies that represent minimum requirements for successful science teaching; in some areas the reader will want to add to the list; in all areas students will learn much that is not described by the objectives.

In order to make an objective clear, it is sometimes necessary to provide specific examples of things that a teacher might be asked to do as evidence that he possesses that particular competency. These are examples for which other activities could be substituted.

Competencies are described at three levels. Level 1 is a general description of the competency and is designated by capital letters. Level 2 provides more specific statements of examples or subordinate skills that contribute to the ability described at Level 1. Level 2 is designated by Arabic numerals. Level 3 provides specific examples used only when there is some danger that the more general descriptions may be misleading. Level 3 statements, which are intended as examples only, are set in smaller type to avoid confusion.

Research and Development

The final chapter of this report discusses the need for greatly expanded efforts in research and development and contains descriptions of recommended projects.

Too little is known about the effectiveness of teacher preparation programs. What evidence is there that teachers who have had courses in science are more effective teachers of science than those who have not? Is there evidence that courses taken as liberal education develop the attitudes and competencies that we ascribe to the liberal man? How much responsibility can college students assume for planning their own learning; what can they learn **without** the professor's lecture as effectively as with? Is it possible to dispense with grades completely and report progress on the basis of acquired competencies; to give credit for competencies acquired before entering college or for competencies acquired through informal learning?

The major thrust of research on teacher education must be toward evaluating the outcomes of instructional programs in terms of the teacher's performance in the classroom.

Definition of Terms

When speaking of teachers at the college level the terms **professor** or **professional staff** will be used. These have a nice ring and are complimentary to those who hold only the rank of instructor. **The college student** is often called just that but more often the term, **teacher,** is used to indicate his future professional role. To avoid confusion between the student in the elementary school and the student in college, **pupil** or **child** is used in referring to the younger learner.

Facilities and Materials

Throughout this report the emphasis is on the competencies that elementary teachers should exhibit. There is no intent to describe the equipment, the written materials, or the laboratory facilities that colleges and universities should have to conduct a teacher education program. Still, it is not uncommon for elementary teachers to take all of their science courses without laboratory experience. Many elementary teachers are graduated without an opportunity to see equipment and materials designed for teaching science to elementary school children. Libraries that they use have few books that may be used for reference when planning science experiences for children.

Standard 1 makes explicit the desire for proper facilities for the teaching of science to teachers. It pertains to conditions that should be provided by the teacher preparation institution rather than competencies that teachers are expected to acquire. Obviously, teachers are expected to use the facilities and acquire certain competencies while doing so; these are described under the guidelines of the report.

Standard 1. The institution should (a) provide laboratory facilities which will accommodate student activities that range from predetermined exercises proposed by the professor to teacher-constructed experiments; (b) furnish science equipment and materials similar to those in well-equipped elementary schools; and (c) provide reference books suitable for use in a school setting.

- What facilities are provided for teachers to conduct laboratory activities?
- What kinds of equipment, materials, and books are provided which enable teachers to prepare to teach science in elementary schools?[5]

Individualizing Instruction

In this report, individualizing instruction means that the past experience and the learning rate of each student are considered when instruction is planned. It means that experiences are assigned on an individual basis. It does not mean that a single person is the learning audience; some instruction may be done better in groups and some may be done better with individuals. The most efficient organization for a particular type of learning is still a matter for research. It is the belief that instruction can be made more efficient and meaningful when students are considered individually that led to Standard 2.

[5] Questions follow each Standard and each Guideline. These questions are included for use by those who will evaluate the programs.

Standard 2. Institutions which prepare teachers should make every effort to allow for individual differences among students by planning instruction so that students may progress at different rates and by giving credit in completing program requirements for learning that is acquired before entering college or that is acquired through informal experiences during college.

- What procedures are used to determine those competencies that students possess in a given field at the time they begin the appropriate college courses?
- What procedures are used whereby students may bypass instructional segments designed to teach what they have previously demonstrated they can do?
- What evidence is provided that students may have a choice in determining how they will acquire a given competency?

2

SCIENCE EXPERIENCES

Our past experiences and professional commitment allow no other view than that science is important; it is important to teachers, it is important to society, it is important to children. The impact of technology is often cited as justification to teach science, and it is. But the mode of thought, the way of looking at the world, the way of solving problems, the way of obtaining knowledge that characterize science are far more important contributions of science to society.

It was this kind of contribution of science to society that prompted the Educational Policies Commission of the National Education Association to state:

> The values of which the spirit of science consists should permeate the educative process, serving as objectives of learning in every field, including the humanities and practical studies.[6] . . . To communicate the spirit of science and to develop people's capacity to use its values should therefore be among the principal goals of education in our own and every other country.[7]

In this chapter an attempt is made to outline the competencies in science that elementary school teachers should have. These competencies can and must be acquired in a reasonable amount of time; time is needed to study literature, the arts, and social sciences as well. The focus is on science experiences that elementary teachers should have in order to teach as well as live in 20th Century society.

How Should Science Be Taught?

The adage that "we teach as we are taught" is not without foundation. If elementary teachers are to present science as an exciting exploration of the natural world where pupils have ample opportunity to interact with that world, to ask questions of nature as well as of people, and to discover that even young people can find order there, teachers, too, must have such opportunities. What is done in college science courses will materially affect the way that elementary teachers teach science.

The following sketch of the science teacher, adapted from a conference

[6] *Education and the Spirit of Science* (Washington, D. C.: Educational Policies Commission of the National Education Association, 1966), p. 22.
[7] *Ibid.*, p. 27.

working paper,[8] was written as a description of the way that an elementary teacher should teach science; it is equally valid as a description of the way science should be taught to the teacher.

A liberally educated teacher understands that his power derives not from the particular content he has mastered but from the way that content is used. Bits of information are a means to an end rather than an end in themselves.

The methodology adopted by the teacher makes learning possible for different subsets of students. The methods themselves are characterized by openness and can be the subject of discussion and analysis by students. The teacher's aims and his methods are tempered by the aims and abilities of his several students.

Some of the practices that distinguish the liberal teacher in the classroom are as follows:

—He acts as a director of learning rather than a dispenser of information.

—He values the asking of questions equal to the giving of answers.

—He understands that learning is cumulative and does not impose closure prematurely.

—He recognizes the importance of speculative thinking and does not insist that evidence be interpreted in conformity with cultural tradition.

—He recognizes that there are several means to an end and provides opportunities for students to utilize means that they find appropriate.

The desired mode of teaching is illustrated by the following approach to the idea of classification. The teacher begins by providing students with experiences which deal with sets of things and he affords them such experiences over a period of time, recognizing that classification is a skill or a method of gaining control of potentially unmanageable objects or ideas; it is not an end in itself. Counting money, sorting the pieces of mixed games, sorting mixed decks of cards, and arranging the food in a cupboard are examples of activities in which classifying is a means to an end.

In the case of teaching biological classification the teacher will recognize that familiarity with living things is a prerequisite to any need to know about their classification. Students will thus be encouraged to culture, cultivate, and maintain a variety of living things. Many questions can be explored that are relevant to these activities. How long does it take for beans to sprout? for corn or wheat? How early can you tell if a sprout is that of a bean or a corn plant? Similar questions might be asked about molds, fish, and insects. Opportunities to do quantitative measurements, develop concepts of mass, nutrition, and growth are also provided in these explorations. Eventually, the phylogenetic classifi-

[8] Adapted from a working paper prepared by Randolph Brown, Elementary Science Study.

cation that biologists favor will also be seen as useful and hopefully for reasons other than passing tests.

What Must the Teacher Know?

