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GUIDELINES FOR SCIENCE AND MATHEMATICS IN THE PREPARATION PROGRAM OF ELEMENTARY SCHOOL TEACHERS.

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GUIDELINES FOR THE DEVELOPMENT OF EDUCATIONAL PROGRAMS FOR THE PREPARATION OF ELEMENTARY SCHOOL TEACHERS OF SCIENCE AND MATHEMATICS ARE PRESENTED. THEY ARE THE RESULTS OF A SERIES OF CONFERENCES THAT INCLUDED ELEMENTARY, HIGH SCHOOL, AND COLLEGE AND UNIVERSITY TEACHERS AS WELL AS ADMINISTRATORS, SCIENTISTS, MATHEMATICIANS, AND REPRESENTATIVES OF GOVERNMENT, INDUSTRY, AND OTHER ASSOCIATIONS AND GROUPS. IT IS SUGGESTED THAT THE GUIDELINES BE USED BY INSTITUTIONS OF HIGHER EDUCATION AND STATE EDUCATION AGENCIES IN DEVELOPING AND IMPROVING EDUCATIONAL PROGRAMS. MAJOR ASPECTS OF THE CURRICULUM CONSIDERED IN THE GUIDELINES INCLUDE--(1) THE ROLE OF THE ELEMENTARY SCHOOL AND SOCIETY, (2) GENERAL EDUCATION, (3) SUBJECT-MATTER ACHIEVEMENT AND INQUIRY TRAINING, (4) BREADTH OF PREPARATION IN SCIENCE AND MATHEMATICS, (6) PROFESSIONAL LABORATORY EXPERIENCES AND THE QUALIFICATIONS OF COOPERATING TEACHERS, (7) DEPTH OF STUDY IN SUBJECT AREAS, (8) 5TH- AND 6TH-YEAR TEACHER EDUCATION PROGRAMS, AND (9) INSERVICE EDUCATION. DETAILED EXPLANATIONS OF EACH GUIDELINE ARE INCLUDED. THIS DOCUMENT IS ALSO AVAILABLE AS AAAS MISCELLANEOUS PUBLICATION 63-7 FROM NASDTEC-AAAS STUDIES, 1515 MASSACHUSETTS AVENUE, N.W., WASHINGTON, D.C. 20005, AT NO COST. (AG)

GUIDELINES

for SCIENCE AND MATHEMATICS in the PREPARATION PROGRAM of ELEMENTARY SCHOOL TEACHERS

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

Recommendations
of the Teacher Preparation-
Certification Study
of the
National Association of State
Directors of Teacher Education
and Certification
and the
American Association for the
Advancement of Science
with the support of the
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Perspective

Scope of the Problem

Children of today need an abundance of knowledge about the achievements of science and mathematics; even more, they need to acquire the seeking, questioning attitude of mind, and the habit and skills of clear, honest thinking which characterize the scientist as he seeks further knowledge. Due to the continuing increase in new knowledge in science and mathematics, it is necessary to reconsider the preparatory program for elementary teachers.

The progression of the nature of interests as children grow has been studied and recorded many times. Basically, both studied and casual observation show that while the interests of elementary school age children change with the times, they do not distinguish mathematics from science or the sciences from each other according to the traditional boundaries.

The good elementary teacher will need breadth in preparation in order to cultivate the viewpoints of each discipline and to acquire as much knowledge of subject matter as time and effort will permit. He will need breadth, too, so that he can discern the relation of the sciences to each other and to other areas of knowledge. The evidence gained in research and the modernization of teaching and learning materials is reduced in usefulness if teachers are not themselves informed in the current content and methods of science and mathematics and in the knowledge of human growth, in the ways children learn, and in teaching techniques.

This study is concerned with the nature and quality of programs for the preparation of elementary teachers in the subject matter areas of science and mathematics. The recommendations suggested here are the result of much shared intensive thinking. The study is sponsored by the National Association of State Directors of Teacher Education and Certification in cooperation with the American Association for the Advancement of Science, and supported by the Carnegie Corporation of New York.

Involved in the study were elementary, high school, and college and university teachers and administrators, scientists and mathematicians from higher education, government and industry, and a large number of representatives from various agencies, associations and groups. These people participated in regional conferences in Chicago, Salt Lake City, and Washington, D. C., in the spring of 1962, and in a final national conference in Louisville, Kentucky in April 1963. Others worked in state meetings and in faculty study groups.

In the *Guidelines* that follow attention is given *only to programs of preparation in science and mathematics*. While the body of this report

relates to the preparation of elementary school teachers in the areas of science and mathematics, the study supports the position that all teachers should be liberally educated and professionally competent for the assignments which they accept.

This is in keeping with the standards set forth by the National Council for Accreditation of Teacher Education (NCATE) for the development of teacher education curricula. The policy of NASDTEC is equally clear on this subject: "NASDTEC believes that the growing and changing demands on society in the last half of the twentieth century require that . . . all teachers have a broad education in the arts, the sciences and the humanities; *intensive study* in the subject matter fields to be taught; and thorough preparation in the education process. . . ." (NASDTEC Declaration of Policy on Teacher Education and Certification, mimeographed, June 24, 1958, p. 1).

Objectives of Science and Mathematics Teaching in Elementary Schools

Since the *Guidelines* are basically concerned with the science and mathematics education of the prospective elementary teacher, it is appropriate to identify the objectives of science and mathematics teaching in the elementary schools. The educated citizen of tomorrow who is today's school child will need a far better understanding of science and mathematics than most people now possess.