There is a teaching style implied in the above account that is important. But what must the teacher know? What kinds of experiences should the college science course provide the teacher to enable him to develop this style and learn enough science to teach?

A list of course titles or a course outline cannot communicate the knowledge requirements of elementary teachers. For this reason this report describes what the teacher should be able to do. How the college science experiences are designed to accomplish these ends may vary, but there is a minimum set of terminal[9] behaviors which every teacher should possess. Where possible, the statements imply the level of competency to be expected as well as the range and are written in such a way that they suggest how to determine whether the objective has been met. Each institution should develop its own list, more complete than the sample provided here. It should be emphasized that statements in small type are **only examples.** The specific activities described in these statements may not be in the curriculum at all; hundreds of similar activities could be substituted.

Science experiences should develop in teachers the habit of continually seeking new information, of testing old concepts against new ideas, and of modifying their instructional procedures if new information about science or learning suggest modification. The way in which science is taught can have a significant effect on developing these habits in teachers. Developing the habit of continuous learning in teachers is probably the single most important outcome of preservice education. Without the habit, a teacher will quickly become obsolete and ineffective; with it, he can continually improve his teaching skill and effectiveness.

The habit of continuous learning should apply to social and cultural areas as well. The examples given in Guideline IV apply to the areas of science and learning. Similar examples could be written for other areas of knowledge.

ATTITUDES TOWARD SCIENCE

Guideline I. Science experiences for elementary teachers should develop those attitudes in teachers which result in improved teaching of science in their classrooms, a more scientific approach to questions which they face in their daily lives, and an increased interest in science-related activities.

[9] There are many points in the course of teacher preparation that could be considered terminal. In this report, terminal behaviors represent those behaviors that the teacher must exhibit before being recommended for certification.

- What attitudes toward science does the institution claim it is developing?[10]
- What evidence is provided that these attitudes are held by teachers at the end of the instructional program?
- What evidence is provided that these attitudes persist after teachers have been in service for one or more years?

Objectives[11]

A. The teacher will **demonstrate confidence** in his ability to make reasonable inferences by doing so when presented with empirical data.

1. Given data concerning the fossil records of a region, voluntarily **construct inferences** concerning its geologic history.
2. **Construct testable hypotheses** to explain the unusual growth rate of a plant without being asked to do so.

B. When judging the validity of a statement which is presented as fact, the teacher will **rely on empirical data and inferences** that are derived from that evidence rather than on authoritative pronouncements.

1. **Reject legislative attempts** to set the value of $g = 2.00$ m/sec^2 or $\pi = 3.00$ as nonsense since these constants are empirically derived quantities.
2. Upon hearing a professor state that the mass of an atom is concentrated in a small space at its center, **ask for supporting data.**

C. Given a statement or circumstance that seems inconsistent with the body of science, the teacher will demonstrate his belief in the self-consistency of science by **reserving judgment** or **attempting to test** its validity.

1. Given experimental results in which the mass of the identifiable products is not the same as the mass of known reactants, **search for some explanation** for the apparent disagreement with the law of mass conservation.

   When presented data that show that the mass of a grown plant and the soil that it is planted in is greater than the mass of the original soil, seed, and water added, suggest other materials that may have contributed to plant growth.

[10] The questions following each of the guidelines may be useful in evaluating preservice science programs.

[11] Writing objectives to describe attitudes is a hazardous undertaking. We cannot measure attitudes in the sense that we measure length, time, or even knowledge. We can only look for a kind of behavior from which we are willing to infer that the attitude in question does exist. But this is not entirely satisfactory. The observed behavior may depend on the person's attitude but it is likely to depend on knowledge, skills and the circumstances surrounding the performance as well (see A-1, B-1, C-1 in this section).
In writing the objectives in this section an attempt has been made to use such terms as "demonstrate confidence," "demonstrate an interest in science" and "suggest investigations" to denote some action on the part of the teacher from which one may infer that the desired attitude is present. For a more elaborate discussion of attitudes and the problems of measuring them, the reader is referred to: Mager, Robert F., **Developing Attitude Toward Learning** (Palo Alto: Fearon Publisher, Inc., 1968).

D. The teacher will **demonstrate his interest in science by** activities such as science reading and conducting experiments.

1. **Read science-related articles** and books which are not required as part of a course.
2. **Plan and conduct experiments** on his own volition or manipulate science equipment provided by the professor when he is invited (but not required) to do so.

E. The teacher will encourage pupils to show curiosity and inventiveness in science by **helping pupils design experiments** that will answer their questions.

1. When asked, "Will a flashlight work if the batteries are turned upside down?" **suggest that the pupil try** to find the answer.
2. **Suggest investigations** that pupils might conduct in their study of the behavior of mealworms without requiring that the suggestions be carried out.

THE PROCESSES OF SCIENCE

Guideline II. The science experiences for elementary teachers should develop competence in the processes used in science as part of systematic, rational inquiry.

- What processes has the institution identified as important characteristics of scientific inquiry?
- What evidence is provided that teachers make use of process skills in their study of science?
- What evidence is provided that teachers continue to use these skills in their own teaching?

Objectives

A. The teacher will **collect and organize data and describe the rationale** for the organization.

1. **Order data** obtained in a science experiment by describing, drawing, constructing a classification, graphing, or tabulating.

   Construct a graph of data collected which shows the volume of a confined gas as a function of temperature.

B. The teacher will **define a term** operationally when the need arises.

1. After stating the hypothesis that the size of a plant increases with time, **define what he means** by size without being asked.

C. The teacher will **accept, reject, or modify a hypothesis,** inference, or generalization based on new data and describe the basis of the decision.

1. **Modify a hypothesis** concerning the volume of a confined gas as a function of temperature by restricting the range of temperatures over which the generalization is expected to hold. **Justify the modification** on the basis of empirical data or of assumptions of the kinetic theory.

D. The teacher will **demonstrate a recognition of the need** for additional information in some situation by searching out the information or designing an experiment.

1. When confronted with alternative interpretations of data which are obtained, **check the results** by returning to the laboratory or referring to a reference work to obtain additional data.

E. The teacher will **construct a hypothesis,** inference, or generalization based on data.

1. **Construct a hypothesis** to explain an unfamiliar phenomenon demonstrated by the professor or shown in a film clip.

F. The teacher will **construct an experimental test** of a hypothesis, inference, generalization, or question.

1. **Test the validity** of the hypothesis made to explain an unfamiliar phenomenon by performing an appropriate experiment.

G. The teacher will **describe an experiment** orally or in writing with sufficient clarity that another person could replicate the experiment.

SCIENTIFIC KNOWLEDGE

The preceding guidelines deal with attitudes toward science and a general knowledge of the processes of science; they cut across disciplinary lines. In addition to these general abilities, the elementary teacher should possess a background of science information. It is unreasonable and unnecessary to expect elementary teachers to learn all of their science while they are teaching it to children. Yet elementary teachers frequently complain that this is precisely what they are required to do because they see no relationship between the content and mode of instruction of their college courses and the courses they are expected to teach.[12] Efforts should be made to relate the science topics that are taught to teachers to the science topics that are taught to children. This **does not** mean that topics must be treated in exactly the same way or at the same level of sophistication. Nor does it mean that no topics should be taught in college unless they are also taught in school. However, the college professor must constantly remind himself that these teachers will not become research scientists. They may benefit more from qualitative and semi-quantitative treatments which are correct but incomplete than from rigorous arguments which depend on mathematical sophistication or logical subtleties that they are unprepared to follow.

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[12] A recent study of science education for elementary teachers states that elementary teachers describe their science program "with near unanimity as 'irrelevant,' 'uninspiring,' and often 'overwhelming.'" Matthew Bruce, "Science Education for Elementary Teachers," Preliminary Report, USOE Project No. 7-c-016 (August 1968), p. 10.