Among the objectives of science and mathematics teaching are the development of:

1. The scientific and mathematical literacy necessary for intelligent citizenship today;
2. A concept of science and mathematics as accumulated bodies of knowledge, as well as an understanding of scientific inquiry and mathematical discovery;
3. Modes of thought that encourage critical thinking and problem-solving ability;
4. Increasing understanding of the broad conceptual schemes of science and mathematics, including the concepts and principles upon which the schemes are structured; and,
5. A more penetrating understanding of the relation of current science and mathematics to the other activities of man and to his cultural patterns.

The teaching of science and mathematics in the first years of school is for all children, for children who will become scientists or mathematicians, and for the far larger number who will not. Learning science and mathematics is an essential part of the child's larger education; neither an intrusion into the rest of the curriculum nor a substitute for it.

The child who learns science learns more than a set of facts about the world of objects and living beings. He also learns ways of finding out about the world and ways of ordering his findings. He finds ways of asking questions and ways of getting answers. He learns, too, that his answers—like those of the adult scientist—are partial and tentative and

that scientific inquiry is not magic but an exciting and active approach to knowledge. The child who learns science as inquiry will be inquisitive, skeptical, and alive to the world in which he lives. The teaching of science, in its best achievement, will help the young child develop knowledge of the concepts of science, skills in methods of science, and enthusiasm for scientific inquiry.

Science cannot be divided into easily labeled categories without loss. An emphasis on relationships within and among biological and physical phenomena will make science more easily understood and science teaching more effective.

Attention must be directed toward two aspects of the science program —the dimension of knowledge or content and the dimension of performance or process.

To be effective, each dimension must become the vehicle for the development of the other. A student will use the study of subject matter as a means for the development of skills and abilities; and his skills and abilities will also be a means by which he increases his knowledge of subject matter. In addition, the treatment of knowledge and performance must recognize the maturity level of children and should be developed with increasing sophistication.

An appreciation of the esthetic aspects of science and mathematics should develop through individual discoveries and experiences. This is of considerable importance in inducing favorable attitudes toward science and mathematics, and hence, in accelerating the learning process. The child should learn to appreciate that science and mathematics are living, dynamic, creative, and changing human endeavors. Both historical and current aspects of these subjects are important and should be brought into the classroom.

It should be recognized that neither the objectives nor the dimensions of knowledge and performance of mathematics are identical with those of the natural sciences. With the rapid and continuing growth and spread of the utilization of mathematics in the biological, physical and behavioral sciences as well as within management and technology, the utilitarian role of mathematics is certain to be intensified. At the same time, it is important to develop an early awareness of mathematics as a study of structure—order, relation, and form.

There should be gradual but steady progress, starting in any mathematical area as early as possible, from the primitive view of mathematics as an empirical science to the more mature view of it as an abstract deductive science. The role of intuition, even as it is related to the more purely deductive aspects of the subject, should be recognized. It should be possible to show by specific examples or models that inductive approaches may lead to distinct mathematical systems. By means of comparisons with the natural sciences, this should lead ultimately to a recognition of the relatively arbitrary nature of mathematical models for the physical world.

Suggested Uses of the Guidelines

These *Guidelines* are offered as resources to be drawn upon by institutions of higher education and state education agencies in developing and improving their programs for the preparation of elementary school teachers in the areas of science and mathematics. The principles and the examples of their implementation set forth here should encourage flexibility in programs, but still assure adequate subject matter in the background of elementary school teachers. The labeling of what are considered to be courses in general education and those for pursuit of depth in a discipline is purposely left vague in order to give institutions wide leeway in building programs.

We are living in a dynamic era involving rapid change. No answers can be final. The flexibility of these *Guidelines* is a recognition of the need for college programs to be brought up to date and to be kept up to date in the years ahead.

The legal responsibility for the approval of teacher education institutions and their programs for the preparation of teachers rests with most state departments of education. In nearly all cases these departments have a leadership responsibility in program planning with teacher preparation institutions. Programs approved by the department are the basis for state certification of students in the programs. These *Guidelines* should prove useful to the state education departments in advising institutions on the program development. The *Guidelines* are intended to supplement, not to repeat or replace, the standards of the National Council for Accreditation of Teacher Education (NCATE) and regional accrediting associations.

No doubt state directors of teacher education and certification, and faculties of institutions educating elementary school teachers will discover other uses for the *Guidelines* in addition to those suggested here. The *Guidelines* may serve:

1. As a starting point for developing the "approved program approach" which places upon each teacher preparation institution the responsibility for developing programs on the basis of criteria adopted by the state. In achieving this approach, the state directors of teacher education and certification have found it wise to use the principle of wide involvement of concerned persons and institutions in developing the criteria;
2. Institutions when they consider the ways of organizing for the study of sciences and mathematics. Institutional autonomy and creativity should be encouraged in seeking increasingly effective ways; and,
3. In helping devise standards for consideration of content and quality of curricula.

While these *Guidelines* were being written there was much discussion going on throughout the country about the relative merits of the self-contained classroom and the departmentalized elementary school. It was

not one of the purposes of these *Guidelines* to state a position on an administrative matter. It is believed that teachers prepared in programs that have been influenced by these *Guidelines* will find themselves able to adapt to good administrative practices. It is hoped that, whatever direction decisions take in relation to patterns of organization, teachers will increasingly be used in positions for which they are best prepared.

In preparing this document, there was some tendency to pursue the intriguing exercise of working out numbers of semester hours, or at least to suggest percentages of the total program to be allotted to science and mathematics. It was held, however, that this was not the job of a national study. Those designing the curriculum on their own campuses must consider all of the essential areas in the elementary school teachers preparation if they are to achieve a balanced program. These *Guidelines* will serve best when they are used by truly creative faculties.

Guidelines

It is neither necessary nor desirable for all institutions to adopt a uniform pattern of organization for preparing elementary school teachers in science and mathematics. Some institutions with a divisional organization may offer a curriculum for the preparation of teachers in a single division. Others, with a departmental pattern of organization, may offer preparation through separate science departments, such as physics, chemistry, biology, etc., or by a panel of instructors from the several departments. Whatever the type of organization, the subject-matter portion of the teacher's preparation should follow a pattern carefully and cooperatively planned by representatives from all departments concerned.

Guidelines I and II which apply to education in all areas, are intended to set the stage for the succeeding *Guidelines* for science and mathematics programs.

GUIDELINE I — *The faculty of each institution should design its program for the preparation of the elementary school teacher after careful analysis of the role of, (1) the elementary school in American society, (2) the elementary school teacher; and, (3) the institutions preparing teachers.*

GUIDELINE II — *The program of preparation for the elementary school teacher should include a broad general education with attention to human growth, learning and behavior.*

GUIDELINE III — *Instruction in science and mathematics should be conducted in ways that will develop in teachers an understanding of processes and in scientific inquiry and mathematical thinking.*

GUIDELINE IV — *The program of preparation for the elementary school teacher should include breadth of prepara-*

tion in the sciences and in mathematics most appropriate as background for the elementary school program, with emphasis on concept development and interdisciplinary treatment.

GUIDELINE V *The program of preparation for the elementary school teacher should include study of the aims and methods of teaching science and mathematics in the elementary school.*

GUIDELINE VI *Professional laboratory experiences, including observation and student teaching, should provide opportunities for the prospective teacher to work with experienced elementary school teachers who are competent in the subject area, skilled in nurturing the spirit of inquiry, and effective in helping children benefit from the study of science and mathematics.*

GUIDELINE VII *The program for the preparation of the elementary school teacher should provide opportunities for pursuit of additional undergraduate study in a carefully planned program in science and mathematics.*

GUIDELINE VIII *Fifth year and sixth year programs for the elementary school teacher should offer appropriate science courses and mathematics courses which might be applied toward an advanced degree.*

GUIDELINE IX *Inservice education should provide opportunities for the elementary school teacher continuously to improve and extend the competencies required for effective teaching of science and mathematics.*

The Guidelines

Basic Assumptions

GUIDELINE I — *The faculty of each institution should design its program for the preparation of the elementary school teacher after careful analysis of the role of (1) the elementary school in American society, (2) the elementary school teacher, and (3) the institutions preparing teachers.*

In designing these *Guidelines* to aid college faculties in the preparation of their teacher education programs several assumptions were made. These assumptions should serve as a basis for understanding the recommendations of the NASDTEC-AAAS Studies. They may be taken as a point of departure by faculties in developing their own statements of objectives and in designing appropriate teacher education programs.

The role of the elementary school in American society. The elementary school is responsible for providing educational opportunities for all children. For most children it is the first formal experience with a program devoted to building those general attitudes, understandings and skills needed by every member of society. The program must provide for the continuous mental, emotional, physical and social growth of each child and must recognize that children differ both in potential for growth and in their rate of development. Growth occurs best in an environment that is permeated by the spirit of inquiry, exploration and discovery and one that encourages each child to work toward his maximum self-realization.

The role of the elementary school teacher. The elementary school teacher must provide a rich, human and cultural environment in the classroom. He must accept children at their level of development and guide them to further discovery and understanding of their world. He must assist children at their level of development and guide them to further discovery and understanding of their world. He must assist children in using materials and in gaining experiences which develop concepts and stimulate further learning in all the subject areas for which he is responsible. He must relate each new concept to those previously learned in the expansion of the child's knowledge and understanding.

Responsibility of the teacher education institution. An institution will wish to design a program that will prepare teachers to guide the learning activities of elementary school children. In order to do this, it will select highly qualified candidates, devise ways to study the qualifications and needs of its entrants, the needs and opportunities in its service area

schools, and take measures to keep its staff up to date and enthusiastic.

The teacher preparation program will give the student an opportunity to acquire a broad background in liberal arts and sciences, preparation in professional education, and, if he so desires, specialization in a major field of interest.

A teacher education institution that assumes the responsibility for the post-baccalaureate education of elementary school teachers by offering regular graduate study or other types of inservice education will wish to plan its offerings in relation to its four year program and to meet the diverse needs of students.

Liberal Education

GUIDELINE II — *The program of preparation for the elementary school teacher should include a broad general education with attention to human growth.*

Since children's interests know no boundaries, the preparation of the elementary school teacher must be sufficiently comprehensive to enable him to encourage and guide these interests into productive channels. In addition, he must be prepared to teach all subject fields offered in the elementary school: language arts, social studies, the sciences, mathematics, health, the fine arts, physical education, and in some cases, a foreign language. To do this well, he must have, beyond subject matter, a working knowledge of human growth, learning, and behavior.

The liberal education of an elementary school teacher should, then, include preparation in the humanities, the sciences, the arts, and human growth, learning, and behavior.

Processes of Scientific Inquiry

GUIDELINE III — *Instruction in science and mathematics should be conducted in ways that will develop in teachers an understanding of and facility in the processes of scientific inquiry and mathematical thinking.*

The study of science and mathematics with an emphasis on processes can be a most stimulating experience. When the student has an opportunity to investigate and to discover for himself scientific phenomena and mathematical properties and to formulate principles which he can test, he achieves that sense of accomplishment which should be a product of all scholarly efforts.