Guideline III. The content of college science experiences for elementary teachers should be selected so that the topics studied by teachers are related to the topics taught in elementary schools.

- What evidence is there that the topics treated in the college science experiences for teachers correspond to topics commonly taught in elementary schools?
- What mechanism is used to assure that the college experiences are periodically revised to reflect changes in content at the elementary school level?

Objectives [13]

A. **Measurement.** The teacher will **demonstrate the measurement** of length, mass, force, time, temperature and volume in standard and arbitrary units and estimate the error of measurement. The following areas should be included:

Determination of Magnitudes
Finding rate of change, given measurements that change with time
Probability and uncertainty

B. **Classification.** The teacher will **construct a classification scheme** for a set of objects, given objects which differ in more than one way. Use a given classification scheme to identify living and non-living materials. Objects from the biological, physical and earth sciences should be used for classification.

C. **Composition Characteristics and Structure of Matter.** The teacher will **describe observations** of living and non-living objects in terms of their physical, chemical and biological composition and characteristics. He will **demonstrate the use** of simple atomic and kinetic theory to explain the observations he describes. The following areas should be included:

Physical properties (density, viscosity, pressure, solubility, elasticity, surface tension)
Physical changes in physical, biological and geological systems
Chemical changes in non-living and living systems
Morphology of living things
Atomic theory
Kinetic theory

D. **Interactions of Matter.** The teacher will **describe observed interactions** of living and non-living matter using concepts such as forces and vectors,

[13] The behavioral objectives in this section follow an outline of a science program developed by a group of scientists who attended a workshop at Stanford University during the summer of 1968. Materials from eight elementary science curriculum projects were examined and the outline was prepared to represent concepts treated in these materials.

It may be correctly argued that some of the objectives (e.g., those on probability, atomic theory, and chemical changes) are not directly related to topics taught in primary grades and, in some cases, not through grade six. These topics *would* be considered in grades seven and eight—grades often included in elementary schools—and represent important ideas of science which contribute to an understanding of science. Because of their importance to the overall structure of science it can be argued that they are useful areas of study, even for primary teachers who will not teach these concepts. No Level 2 and Level 3 examples are given for this guideline. To have included examples for each general objective would have made this section inordinately long. It is suggested that anyone using this Guideline in developing a science program should start by preparing Level 1 and Level 2 examples for each objective.

electrical charge, magnetic fields, biological tropisms, and food webs. He will **construct hypotheses and tests of hypotheses** concerning the observed interactions.

E. **Conversion and Conservation of Energy.** The teacher will **demonstrate the conversion of energy** from one form to another, will **measure the amounts of energy transformed,** and will **search for sources of energy loss** when observations appear to contradict the generalization that energy is conserved. The following areas should be included:

- Forms of energy (potential, kinetic, heat, light, sound, electrical and chemical)
- Transfer of energy
- Transformation of energy in living and non-living systems
- Conservation of energy
- Energy carried by waves

F. **Growth and Reproduction.** The teacher will **describe the processes** of growth and reproduction in plants and animals including man.

G. **Evolution and Genetics.** The teacher will **construct inferences** about the long range effects of selective mating and genetic mutation on plant and animal communities and sometimes including human communities and societies. Topics should include the following:

- Variation
- Adaptation
- Mutation
- Principles of Evolution and Genetics
- Structure and Function
- Population
- Growth Curves

CONTINUOUS LEARNING

Guideline IV. Science experiences should be selected so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by habitually engaging in science activities which will provide new information and experiences caable of affecting existing attitudes, ideas, and teaching.

- What experiences are provided in which the teacher can demonstrate a capacity and disposition for continuous learning?
- What evidence is there that new information and experiences affect the teacher's attitudes, ideas, and teaching?

Objectives

A. **Capacity and Disposition for Continuous Learning.** The teacher will **demonstrate his capacity and disposition** for continuous learning by habitually engaging in activities which will provide new information capable of affecting existing attitudes and ideas.

1. **Identify and describe viewpoints** on contemporary scientific issues and on the learning process as presented in current literature, or through personal contacts.

   Describe arguments for and against the use of an insecticide and suggest possible safeguards, after reading an article about potential damage to wildlife from uncontrolled use of the insecticide.
   After reading about some recent research on the learning process, infer the implications of that research for elementary school programs.

2. **Demonstrate the ability** to obtain relevant information on scientific and educational issues.

   Locate historical accounts of experiments pertaining to Mendel's law.
   Identify sources of analyses of educational philosophies.

3. **Identify possible interrelationships** between events in different fields of knowledge.

   After reading an article on physiological changes brought on by malnutrition, consider whether such changes might affect the learning behavior of a child from a ghetto.
   Describe some of the interrelationships between scientific and political developments.

4. **Identify and take action to eliminate gaps** in his educational background.

   After reading an article on the use of behavioral objectives, develop skill in writing them by reading books such as **Preparing Instructional Objectives** by Mager and discussing his work with informed colleagues.
   After hearing that irregularities in the gravitational field of the moon have introduced an unexpected hazard in landing men on the moon, demonstrate his ability to use current popular or semi-popular scientific periodicals to obtain information about the cause of the gravitational irregularities.

Special Science Teachers

In the above list of competencies no distinction is made between the person who will teach in a self-contained classroom and the special science teacher. The question of whether science should be taught by a special teacher or the teacher responsible for all other subjects was discussed at all three AAAS conferences and good arguments were heard for both sides.

The nature of the science programs for **pupils** will determine the competencies their teachers should possess. Thus, it is the nature of the science that is to be taught in elementary schools rather than the instructional organization that dictates the requirements of he preservice program. The important question is what any teacher who teaches science should be qualified to do. At the same time the desirability of having some teachers who can do more, is fully recognized.

The "science specialist" may be defined as a person who assumes a leadership role in the development of curriculum materials and the inservice education of other teachers. The specialized part of the education of this kind of science specialist is commonly postservice rather than preservice, and a description of the unique set of behaviors required is beyond the scope of this report.

Are the Competencies Reasonable?

It is anticipated that a number of prospective teachers possess many of the competencies that are described at the time they enter college. Certainly much of the content implied in the objectives is standard fare in modern high school courses. It cannot be overemphasized that the teacher is expected to **exhibit certain competencies,** not to amass a certain number of credits in college science. If a teacher can measure mass, length, temperature, volume, and time when he begins his first college science course, activities designed to teach him to do so are a waste of time. If he has demonstrated his ability to construct a classification scheme for plants during college experiences in the biological sciences, it is unlikely that extensive experience will be required before he can do the same thing with rocks and minerals. There is every reason to believe that the proper coordination and individualization of science instruction can eliminate needless repetition and conserve considerable time needed for other activities.

3

CHILDREN, TEACHING, AND SCHOOLS

Everyone would agree that to teach science a teacher must know something about science; he must understand the attitudes, the principles, and the procedures from which the scientist operates; and he must be able to operate within this same framework, though at a different level of sophistication. Even if the science experiences produce the attitudes, the knowledge, and the process skills described in Chapter 2, there is no assurance that the teacher will be able to communicate science to children. It is one thing to believe in conservation of substance; it is another to select activities which will convince children that such a generalization is plausible. It is one thing to be able to observe, classify, define operationally, or to make and test a hypothesis; it is another to lead children to do the same.

This chapter provides some description of the experiences with children and schools that may facilitate development of skills required to teach science to children. The USOE Model Projects[11] have been closely examined and an effort has been made to make these recommendations compatible with those Models. Reference in this chapter is purposely made to the management of science instruction, although most of the behaviors that are described may be applicable to other areas.