In the area of sciences an essential ingredient in the proper education of elementary teachers is the development of skills in scientific inquiry. Such skills include: investigating; observing accurately and reporting concisely results of investigations; formulating and stating questions clearly; designing and executing experiments; conducting field studies; using equipment for counting, measuring and weighing; documenting findings with evidence; classifying materials and ideas; organizing and

interpreting data; and, analyzing and critically reviewing scientific literature.

In the area of mathematics, concepts and manipulating skills are both of high importance. Skills without conceptual understanding are relatively sterile as are concepts unaccompanied by skills to give them succinct expression. Mathematics courses should be organized and taught so that there will be continuing emphasis on understanding the deductive nature of mathematics; the importance of mathematical structure in arithmetic, algebra, and geometry and recognition of common ideas that tend to unify these areas; the patterns of logical reasoning; recognition of the role of experience and intuition in mathematical discovery and appreciation of their significance when they appear in the classroom; the importance of the role of precise definitions and the use of mathematical terminology; and, proficiency in manipulating skills.

To accomplish these ends college teachers must look critically at the instructional procedures in their courses as well as at organization and content. It becomes necessary that college study for prospective elementary school teachers include a wide variety of techniques and materials which lend themselves to the development of these skills. For instance, individual and group laboratory experiences must be provided and should include experimental activities as well as the more traditional exercises involving verification.

An appreciation of the processes of mathematics and sciences can be derived only from an active participation in these disciplines on the part of the student. Prospective teachers must receive preparation that will develop in them the attitudes that they should cultivate in their students.

Subject Matter in Science and Mathematics

GUIDELINE IV — *The program of preparation for the elementary school teacher should include breadth of preparation in the sciences and in mathematics most appropriate as background for the elementary school program, with emphasis on concept development and interdisciplinary treatment.*

The education of elementary school teachers in the sciences and mathematics should be viewed as a continuous process beginning with the elementary school, including the substantive courses in science and in mathematics in the high school, continuing through the liberal education courses in these fields in college with opportunities for advanced study in the sciences and in mathematics.

In planning a program careful attention should be given to the previous achievement of the prospective elementary school teacher in high school courses. If full recognition is given for the proficiency level already reached by the student, the amount of time required in science and mathematics may not be as great as the following paragraphs appear to suggest. However, for the student who enters college inadequately

prepared, more than four years may be necessary to complete an appropriate program.

The preparation needed is in the spirit of the best new liberal education courses. The scope must be very broad with emphasis on the underlying concepts, scientific principles, and the nature of scientific inquiry and mathematical discovery.

Every elementary school teacher should be educated in the fundamental concepts of the biological sciences, physical sciences, earth sciences, and mathematics; in particular those with implications for the education of the elementary school children. Colleges should explore the development of interdisciplinary courses designed to draw upon the subject matter of the various sciences to illustrate these fundamental concepts. The educational program should be organized so that the appropriate sequences of experiences in the sciences and mathematics are provided. It is essential that scientific inquiry be stressed in all science and mathematics courses designed for prospective elementary school teachers. These elements are to be obtained by providing:

1. Experiences which lead to increased understanding, knowledge and skills in science and mathematics appropriate to the needs and capabilities of children;
2. Experiences which lead to understanding the relationships between branches of science and mathematics and between these areas and other branches of learning;
3. A study of the current and historical developments and philosophies of science and mathematics;
4. Experiences which lead to awareness and appreciation of the continuous expansion of knowledge and the changing emphasis in science and mathematics;
5. Work which will be acceptable as prerequisite for intermediate level undergraduate study in various science fields.
6. Student teaching of many kinds, especially laboratory and field experiences, which illustrate how the methods of science are communicated; and,
7. Opportunities to increase understanding of problem solving, critical thinking, and methods of inquiry and discovery in science and mathematics.

It is recognized that the skeletal statements of course content which follow are subject to varied interpretations and realizations by institutions. Institutions should expect to devote continuing attention to the ordering and articulation of the separate offerings.

***Earth** Science and Space Science.* Earth science is concerned with the description and interpretation of earth phenomena in all their intermingled, physical, chemical, biological, and mathematical aspects. Its data come largely from field observations, often at widely spread data points, and it is, therefore, concerned with sampling, broad extrapolation of data, and analysis of controlled variables.

Because every child naturally encounters the rocks and the hills, the wind and the rain, and the sun and the stars, earth science serves as a focal point for introduction of other sciences. Furthermore, field examples are available to teachers everywhere that can stimulate creative, disciplined imagination and focus attention on existing phenomena in a search for explanations of our natural world.

The program in earth science for elementary school teachers should consider descriptions and interpretations of features of the earth, the oceans, the atmosphere, and the relation of the earth to the solar system and the universe. The study of earth science for elementary teachers might contain the following elements: field observations, incorporating elements of sampling, the multiple working hypothesis, methods of making measurements, and the limitations and uncertainties of observations; laboratory measurements including development of experiments, control of variables, and the development of ideas about scale and theory of scale models; display of data, including development and use of maps and cross-sections; and, interpretation and extrapolation of data.

Subject matter should include:

1. Ideas about the origin of the earth in the context of the solar system;
2. The development of an earth model and the methods, sources of data, and uncertainties inherent in the construction of this model;
3. Ideas about the origin and distribution of continents and oceans;
4. Something about geochronology and the history of the earth, including the methods used to determine time relations, such as isotope dating.
5. The distribution and origin of elements, the nature of solids and crystal structure, and derivation of rocks and minerals from silicate and aqueous systems;
6. The sources of the earth's energy and energy changes relating to processes on the surface of the earth;
7. The origin of the earth's atmosphere, climate, and the hydrologic cycle;
8. Evolution of life and the character of the fossil record in extending concepts of evolution backward in geologic time; and,
9. Something about the economic utilization of earth materials and the relation of earth materials to human affairs.

Biological Sciences. For the purposes of instruction, the discipline of biology can be organized in a variety of ways. It is recommended that biology instruction for elementary school teachers present a coherent view of the field of biology and also focus on aspects of the field which are most meaningful and useful for future work with elementary school students. Such foci are:

A. Kinds of living organisms-microbes, plants and animals;
B. The functioning of organisms, including complementarity of structure and function;

C. Growth and development of organisms, including genetic continuity; and,

D. Interrelations of organisms and environment.

In organizing the foregoing aspects of biology into a coherent view of the field, there are three essential considerations. The first is the reciprocal relationship between biological inquiry and the development of biological knowledge. To illustrate and develop an understanding of this relationship, college instruction in biology should emphasize: descriptive and experimental aspects of investigation, significant experiences in scientific inquiry (this can be achieved through critical analysis of research reports as well as through laboratory experiences planned to illustrate design of experiments relative to a problem, gathering and interpretation of data, etc.); experience in selection and use of biological literature and, laboratory experience as an integral part of the course. (Living and preserved materials, instrumentation techniques, and field experiences which demonstrate development of biological concepts should be used.)

The second essential consideration in presenting a coherent view of the discipline is to show the interrelationships among the various areas of biology. Broad concepts such as the following can provide a basis for such interrelationships: evolution, diversity of type and unity of pattern; biological roots of behavior; and, community (molecular and cellular as well as ecological). In addition to these concepts, macromolecular biology can be used as a unifying thread.

The third essential consideration is to stress the interrelationships between biology and other disciplines. Some areas in which these are most readily seen are: photosynthesis and respiration; kinematics of enzyme systems; probability and statistics; studies of behavior; ecosystems; biological evolution and culture evolution; and, history of the controversy over spontaneous generation.

To illustrate the foregoing principles to be used in selecting and organizing material from biology for elementary school teachers the following descriptions are provided:

A. *Kinds of living organisms.* Experience in careful observation, description and discrimination with the construction and use of keys for classification often provides experience in the ordering of knowledge. It can provide an understanding of the development of taxonomy as an area of biology by showing the need for frequent review in setting up criteria used in classifying organisms.

B. *The functioning organism.* Consideration should be given to all major kinds of organisms—plants, animals and microbes. Also, life functions should be studied on the level of the behavior of organisms as well as on the molecular-cellular and organ-tissue level. Concepts of significance in studying the functions of organisms are exchange of materials and energy between organism and environment (illustrated by respiration and photosynthesis); regulation and homeostasis; and interaction

between environmental stimuli and the organisms. The similarities and differences in these phenomena as they occur in major kinds of organisms—microbes, plants, animals—should be stressed. Differences in kinds of biological problems and modes of experimentation can be readily brought out by comparing key studies of exchange of materials and energy, homeostasis and regulation, and behavior.

Of course, throughout, the complementarity of structure and function should be emphasized. This would entail careful morphological studies of a variety of organisms. In its broadest sense, morphology explains the gross structural differences between plants and animals; in its narrowest sense, it interprets the molecular organization or the structural unit of living organisms—the cell. By drawing upon the equipment and procedures of conventional microscopy and electron microscopy it can be shown how the biological and physical scientists integrate their efforts, their skills, their investigative approaches and their problem solving to interpret taxonomy, ecology, embryology, genetics and physiology. However, these outcomes are not likely to be developed if morphology is restricted to preserved materials. Living materials should be used as much as possible. In this way the elementary school teacher can become familiar with opportunities for studying the live materials abundantly on hand in every elementary school environment.

C. *Growth and development.* The unique contribution which *genetics* can make to the education of elementary teachers is an understanding of how both similarity and variation in successive generations of organisms is possible.

The study of genetics also provides an excellent opportunity for developing an understanding of biological inquiry. Examination of a sequence of key papers in genetics can reveal the development and revision of concepts and the revision of modes of investigation in light of the developing concepts. In addition, the concept of genetic continuity, built up through numerous particular examples of transmission of hereditary characteristics can be used to integrate many areas of study of biological phenomena.

To develop these understandings it is necessary to have first, a precise, disciplined knowledge of the phenomena of mitosis and meiosis; second to understand that there have been different explanations of the mechanisms of these phenomena and why the current explanation is considered most adequate; third, to understand the relationship between the phenomena of mitosis and meiosis and the evidence pertaining to the transmission of hereditary characteristics—i.e., how evidence from cytological, molecular-biochemical and hereditary studies supplement one another; fourth, to see how mathematical concepts have been crucial to the development of the field of genetics; and fifth, to recognize the importance of shifting the unit of study in genetics from individuals to populations.

D. *Interrelations between organisms and environment.* Modern biology should approach the study of living organisms in relation to their

total environment, both animate and inanimate. Emphasis should be placed on the interactions between an individual organism and into environment as well as on interrelations between populations. Changes in the behavior patterns in response to changes in environmental factors such as radiation, temperature, moisture, mineral elements and associated organisms are subjects for profitable investigation. Any classroom teacher has within his immediate surroundings a ready-made situation for ecological study, without the necessity of costly equipment. Furthermore, ecology provides an excellent means of bringing the earth sciences, physical sciences, social sciences, and biological sciences into a unified whole. Adequate ecological studies lead directly into the areas of health, safety, and conservation of natural resources.

Physical Sciences. The teaching of elements of physics and chemistry in the elementary schools will probably undergo a considerable change during this decade as a result of the work of various study groups. These groups are exploring the questions of concept formation in the sciences, and their findings will have a great effect on ways in which science is presented to children.