There may be some argument that the behaviors regarding human relations that are described in this chapter should be used as criteria for screening students seeking entrance into teacher education, rather than as abilities to be developed as a part of the preservice program. However they are viewed, they are behaviors crucial to effective science teaching.

A Suggested Program

Much of what prospective teachers must learn about teaching will develop out of carefully planned experiences with children and schools. Figure 1 illustrates a model for the progressive involvement of students in the act of teaching. In the beginning, the student is aware that he has some interest in teaching. Careful guidance is required as he proceeds through the various experiences designed to develop his teaching competence and confidence.

[11] Here and throughout the report, "Model Project" refers to one of the nine models for elementary teacher education developed under contracts with the U. S. Office of Education, Bureau of Research. Models were submitted to the Bureau on October 31, 1968, and are available from the Division of Elementary and Secondary Education, Bureau of Research.

Early experiences of the teacher with children in schools should occur during the first or second undergraduate year when the prospective teacher is enrolled in science and other courses which provide background for his future career. These early experiences may involve in-class observations or part-time work as a teaching aide but many of them could be simulation experiences presented by film or video-tape and designed to focus attention on particular science teaching strategies. Provision should be made for the teacher to suggest the strategy that he should use at critical points in the lesson.

The observations and simulated classroom episodes should be followed by opportunities for students to teach science lessons; first with one child in a tutorial, later to a small group in a microteaching format, and finally in a self-contained classroom or as a member of an instructional team. Many opportunities should be provided for the student and professional staff to evaluate the student's teaching performance. Only when the student shows proficiency in teaching science in a small group teaching situation should he proceed to work with larger groups with all of the complex interactions which characterize the science classroom.

The preservice experiences would culminate in an internship program or assignment to a portal school.[15] By this time the teacher would be largely self-directed. He would be paid for his work in the portal school and would teach without constant supervision. However, experienced teachers, psychologists, consultants, supervisors, test specialists, and others would be available for consultation should the teacher be faced with a problem he is not equipped to handle. After one or two years of service the teacher candidate would be recommended for certification as a fully responsible teacher.[16]

Inherent in this model is the assumption that universities and schools can and will develop a coalition for the preparation of teachers. There are compelling reasons to do so. Beginning teachers complain that they are dumped into the schools with new ideas which they are never allowed to implement and are faced with unexpected demands which they are unprepared to meet. University professors lament that they have developed promising approaches to teaching and have prepared teachers to use them but it is of no avail

[15] The term "portal school" is borrowed from *A Model for the Preparation of Elementary School Teachers* developed by Florida State University under USOE Grant No. Vogel OECO-8-089021-3308(010). The term refers to schools which have cooperative agreements with universities for the preparation of elementary teachers and have "principals and other status leaders . . . favorably inclined toward innovation, . . . use some of the 'new' curricula . . . in mathematics, science. or social studies, . . . will be employing organizational arrangements that include utilization of para-professionals and teacher aides. . . . [and] will make considerable use of new teaching media." p. 118.

[16] Instructional manager is sometimes used in place of teacher to emphasize that the teacher's responsibility goes beyond direct interaction with pupils. A teacher must make decisions concerning objectives, the selection of instructional materials, and strategies to be used in confronting the pupil with what is to be learned; he may arrange for instruction to proceed whether or not he is physically present. Manager should not connote a mechanical, rote manipulation; a manager in any field may be as aloof or cordial as he pleases. Cordiality should certainly characterize the manager of instruction.

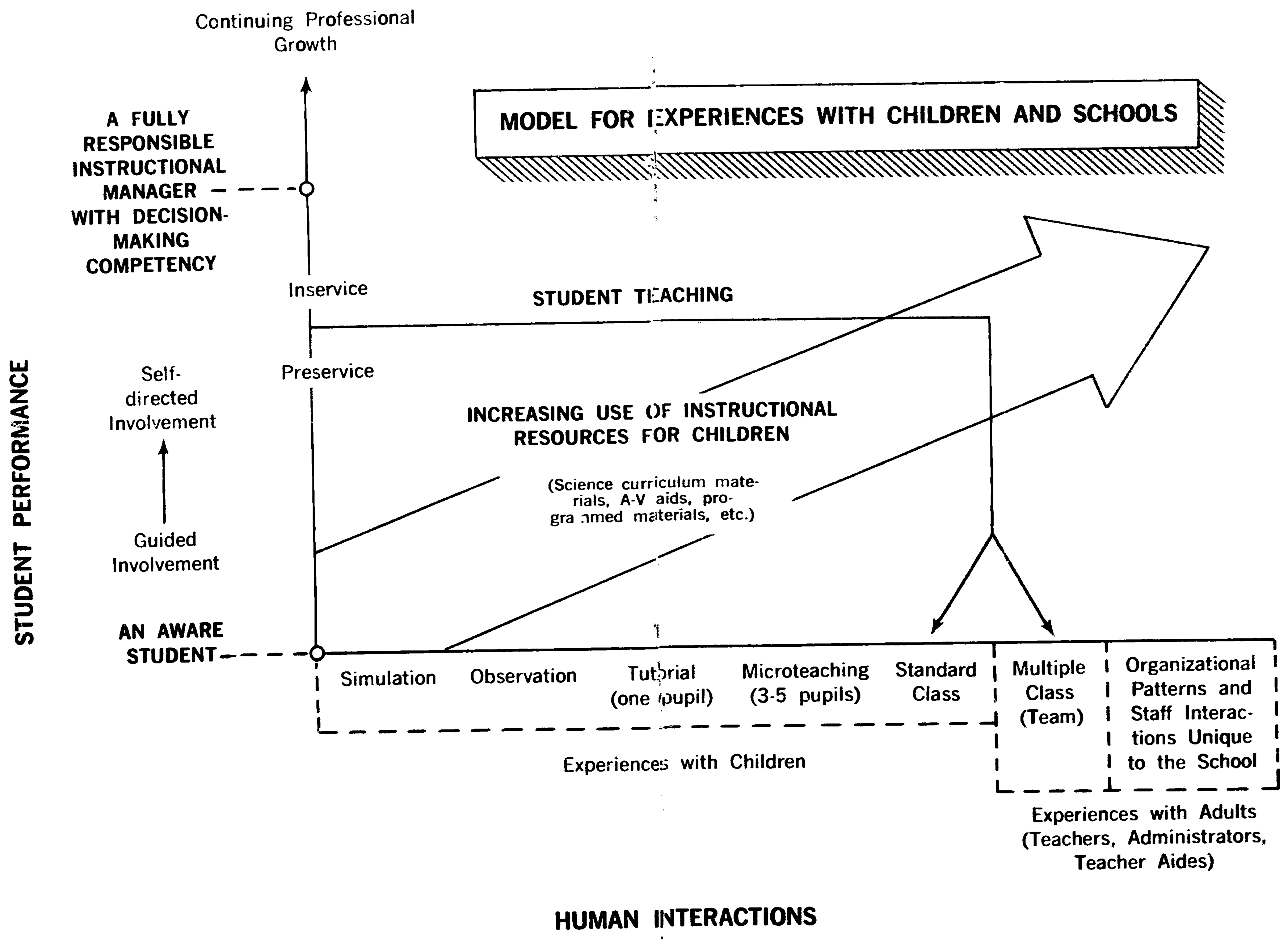
MODEL FOR EXPERIENCES WITH CHILDREN AND SCHOOLS
Continuing Professional Growth
A FULLY RESPONSIBLE INSTRUCTIONAL MANAGER WITH DECISION-MAKING COMPETENCY
Inservice
Preservice
STUDENT TEACHING
Self-directed Involvement
Guided Involvement
AN AWARE STUDENT
STUDENT PERFORMANCE
INCREASING USE OF INSTRUCTIONAL RESOURCES FOR CHILDREN
(Science curriculum materials, A-V aids, programed materials, etc.)
Simulation
Observation
Tutorial (one pupil)
Microteaching (3-5 pupils)
Standard Class
Multiple Class (Team)
Organizational Patterns and Staff Interactions Unique to the School
Experiences with Children
Experiences with Adults (Teachers, Administrators, Teacher Aides)
HUMAN INTERACTIONS

FIGURE 1

because the schools are stagnant and refuse to change: the new teachers are forced to revert to outmoded practices. Meanwhile, the frustrated practitioner in the school point out that the professors are far removed from the realities of the classroom and fail to develop in teachers the skills they require for survival. The muffled debate has been waged for years; we can no longer afford to let teacher preparation programs deteriorate in the face of perennial buck-passing.