It is important that physical science be taught in a way that will emphasize the investigative nature of science. The teaching of physical science should reveal the way in which these disciplines have developed theoretical and abstract concepts. The physical sciences should be appreciated equally for freeing man from the limitations of common sense observation and for providing the technology that has changed man's environment.

In general, emphasis should be placed on depth of treatment, rather than breadth of coverage. Each course should examine at least one specific topic so that the student acquires an understanding of the application of one or more aspects of chemistry and physics in the development of a rigorous and penetrating scientific argument. Guidance for the role of laboratory to accompany these courses may well come from recent course content experimentation in both high school and college. Opportunities must be provided for students to develop their scientific powers through designing and conducting their own laboratory investigations.

An interdisciplinary approach might well be explored by colleges in offering courses that cover the appropriate topics. Emphasis should be put upon the unity of the sciences, however these topics are presented, and every opportunity taken to show interdisciplinary connections. The history and philosophy of physics and chemistry offer many opportunities to relate the physical sciences to studies in the humanities and social sciences, and historical and philosophical topics should be judiciously introduced into the physical science courses.

Studies in the physical science for elementary school teachers should include topics selected from such major areas as:

1. Measurement and experimental errors in chemistry and physics;
2. Kinematics in one and two dimensions;

3. Dynamics of a particle—Newton's laws, motion of a projectile, Keplerian orbits;
4. Conservation principles: conservation of mass-energy, momentum and charge;
5. Structure of matter and origins of the atomic theory; kinetic-molecular theory, gas laws, atomic species and the periodic table;
6. Descriptive chemistry of important elements and compounds: formulas and equations;
7. Heat phenomena: temperature, transfer of heat, change of phase;
8. First and second laws of thermodynamics: mechanical equivalent of heat, order and disorder;
9. Waves: waves on strings, acoustic waves;
10. Electric and magnetic fields: electrostatics, electric currents, electromagnetism, electromagnetic induction;
11. Electromagnetic waves: geometrical and physical optics developed for optical waves, but extended to other electromagnetic radiations; the electromagnetic spectrum;
12. The atom-quantum theory of Planck and Einstein, discrete spectra, Rutherford model of the atom, Bohr theory, matter-waves and indeterminacy;
13. Chemical bonding: ionic, covalent, metallic;
14. Chemical reactions: rates, equilibrium, energy of reaction. The solid state; and,
15. The nuclear atom and nuclear energy—radioactivity and isotopes, mass-energy equivalence, fission and fusion, models of the nucleus.

Mathematics. The recommendations of the Committee on Undergraduate Program in Mathematics of the Mathematical Association of America for the preparation in mathematics of prospective elementary teachers are strongly endorsed in principle. The amount of time needed to satisfy the CUPM recommendations is dependent upon the ability and previous preparation of the teacher candidate and will vary from student to student. Programs should be based on at least two years of college preparatory mathematics and more if feasible.

The following are brief descriptions of essential mathematical preparation of the elementary teacher:

A. *Algebraic structure of the number system.* This is a study of the numbers used in elementary school whole numbers, common fractions, irrational numbers. Emphasis should be on the basic concepts and techniques: properties of addition, multiplication, inverses, systems of numeration, and the number line. The techniques for computation with numbers should be derived from the properties and structure of the number system, and much attention should be paid to approximation. Some elementary number theory, including prime numbers, properties of even and odd numbers, and some arithmetic with congruences should be included.

B. *Algebra.* Basic ideas and structure of algebra, including equations,

inequalities, positive and negative numbers, absolute value, graphing of truth sets of equations and inequalities, examples of other algebraic systems—definitely including finite ones—to emphasize the structure of algebra as well as simple concepts and language of sets.

C. *Intuitive foundations of geometry.* A study of space, plane, and line as sets of points, considering separation properties and simple closed curves; the triangle, rectangle, circle, sphere, and the other figures in the plane and space considered as sets of points with their properties developed intuitively; the concept of deduction and the beginning of deductive theory based on the properties that have been identified in the intuitive development; concepts of measurement in the plane and space, angle measurement, measurement of the circle, volumes of familiar solids; and, the treatment of coordinate geometry through graphs of simple equations.

These recommendations are minimal. Students who have already covered much of the material recommended by CUPM should be encouraged to extend their studies. A good percentage of the prospective elementary school teachers should enroll in a program comparable to the CUPM recommendations for level II. All students should be prepared to meet changes in content, terminology, and methods in elementary school mathematics with a minimum of inservice assistance. The required flexibility of mind can best be attained by an emphasis on fundamental, widely applicable concepts, such as: set, relation, function, operation, one-to-one correspondence, and isomorphism.

With the inevitable increased future dependence of society on quantitative thinking throughout the many areas served by mathematics it is vital that the teacher bring to the elementary school as much related academic background as possible. For example, elementary notions of probability and statistics may find their way into the secondary and elementary curricula of the future. The applications of these ideas to the physical and social sciences are increasing. Thus some experience with probability and statistics is desirable. Some knowledge of the significance of the computer and its place in society, as well as some idea of the things that programmers do, would be appropriate.

Elementary school teachers should be thoroughly acquainted with the curricula of the higher grades (junior and senior high school) toward which their pupils are moving. This in keeping with the more general principle that any teacher should thoroughly understand the subject matter at levels beyond the one that he is teaching.

Elementary Science and Mathematics Curriculum and Methods

GUIDELINE V — *The program of preparation for the elementary school teacher should include study of the aims and methods of teaching science and mathematics in the elementary school.*

The prospective elementary school teacher should have ample and appropriate opportunity to relate the concepts, information and techniques of college science and mathematics to the educational needs and potentialities of elementary school pupils.

The professional courses should provide both classroom and laboratory experiences specifically designed to develop skill in teaching science and mathematics in the elementary schools. Attention should be given to the identification and development of teaching procedures according to the unique abilities of each prospective teacher.

Professional experiences should include:

1. Systematic consideration of purposes, methods, materials, and evaluation procedures appropriate to the teaching of mathematics and science to children;
2. Study of current trends and research in the teaching of science and mathematics;
3. Laboratory and field opportunities to encourage development of individual initiative in conducting experiments, devising demonstration equipment, developing teacher resources, and planning other types of learning activities;
4. Study of the implications of psychology for the teaching and learning of science and mathematics; and,
5. Opportunities for prospective teachers to become acquainted with the professional organizations in science and mathematics, their services to teachers, and the importance of active participation in selected organizations including the encouragement they provide for professional growth.

Teachers of methods courses should be well informed about basic mathematical and scientific concepts; the concepts, problems, and literature of mathematics and science education; the nature of the learner; and, the nature of American public schools. They should be excellent teachers who have the confidence of the mathematics, science and education departments.

Experiences With Children

GUIDELINE VI — *Professional laboratory experiences, including observation and student teaching, should provide opportunities for the prospective teacher to work with experienced elementary school teachers who are competent in the subject area, skilled in nurturing the spirit of inquiry, and effective in helping children benefit from the study of science and mathematics.*

The institution should have a well-developed program of professional laboratory experiences for future elementary school teachers. With reference to science and mathematics, there should be provision for the

effective utilization of personnel appropriately sensitive and competent in science, mathematics and education. This includes the director of laboratory experiences, the immediate supervisor of student teaching experience, the college visitors from the sciences and mathematics departments, and the local cooperating teachers.

The young teacher's confidence in his own ability to teach children science and mathematics in the elementary school is important in initiating and carrying out his own activities. His college experience, including student teaching, should encourage self-confidence. Important in his preparation to teach science and mathematics is contact with teachers who know how to teach science and mathematics to children of differing interests, backgrounds and abilities. Observations and demonstrations should be planned to help prospective teachers relate both content and professional education courses to the interests and maturity levels of children.

The student teaching experience should be under the control of a supervising teacher who has the experience and ability necessary to plan and execute a well-balanced classroom program in which science and mathematics are effectively taught. The cooperating teacher should help the student teacher to develop and utilize teaching plans that integrate effectively science and mathematics in the total elementary school curriculum. He should provide opportunities for student teachers to guide and stimulate children through problematic approaches, and through activities that will resul' in learning. He should teach student teachers to carry on varied and responsible evaluations with their pupils.

The student teaching supervisory staff should include staff members who have strong backgrounds in science or mathematics education. In addition, these staff members should be well acquainted with the characteristics of children as learners, with the teaching process, should have practical insights into the program of the elementary school, and should make an effort to work with the cooperating teacher.

Additional Undergraduate Study

GUIDELINE VII *The program for the preparation of the elementary school teacher should provide opportunities for pursuit of additional undergraduate study in a carefully planned program in science and mathematics.*

Prospective teachers should seek depth in a subject matter area, whether it be in the humanities, in the sciences or in the arts. The demands of elementary teacher preparation within a four year college program may restrict specialization to something less than a conventional academic major but there should be opportunities to pursue a subject beyond the introductory level. Additional emphasis on specialized content and instructional techniques in both science and mathematics, for instance, should be available in professional methods courses, in the

study of elementary school curriculum and in pre-professional participation and student teaching.

In the material suggested below opportunities for study should go beyond those recommended in the preceding *Guidelines*.

Biological Sciences. For those who seek depth in biological science, additional study of biology should be provided with problem solving laboratory and field experiences deliberately oriented in favor of an investigative approach. Further depth in concepts should be developed in accordance with material listed in *Guideline IV*.

Physical Sciences. For those who seek depth in physical science additional study in chemistry and physics might be selected from such areas as general chemistry, analytical chemistry, biochemistry, organic chemistry, physical chemistry, introductory classical physics, and introductory modern physics.

Earth Sciences. For those who seek depth in the earth sciences, the study selected will depend on the background of the student. Additional study may be done in such areas as astronomy; meteorology and climatology; geology; mineralogy and paleontology; and oceanography.

Mathematics. For those who seek depth in mathematics, study should continue into mathematical analysis (including the fundamentals of analytic geometry), abstract algebra, geometry, and probability from a set-theoretic point of view. This program is spelled out very well by the Committee on the Undergraduate Program in Mathematics (CUPM) but currently would probably not be adequately covered by standard programs in mathematics departments over the country.

Fifth and Sixth Programs

GUIDELINE VIII *Fifth year and sixth year programs for the elementary school teacher should offer appropriate science courses and mathematics courses which might be applied toward an advanced degree.*

Post-baccalaureate opportunities should be available within the institutions or through cooperation with other institutions so that elementary school teachers can extend their competence in the sciences and mathematics with the purpose of becoming better teachers, special teachers, or supervisors. In working out the details of any such program, primary attention must be focused on what would best contribute to increasing the competence and effectiveness of the teacher.

Institutions are encouraged to experiment with new approaches to the development of science and mathematics programs for elementary school teachers at the post-baccalaureate level.

It is recommended that institutions offer graduate level credit for the courses developed. Courses so designed should be considered as adequate to permit further study in regular programs of the departments included under science and mathematics.

In the fields of science, these courses will probably differ from those designed for the preparation of professional scientists in the following ways. There will be an emphasis on simple but revealing laboratory experiments; more attention will be paid to an interdisciplinary approach; greater emphasis will be placed on concepts of science relevant to the teaching of science in the elementary school; use will be made of a simple quantitative approach with emphasis on quantitative representation; the historical development of science will be emphasized; and, less emphasis will be placed on the enumeration of scientific facts.