The Guidelines

The behaviors of science teachers outlined below are presented as a sample. They represent the skills and competencies that the experience of conference participants and authors of the USOE Model Projects believe to be characteristic of successful elementary teachers.

INSTRUCTIONAL MANAGEMENT

Guideline V. The institution, working cooperatively with schools, should provide experiences with children and schools so designed that the teacher develops the skills required for effective instructional management of the science program.

- What skills has the institution identified as required for effective instructional management?
- What systematic method of recording or describing teaching performance is used to enable prospective teachers and staff members to analyze the extent to which instructional management skills are demonstrated?
- What evidence is provided that plans for the experiences with children and schools have been developed cooperatively between the institution and the schools involved?
- What evidence is provided that the experiences provided by the institution are effective in producing the desired management skills?

Objectives [17]

A. **Objectives of Instruction.** Upon being asked the purpose of an activity in the classroom, the teacher will be able to **describe the objectives** of the science instruction in precise terms and **defend his choice of objectives** on the basis of commonly accepted educational and social theory.

1. **Identify objectives** appropriate to developing (a) intellectual or process skills, and (b) concepts in science.
2. **Identify examples of objectives** which illustrate systematic thinking.

   From a list of science objectives, ***identify*** those which require application, analysis, or synthesis as defined by Bloom.[18]

[17] Other excellent lists of behavioral specifications may be found in reports of the USOE Model Projects; c.f., *A Competency Based, Field Centered, Systems Approach to Elementary Teacher Education,* Northwest Regional Educational Laboratory, USOE Contract No. OEC-0-8-089022-3318(010). Vol. 1, pp. 54-62; Vol. 2, Appendix F and H.

[18] Benjamin S. Bloom (ed.), *Taxonomy of Educational Objectives: Cognitive Domain,* New York: David McKay Co. (1956).

From a description of elementary science lessons, *infer* which lessons require the pupil to use application, analysis, or synthesis.

3. **Identify or construct instructional modules** or units which contribute to specified long-term goals of science teaching.

Given the objective, "The pupil will be able to distinguish facts from conjectures or inferences in a variety of situations," **select or construct** instructional materials which contribute to the accomplishment of that objective.

B. **The Learning Environment.** The teacher will **demonstrate the organization and maintenance** during instruction of a classroom environment which fosters inquiry.

1. **Schedule class time** to allow for both group and individual activities designed to accomplish specified objectives.
2. **Demonstrate the introduction** of a science activity in such a way that pupils are motivated to conduct investigations.
3. **Create an atmosphere** in which children participate freely in planning, carrying out, and interpreting results of investigations.
4. **Use questions** to assist children in conducting an investigation without telling them what to do or giving away the expected results.
5. **Arrange instructional resources** in the classroom to maximize pupil interaction with the materials.

Collect materials locally to be used in an exercise on classification.
Locate resource books for children to read on the care of animals in the classroom.

6. **Locate and use instructional resources** available in the school and community.
7. **List sources** of science materials other than local ones.

Identify at least three sources of chemicals that might be used in elementary classrooms.

C. **Instructional Strategies.** The teacher will **demonstrate the ability to select and use** a variety of learning strategies appropriate to various learning requirements.

1. Given an objective for science instruction, **select materials, media, and activities** that have been demonstrated to be effective in producing the desired change in behavior.
2. **Identify instructional materials** and learning activities for different classes of learner interests and capabilities.
3. **Modify planned strategies** as a result of unexpected pupil performance.
4. **Direct individual pupils** to sources of information in conducting an investigation which is not of interest to the entire class.

D. **Evaluation of Pupil Progress.** The teacher will demonstrate the use of various individual and group assessment devices to determine whether specified objectives have been met.

1. **Select, or construct, and administer assessment items** which require

pupils to use concepts in new contexts and inquiry skills in new problem situations.

2. **Distinguish between acceptable and unacceptable responses** to assessment items in science.
3. **Use various assessment devices** to determine the degree to which pupils possess necessary prerequisites for a learning task.
4. **Use the results** of evaluation in planning subsequent learning activities.
5. **Describe the results** of evaluation to pupils and parents so that it is clear whether the pupil is or is not making reasonable progress in science.

E. **Constructing a Sequence of Learning Activities.** The teacher will **construct a sequence of learning activities** on the basis of long-range objectives and knowledge of prior pupil performance.

1. **Select, or construct, alternative learning activities** when pupils demonstrate that they have achieved the objective of a science activity prior to its being carried out.
2. **Select, or construct, alternative science activities** when prior instruction has been unsuccessful.
3. **Construct appropriate and significant science activities** for pupils whose lack of achievement indicates that they are not ready to continue with the rest of the class.
4. **Identify a learning sequence** appropriate to the development of skills and attitudes which may emerge over a long (at least two-month) time interval.
5. **Identify the information and conceptual knowledge** prerequisite for specific science principles, laws, and theories and make reasonable inferences that these prerequisites exist before attempting instruction dependent on them.

RELATIONS WITH CHILDREN

Guideline VI. The institution should insure that the teacher possesses skills required for effective human relations with children in the classroom by carefully screening candidates for the teacher education program and/or providing experiences in which students develop the required behaviors.

- What skills in relations with children must the teacher demonstrate in order to be recommended for certification?
- What screening procedures and/or learning experiences are provided to assure that teachers possess the required behaviors?

Objectives

A. **Recognition of the Importance of Individual Children.** The teacher will **demonstrate the ability to accept pupils as individuals** by responding to manifestations of individual differences in a controlled manner.

1. **Remain relaxed** with a calm demeanor in the presence of pupils who are creative, ask probing questions, and present challenging ideas in science.

2. **Exhibit patience** with the pupil who has poor manipulative skills in handling equipment or who is slow in acquiring process skills by giving words of encouragement or deferring required performance when the child shows evidence of extreme frustration.
3. **Demonstrate empathy** toward pupils with personal problems by modifying requirements for the individual.

   Reschedule a conference with a pupil who is expected to baby-sit so a parent can work.
4. **Demonstrate empathy and appreciation** for children of divergent backgrounds and interests by listening attentively to and rationally examining the contributions of children from rural, urban, suburban, and foreign cultures.
5. **Demonstrate control** over expressions of attitudes, feelings, and emotional reactions as shown by voice quality or facial and body gestures when responding to children's statements or questions about science.
6. **Demonstrate the ability to analyze reasons** for unacceptable social behavior on the part of a pupil by **inferring causality** after viewing a real or simulated incident. **Test the plausibility** of the inference by examining permanent records (real or simulated) and discussing the incident with a professional counselor.
7. **Demonstrate faith in the ability of children** to make contributions by encouraging pupils to suggest answers to questions asked by other pupils.
8. **Assist children in developing empathy** for and a willingness to help their peers by suggesting ways that they may assist others or by suggesting understandable reasons why a child may have behaved in an undesirable manner.