Teachers who engage in fifth and sixth year programs of study should have an opportunity to take additional work in science and mathematics to enable them to teach these subjects more effectively. Teachers who have a special responsibility for science and mathematics in a team teaching plan in their schools will need to strengthen their backgrounds of experience in the study of science and mathematics and to be kept up-to-date on new developments in scientific research, curriculum, and teaching methods.

For fuller realization of a program of science and mathematics in an elementary school, the use of science and mathematics specialists should be considered. Post-baccalaureate programs for the preparation of these specialists should be developed by colleges and universities with qualified staff members who are particularly interested in this endeavor. Such programs should produce specialists who have at least a masters degree which includes substantial work in science and/or mathematics.

A specialist may be a consultant, special teacher, resource person, supervisor, or coordinator. The functions of mathematics and science specialists may include: preparing instructional materials and coordinating resources available from the immediate community; assisting in selection of equipment, facilities and instructional materials; developing inservice programs; facilitating articulation of K-12 programs in science and mathematics; providing liaison with college, university and state department personnel in science and mathematics; interpreting new developments in research and teaching to administrators and the public; teaching demonstration lessons; and, providing leadership for evaluation of science and mathematics programs.

Inservice Education

GUIDELINE IX — *Inservice education should provide opportunities for the elementary school teacher continuously to improve and extend the competencies required for effective teaching of science and mathematics.*

Guidelines I to VIII recommend that elementary teachers have four years of preservice undergraduate education and that they spend a fifth year in rounding out their preparation for elementary teaching and in pursuing advanced work in areas of particular interest. Inservice offerings must take into account the needs of those now teaching whose pre-

service preparation does not meet *Guideline* standards. Inservice education is interpreted to mean both planned group and planned independent study. Its primary aim is to keep teachers alert to changes in content and method.

The preservice education of teachers should encourage and develop those qualities which enable teachers to supplement inservice course opportunities with a continuing program of independent study. The object should be to develop those habits, ideas, techniques, and powers of judgment and understanding that will not only enable but will also inspire the postgraduate to an active continuation of self-education throughout life. Due to the present explosive rate of growth of knowledge in mathematics and in the sciences, the preservice teacher trainees of today will be required in the future to judge programs and teach materials which they have never studied formally and for which inservice programs will not always be available.

Teacher education institutions, state, and local agencies are urged to provide appropriate inservice programs. School systems are urged in turn to provide time and incentives for teacher participation in these programs. The suggestions made earlier in these *Guidelines* for the preservice preparation of elementary school teachers should be considered in planning inservice programs for teachers in modern mathematics and science.

These programs should: provide the teacher with analyses of current research pertinent to the teaching of science and mathematics; the study and evaluation of contemporary learning materials for science and mathematics education; and, assist teachers in planning effective applications and in orienting their subject matter to the general or unique needs of their students.

Effective methods of conducting inservice education should be investigated; e.g., programmed instruction, radio, television, correspondence, guides, films, supplementary materials, tapes, and laboratory and field experiences. Mass media coupled with actual personal involvement should be explored.

It is assumed that increasingly young teachers will enter teaching better prepared in science and mathematics. Recurring surveys of inservice education programs will be required to keep up with the changing needs of teachers.

Other Publications

Guidelines for Preparation Programs of Teachers of Secondary School Science and Mathematics. NASDTEC-AAAS Studies, 1515 Massachusetts Avenue, N. W., Washington, D. C. 20005, 1961.

Secondary School Science and Mathematics Teachers: Characteristics and Service Loads, NASDTEC-AAAS Studies. Order from Superintendent of Documents, Government Printing Office, Washington 25, D. C., (Catalog No. NS 1.2:T 22/2), 35 cents; 1963.

The New School Science: A Report to School Administrators on Regional Orientation Conferences in Science. AAAS, 1515 Massachusetts Avenue, N. W., Washington, D. C. 20005, 1963.

NASDTEC DECLARATION OF POLICY

The changing needs of society make increasing demands on teachers for the education of all citizens. If the teacher is to meet these demands, his education must be broader and more intensified than ever before.

Every state requires a license for those who direct the education of children and youth in order to protect and promote the educational welfare of its citizens. Similar provisions exist for licensing in all professions. The state directors of teacher education and certification are the administrators of this legal authority for state licensing of teachers. The National Association of State Directors of Teacher Education and Certification, recognizing the obligation of states to provide competent teachers for their youth, will continue to work for the improvements needed in the education and certification of teachers.

NASDTEC believes that the growing and changing demands on society in the last half of the twentieth century require that:

1) Prospective teachers be carefully selected from among our more capable college students.

2) The beginning teacher have completed a well-planned college program of at least four years.

3) All teachers have a broad education in the arts, the sciences and the humanities; intensive study in the subject-matter field(s) to be taught; and thorough preparation in the educational process.

4) School districts assign teachers only to subject-matter field(s) in which they are adequately prepared.

5) Standards and procedure for approving colleges and universities which prepare teachers be strengthened and enforced.

6) Reciprocity in teacher certification among the states be accorded to graduates of approved teacher-education programs in colleges and universities.

NASDTEC believes that the quality of the educational program is directly affected by the quality of the teacher. Furthermore, the association believes that to attract and retain competent teachers, it is necessary that increased funds be provided to raise the economic status of teachers and to improve teaching conditions.

NASDTEC will continue to work for the objectives which its members consider vital to the needed improvement of our system of public education. The members in their respective states, as well as in their national association, will continue to work closely with lay and professional groups and persons to improve programs of teacher education throughout the United States.