B. **Showing Confidence and Flexibility in Relations with Children.** The teacher will **demonstrate confidence and flexibility** by making reasonable alterations in teaching procedures in the face of unexpected events.

1. **Demonstrate confidence in his knowledge** of science by failure to display frustration or embarrassment in the face of questions that he cannot answer.
2. **Demonstrate a calm demeanor** in the face of ambiguity and unpredictable events which occur during the course of a science investigation.
3. **Demonstrate the ability** to relinquish traditional controls in the interest of letting individual children and small groups work independently in science.
4. **Assist children in making plans** for a science activity without making the decisions.
5. **Assist pupils in the conduct and interpretation of** results from an investigation without telling them what must be done or what conclusions are reasonable.

RELATIONS WITH THE SCHOOL AND COMMUNITY

In his preservice years the teacher must learn about schools—their relationship to the community and the relationships among members of the school staff. He must be able to work effectively with parents, administrators, and other teachers. These abilities, necessary for all teachers, are not peculiar to those who are teaching science. But the importance now placed on science by the school and community, and the concerns about science felt by many, make these abilities of special importance for the science teacher. The development of these abilities is the concern of Guideline VII. Guidelines on school and community relationships of the USOE Model Projects also provide needed guidance on the development of these important competencies.

The ability to participate effectively in team teaching is also important for all teachers. Team teaching in science is now being introduced in many school systems. The teaching team can play an exceedingly effective role. The teacher of science should understand the role of the teacher, assistant teacher, teacher aide, educational clerk, media aide, science consultant, and other members of instructional teams and should be able to work with these people to plan and execute science instruction.

Guideline VII. Experiences with children and schools should be selected so as to develop a sensitivity toward, and an appreciation for, the school and community and for individuals in the community including those individuals whose ideas are different from his own.

- What kinds of experiences are planned to assist the teacher in developing a sensitivity toward the school and community?
- What evidence is there that the student may satisfy the requirements in different ways, including informal learning experiences?
- What evidence is there of the kind of relationships that the student has established with other adults?

Objectives

A. **Relations with Others.** The teacher will **demonstrate emotional maturity** by behavior consonant with accepted social norms.

1. **Demonstrate respect** for the opinions of others.

   Listen to what others have to say.

   Seek rational bases for the views of others even when they are different from his own.

2. **Demonstrate confidence** in his ability by taking considered action that may be criticized by others.

   Agree or disagree with policy set by school administrators or teacher groups and give reasons for his position.

3. **Seek assistance and counsel** from more experienced colleagues and take appropriate action.
4. **Recognize the personal concern of** a parent for his own child, and show respect and admiration for this concern.

Show patience when a parent values his own child's welfare above that of the class as a whole.

5. **Demonstrate empathy and appreciation** for individuals of divergent backgrounds and interests by listening to and rationally examining the contributions of persons from rural, urban, suburban, or foreign cultures.

   Broaden the basis for understanding different cultures by participating in cross cultural experiences.
   Read about peoples from other cultures.
   Work directly with peoples from other culturals.

B. **Relations with the Community.** The teacher will **demonstrate respect** for local community values and institutions, even when they seem provincial or limited.

1. **Demonstrate an active interest** in local community affairs.

TEAM TEACHING

Guideline VIII. The institution should provide experiences which enable the teacher to function both as a science teacher in a self-contained classroom and as a member of an instructional team.

- What experiences are provided in which the teacher functions as a part of a team?
- What evidence shows that the experiences provided are effective in developing the desired competencies?

Objectives

A. **Team Planning and Management.** The teacher will **demonstrate the ability** to contribute to team planning of instruction.

1. **Demonstrate the ability** to contribute to team planning by negotiating and accepting compromises while developing science activities to be carried out by the team.
2. **Modify teaching behavior** where it is appropriate to improve team effectiveness.

B. **Human Relations in Team Teaching.** The teacher will **demonstrate the ability** to work in a team without alienating other members of the team or becoming alienated himself.

1. **Direct a teacher aide** in a task supporting the team effort without alienating the aide.
2. **Modify the directions** given to a teacher aide on the basis of suggestions made by the aide.
3. **Accept directions or** help from another member of an instructional team (lead teacher, science consultant, principal) without demonstrating personal disaffection.
4. **Demonstrate the ability** to tolerate differences in values, language, and behavior patterns of other team members.
5. **Demonstrate self-control** by not showing frustration or anger in the face of probing questions or ideas which challenge his own position.

4

THE TEACHER AS A LIBERALLY EDUCATED PERSON

Above all else, the elementary teacher should be a liberally educated person. Because of this, the report would be incomplete without a discussion of the importance of liberal education in the preparation program for elementary teachers. However, a careful description of guidelines and behavioral objectives needed to accomplish the desired end requires careful consideration by experts in fields other than science and education. Consequently, no attempt is made to provide guidelines for the liberal education of teachers as has been done for experiences in science and experiences with children and schools. The following discussion is provided in the hope that appropriate agencies will provide some needed direction for improvement in this important segment of the preservice program for elementary teachers.[19]

Liberal education is commonly defined by a prescribed number of courses in the humanities, social sciences, natural sciences, and the arts. Robert Bush describes it as "an education which liberates the mind from the shackles of prejudice and superstition and the confines of a single culture, that permits one to move freely and joyfully in the past and the present and to speculate objectively with his fellow men about the future." [20]

Such a definition admits that a liberal education is not achieved by the simple acquisition of a core of knowledge, however complete it may be. It must include an understanding of the interrelationships among ideas and people. It is an active pursuit which never ends.

Many activities other than formal courses can contribute to a liberal education. Colleges provide valuable informal experiences in the form of concerts, lectures, and plays; in some colleges, students attend these activities; in none are they a way to satisfy requirements for graduation. Is it not possible to encourage participation in these and other informal activities as a means of satisfying the need for a liberal education? Why not provide areas in dormitories or in student centers where students can paint, make pottery, and do wood or metal work? Off-campus experiences such as living or working in a ghetto area, visiting courtrooms or hospital emergency rooms, or working for agencies where the student would have close contact with segments of society with which he lacks familiarity could contribute to the student's education in a way that is impossible through formal study.

Far too little has been done to recognize the contribution that such activities can make toward the education of the liberal man. Procedures can and should

[19] The reader may wish to refer to the Model Teacher Education Program developed by the University of Massachusetts under USOE Grant No. OEC-8-089023-3313(010). The appendices on aesthetics, human relations, language arts, and social studies provide numerous examples of performance criteria related to the liberal education program.

[20] Robert N. Bush, "The Formative Years" in *The Real World of the Beginning Teacher*. Report of the 1965 Conference of the National Commission on Teacher Education and Professional Standards, National Education Association (1966) p. 4.

be devised to include informal learning experiences in the liberal education program, to devise a means to assure that the experiences result in the learning that was intended, and to recognize the contribution that is made to the degree program.

Informal experiences can help students relate ideas to the "real world" of people and social institutions and to associate the ideas from one field of study with those from another. But the organization of formal courses must also be considered. There is a place for interdisciplinary courses and a great deal more can be done in courses within a discipline to relate ideas to other fields. Certain lectures by sociologists could contribute to the course in biology, historians could contribute to the course in chemistry, anthropologists have something to say about ancient history, economists about urban culture. Such possibilities are limited only by the energy and imagination of the professor.

Three questions must be considered by those who design experiences for teachers in the area of liberal education: How does one equip the teacher emotionally and intellectually for the uncertain world of the future? How does one develop the capacity and disposition for continuous learning? How does one develop a sensitivity toward and appreciation for, individuals—including those individuals whose ideas are different from his own?

The acquisition of the behaviors described in the objectives of Chapters 2 and 3 will contribute to the goals implied by these questions, but a major responsibility for them rests with the liberal education program.

In this age of rapid social change, instant communication, and accelerated technological development, the need for better understanding among individuals from different cultural traditions is more important than ever before in history.

Our society is troubled by individuals who question the values of our institutions and the effectiveness of our political systems. Society is confronted by the fact that various ethnic groups have been deprived of opportunities that are taken for granted by others. The disparity between the material wealth of different nations is forcefully displayed by the mass media. All of these forces compel each individual to question his philosophical position and his obligation as a citizen of the world. Surely a liberal education should prepare teachers to face these and other social issues openly and with rational consideration.

Educators must face the fact that much of what we teach today will be obsolete or irrelevant in the near future. Perhaps the most important characteristic of the liberal man is his ability to keep informed and his willingness to adapt to changing conditions. We must educate for the future.

Experiences that prepare teachers for the future—that prepare them for continual self-renewal and rational adjustment to inevitable change—are an essential part of their preparation. Experiences in science and with children and schools contribute to the development of necessary attitudes and skills but they will not be sufficient. It will be necessary for many other groups to give serious consideration to this problem and to provide the needed guidelines and descriptions of behavior that characterize the liberal man.

5

EFFECTING CHANGE

This chapter is developed in three sections: a call for action, a list of recommended demonstration projects, and some sample questions for research.

A Call for Action

The success of the new programs in science for high schools pointed up the urgency of, and possibilities for, improving science teaching in elementary schools and colleges. Now new science programs for elementary schools are becoming available and there is widespread concern about the quality of college science teaching. At the same time preservice teacher education programs are under constant study. Many innovations are being introduced. The support by the U. S. Office of Education of the development of Model Projects for the preservice education of elementary teachers may result in changes on a wide scale. Furthermore the more realistic and flexible standards of the National Council for Accreditation of Teacher Education not only make change more possible, but actually place a premium on carefully conceived innovations.

The time could scarcely be more propitious for a re-constitution of the preparation of elementary teachers to teach science. This report calls for cooperation among all of those responsible for the many different aspects of preservice teacher education. Scientists, teacher educators, school administrators and teachers, state department of education personnel, scientific and professional organizations must all become involved, and must work together toward commonly accepted goals.

These considerations will be crucial to success:

1. Scientists and teacher educators, the institutions and professional organizations with which they are associated, and the schools, their administrators and teachers, and their supporting lay public, must be persuaded of the need for change, the exciting possibilities for improvement, and the value of cooperative effort.

2. All usual avenues of communication, and new ones, are needed to help persons responsible for preservice teacher education to recognize the need and the opportunities. This report may contribute. Regional and state conferences of scientists and educators, papers in professional journals and at professional meetings are needed. Most of all communication between scientists and professional educators of a college, and with the school people they serve, is necessary to bring about the action that is called for.

3. Research and development are essential for progress in education, as

well as in science and in society. Government and private foundation support is available for educational research and development. The burden of seeing that these funds are used wisely rests with all of those concerned about better science education and better teacher education.

4. The more than 1200 colleges and universities that prepare teachers for elementary schools bear first responsibility for work on their own campuses, and for enlisting other agencies that may be of assistance to them, the schools, the state departments of education, the public, and the foundations.

5. Professional scientific and educational organizations, and groups that they establish having a direct association with them, or as independent agencies, have made major contributions in the past decade to the improvement of teacher education and science education, and they should be supported in further efforts.

6. Development projects are essential to demonstrate what can be done. They hold the promise of bringing about early improvement. Participation of college and university and school personnel in development and demonstration must have greater professional recognition in promotions and salary. This chapter reviews briefly a number of desirable development projects.

7. Research in teacher education and science education is crucial. Support is available and many more competent scientists and educators need to become involved. Some questions for research are sketched in this chapter as samples of what might be done.

Development Proj s

NEW SCIENCE MATERIALS

College science courses should be developed which will accomplish the objectives outlined in Chapter II and which will provide a more appropriate model for teaching science to children. Several new and promising science courses for college students who are not science majors have been prepared in recent years. However, none of the new courses meet the Guidelines outlined in this report. For example, performance specifications are not stated, little provision is made for individualized instruction, and what is taught in the courses does not appear to be closely related to the science that is taught in schools.

It is possible for each institution to develop its own science materials but the personnel and financial resources that would be required for the undertaking that is envisioned preclude this procedure. It is desirable that sets of materials be developed by a number of different groups so the teacher education institutions will have special programs from which to choose. The materials should be written, field tested, and carefully evaluated before they are widely used. Some characteristics of the program that is proposed are outlined below:

1. The science requirement for elementary teachers and the instructional materials that they would study should be based on performance objectives. With necessary elaboration and modification the objectives outlined in this report could provide the framework for these specifications. Assessment devices

must be developed to evaluate the effectiveness of the materials and to be used as diagnostic and achievement tests for students.

2. The instruction should be individualized so that students can satisfy the requirements in different ways and in different lengths of time. Students who demonstrate a particular competency before instruction would by-pass activities designed to develop that competency.[21]

3. The instructional materials in the proposed science program should emphasize the processes of science as well as science concepts. Process is used in a broad sense; emphasis should be on developing the skills of inquiry rather than on accumulated knowledge.

4. A science course which emphasizes process must also teach science concepts. Concepts should be drawn from areas normally treated in the new elementary science courses. The course should be organized around the laboratory and students should have opportunities to conduct investigations of their own design. Student progress should be checked frequently and remedial activities or alternative exercises prescribed when they are needed.

5. Ideally the science experiences for elementary teachers should comprise an integrated sequence including physical, biological, and earth sciences. As a first step, major improvements could be made if separate materials in physical science, including earth science, and biological science were developed.

6. For the larger institutions, an instructional package should be designed so that it could be taught to a group of at least 200 students without resorting to a lecture presentation, while utilizing the talents of a single person of professorial rank to have first responsibility for the course or science experiences. Colleges are faced with large enrollments which are likely to increase. The present reliance upon graduate students and large lectures for instruction is not because it is believed to be the best system. Rather, it is because alternative means of dealing with large groups of students and small groups of professors have not been developed.

7. It will not be sufficient to prepare student materials alone. Teaching assistants, at least in the larger institutions, will need some kind of guide to help them understand how and what they are expected to teach. In addition to the guide, some seminars or inservice training for teaching assistants is desirable. The professor in charge of the course must be a director of instruction and a real team leader. He must have an overall model which will help him organize the course, provide help for the graduate assistants, and obtain information which could be used to revise the course or adapt it to local conditions.

NEW EDUCATION MATERIALS

There is need for new materials and new approaches in education as well as science. The USOE Model Projects provide ample suggestions for the develop-

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[21] Both the Intermediate Science Curriculum Study (ISCS) at Florida State University and the Audio-Tutorial program at Purdue University have characteristics of individualized instruction. Although neither of these provides an exact model for the materials that should be developed, each contains ideas that could be incorporated.

ment of these materials—their influence could be revolutionary. The focus of these programs is on preparation of the elementary teacher without specific reference to disciplines as such, but the framework of these Models and their philosophy have many implications for preparation to teach science. If professors of education with special interest and responsibility for preparation to teach science have participated in planning the science experiences, as it is strongly recommended that they be, then they will be in a better position to develop educational materials that supplement the science experiences making use of many ideas in the Model Projects.

Fresh approaches and new directions are needed in programs to provide experiences with children and schools. Specific behaviors desirable for teaching science to children should be identified first. It is then recommended that projects be implemented in which experiences planned to develop these behaviors are provided through modules of instruction, seminars, readings, research participation, or other structures without the limitations of credits and traditional courses.

Samples of development projects that might be considered are the following:

1. Development of materials for evaluating teachers to determine if they possess specific competencies, and development of instructional modules for those who do not possess the competency, in part or in all respects.

2. Formulation of administrative plans by which individuals or groups can be given unique experiences compatible with individual needs that are identified.

3. Preparation of filmed classroom episodes showing good science teaching, and associated study materials in which the prospective teacher identifies appropriate teaching strategies. Eventually these materials should be made available for sale or loan on a national scale.

4. Preparation of simulation and micro-teaching materials designed especially for teaching science. The materials should be arranged in sequence to progress from teaching one child, to two or three, to larger groups as preparation for teaching science in the usual class of thirty or more.

5. Organization of seminars on one or more of the new elementary programs including opportunities to teach units from these programs to children.

6. Development of an elementary teacher's "Invitations to Inquiry"—a collection of suggested investigations in science which could be done by students independently or in small groups outside formal class organizations.

7. Provision of experiences in which teams of students and professors cooperate in the development and field trial of experimental units in science.

8. Establishment of "professional service centers" in teacher training institutions where the students could obtain advice about problems they encounter in teaching without the threat that is often associated with taking problems to college supervisors or cooperating teachers. Such centers should have specialists in testing, and audio-visual materials, and psychologists available for consultation by teachers.

COOPERATIVE ARRANGEMENTS WITH SCHOOLS

Personnel in colleges who are responsible for the preparation of teachers need closer contact with changing programs in the schools. Models which provide for sharing the responsibility for teacher education between college and school personnel are needed. Such models should provide for joint financing of programs and for cooperative efforts in making decisions about the program. Provision should be made for classroom teachers to assume active roles in that part of the preservice program carried out in the college and for college professors to provide services during that part of the program carried out in the schools.[22]

If teachers are prepared by the preservice program to teach new elementary school science programs, personnel in schools must lend support and encouragement. Such support is often missing because school administrators and concerned parents do not understand the new science programs and resist the changes which are being encouraged. Such resistance is real and important. Its causes must be understood and dealt with.[23]

There are several possibilities for projects aimed at educating the public and school officials as to the methods and purposes of new science programs. Conferences for administrators represent one; the inclusion of administrators in inservice programs for teachers is another. Still another suggestion is that an "elementary science sampler" including materials from several of the new elementary science curriculum projects be prepared to introduce laymen to the new programs. Filmed materials which show these materials being taught might be included to give an idea of how modern science should be taught to children.

Sample Research Projects

VARIABLES IN THE COLLEGE SCIENCE PROGRAM

The effectiveness of college courses and programs is taken too much for granted. By demonstration we see exciting course outlines, we hear stimulating lectures, we observe interested students, and we know many excellent teachers who were graduated from these programs. Still very little has been done to measure how his college science experiences affect what the elementary school teacher does in his classroom. The objectives of liberal education are difficult to define and research on the achievement of these objectives is exceedingly complex.

[22] Programs developed at the University of Maryland and the University of New Mexico are representative of the kind of cooperation described here. Brief descriptions of these two programs may be found in *Teacher Education: Issues and Innovations*, the 1968 Yearbook of the American Association of Colleges for Teacher Education.

[23] For an excellent discussion of sources of resistance see: Watson, Goodwin, "Resistance to Change", *Concepts for Social Change*, pp. 10-25. Edited by Goodwin Watson. Washington, D.C.: National Training Laboratories, NEA (1967).

On the other hand the goals of a teacher education program are easier to identify, and definition of these goals is now being attempted by many, including the efforts represented in this report. Thus research on the effects of college courses and programs, while still very complex because of the multitude of difficult-to-control variables, becomes more feasible. In this section a few variables to be manipulated are proposed and some responding variables to be measured are enumerated. In a single research, probably only one manipulated and one responding variable should be chosen. In various combinations, many possible studies are proposed—each one complex because of the difficulty of controlling other variables.

Variables to be manipulated

- **Instructional method:** teaching by lecture versus teaching by laboratory inquiry, or teaching by different "mixes" of the two.
- **Breadth vs. depth in science:** introductory courses in several of the sciences versus depth study of one science.
- **Content selection:** topics selected for their relevance to concepts in new elementary school science versus topics selected for their importance in frontiers of research.
- **Primary objective:** teaching the methods of scientific inquiry versus development of key concepts.

Responding variables to measure

- The teacher asks questions which help individual pupils distinguish between evidence and inference.
- The teacher adapts lessons to different groups of pupils; uses examples and analogues likely to be within their experience.
- The teacher suggests sources of information when pupils raise questions.
- The teacher uses a variety of motivational techniques.
- The teacher shows resourcefulness in obtaining materials in poverty situations.
- The teacher is able to determine whether a statement made by a pupil is relevant.
- The teacher recognizes unusual but correct answers and uses them.
- The teacher is able to lead investigations by children that are novel to him as well as to the children.
- The children show achievement on standardized or especially prepared tests.
- The teacher and/or the children demonstrate acceptable attitudes toward science as measured by appropriate attitude tests.

In the list of responding variables an attempt has been made to make the ultimate criterion, success in teaching. This success might be measured in a "normal" classroom situation but useful results could also be obtained in a micro-teaching situation or a simulation arrangement where teacher responses are obtained to filmed classroom situations.

The importance of recognition and control of variables in these studies cannot be overemphasized. They will require real expertness in educational research and probably should be undertaken only by teams of researchers including scientists, specialists in learning and in elementary education, and statisticians with competence in research design.

VARIABLES IN EXPERIENCES WITH CHILDREN AND SCHOOLS

In addition to the research projects suggested for the preservice science program, research in experiences with children and schools was also considered at the AAAS conferences. Some of the suggested projects were quite specific, others were broad. Among the specific proposals were the following.

- If the teacher is engaged in planing as well as carrying cut investigations in his college science program, does he do a better job of teaching science modules to children than if his college science investigations had been planned for him?
- Does the length of time the teacher waits before asking another question or calling on another child increase class participation by slow children? [24]
- Will pupils acquire a particular behavior, such as the ability to construct a test of a hypothesis, faster if they are taught in large groups, small groups, or individually?

Other somewhat less sharply defined questions were raised concerning the effect of preservice experiences with children on the teacher's performance in the work situation.

- Will early contact with children make prospective teachers aware of problems of teaching science to children and in turn increase the value of their other college experiences?
- How well does the teacher's performance in micro-teaching and simulated classroom situations predict his later performance in the schools?

Other questions relate to the teacher's attitude toward science.

- To what extent can these attitudes be changed? How do these attitudes develop in the first place?
- Is it true, as some educators suggest, that inept teaching by graduate assistants results in the alienation toward science so frequently observed in elementary teachers? If so, would it be possible to prevent such alienation by providing graduate assistants with special training to teach?

Two broad areas of needed research were identified: the cost of effectiveness of different instructional procedures, and ways that needed changes in

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[24] This topic was suggested by work done by Mary Budd Rowe at Teachers College, Columbia University.

social institutions such as colleges and schools can be brought about.

Thorough study of the many questions pertaining to the preparation of elementary teachers will require decades, and improvements are needed now. We cannot wait for research to provide all of the useful measurements before we decide on our educational shoes. But just as shoes are replaced, so are educational practices. By continuing effort in both development and research, the improvements in preservice education of elementary teachers that are needed today can eventually be brought into being, some of them within a few years, if the effort and support is as massive as the need dictates.

Appendix

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