REPORT RESUMES

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THE DEVELOPMENT AND TESTING OF INSTRUCTIONAL MATERIALS FOR GIFTED PRIMARY PUPILS. FINAL REPORT.

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PUB DATE 65
EDRS PRICE MF-$0.18 HC-$2.76 69P.

DESCRIPTORS- *ELEMENTARY SCHOOL SCIENCE, *INSTRUCTION, *INDIVIDUAL INSTRUCTION, *PROGRAMED INSTRUCTION, AUDIOVISUAL INSTRUCTION, ABLE STUDENTS, MATHEMATICS EDUCATION, PHYSICAL SCIENCES, PRIMARY EDUCATION, NORMAL

SELF-INSTRUCTIONAL SCIENCE MATERIALS FOR GIFTED PRIMARY STUDENTS WERE DEVELOPED AND USED WITH FIRST- AND SECOND-GRADE STUDENTS. UNITS ON ATOMIC STRUCTURE, THE NATURE OF MOLECULES, MEASUREMENT, AND MATHEMATICS WERE DEVELOPED, USED, EVALUATED, AND REVISED OVER A 2-YEAR PERIOD. LESSONS WERE PRESENTED THROUGH THE USE OF TAPE PLAYERS, ILLUSTRATIVE MATERIALS, AND WORKBOOKS. STUDENTS WERE SELECTED ON THE BASIS OF IQ SCORES AND ASSIGNED TO TWO GROUPS. EACH GROUP USED THE MATERIALS FOR ONE-HALF OF THE EXPERIMENTAL PERIOD. ALL STUDENTS WERE PRETESTED, TESTED AT THE END OF THE FOURTH WEEK, AND POST-TESTED FOR ACHIEVEMENT WITH INSTRUMENTS DEVELPED FOR THE STUDY. OTHER DATA WERE OBTAINED FROM TEACHER EVALUATION FORMS AND QUESTIONNAIRES COMPLETED BY TEACHERS AND PARENTS. ANALYSIS OF COVARIANCE WAS USED TO COMPARE PRETEST AND POST-TEST SCORES OF STUDENTS IN THE TWO GROUPS. NONPARAMETRIC TECHNIQUES WERE USED TO CHECK SCORE DISTRIBUTIONS FOR GROUPS WITH NONSIGNIFICANT F VALUES. SIGNIFICANT GAINS, AT THE .05 LEVEL, WERE OBTAINED FOR THE UNITS CONCERNED WITH MATHEMATICS, ATOMS, AND MEASUREMENT. A MAJORITY OF THE PARENTS FAVORED THE USE OF THE MATERIALS AND INDICATED THAT THE CHILDREN DEVELOPED INTEREST THROUGH THEIR STUDIES. (AG)

FINAL REPORT

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This project was supported by a grant from
The Department of Program Development for Gifted Children
Office of Superintendent of Public Instruction, State of Illinois

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ACKNOWLEDGEMENTS

This project would not have been possible without the help and cooperation of teachers and administrators in the elementary schools in Unit District 5, Bloomington, Illinois, and the Metcalf Laboratory School at Illinois State University. Mr. George N. Wells, Superintendent of Schools, Bloomington, Illinois and Mr. Loren E. Klaus, Superintendent of Schools for Unit District 5, Normal, Illinois gave the project their full support. Miss Rosemary Dustman, Mr. Lowell Krutsinger, and Miss Lois Green skillfully handled the liaison and coordination between the project and the participating schools. A special debt of gratitude is owed Dr. Vernon Replogle for his unfailing patience and his good counsel.

In the exploratory and developmental stages the assistance and advice of the supervising teachers of two classes of gifted children in the Metcalf Laboratory School, Mrs. Genevieve Langston, Mrs. Anita Jones, and Mrs. Margaret Weiser, were particularly valuable. These teachers helped in the formulation of experimental lessons, tried lessons and tests with their pupils, and allowed project personnel to observe and try materials in their classes. Miss Ruth Cole, supervising teacher in Metcalf Laboratory School, also made her class available for trial of materials.

The cooperation of the participating teachers in the public schools is testimony to their interest in curriculum development and research. For a period of eight months they administered a special lesson each day, and followed a rigorous schedule of pre- and posttesting of pupils. The following teachers served both as participating teachers and consultants: Miss Lois Ambrose, Mrs. Grace Blake, Mrs. Kathryn Carnahan,

Mrs. Eugenia Crowe, Mrs. Dorothy Cushman, Mrs. Ruth Dalrymple, Miss Rena Ellis, Mrs. Theresa Garrison, Mrs. Patricia Jaeger, Mrs. Carol McNulty, Mrs. Eleanor Mears, Mrs. Nancy Neeves, Mrs. Shirley Passmore, Mrs. Amy Tabor, Mrs. Hallie Raab, Miss Elizabeth Reilly, Mrs. Hazle Ringer, Mrs. Gladys James, Mrs. Trunella Stewart, Miss Lucile Thompson, Miss Mildred Thompson.

We are deeply indebted to the creative efforts of Mr. William B. Price, who acted as a technical consultant and designed many of the illustrative materials, and to Mr. Jay Richardson, who wrote two computer programs for the project.

A special mention should be made of the contribution of Mrs. Barbara Price, whose official title does not do justice to her large contribution to the writing of the experimental lessons. Mrs. Price did most of the writing of the Measurement Unit, made valuable suggestions for improving other units, and contributed useful ideas in the construction of test items.

The construction of tests and evaluation of data is largely the work of Robert Rumery. Mr. Tom Edwards was active in formulating the science units in the exploratory stage and Mr. Richard Youngs is largely responsible for their final form. Mr. Kenneth Retzer wrote the Mathematics Units and Mr. John Esbin and Mr. Wilson Banks assisted with the Measurement Unit. Dr. Thaddeus Ichniowski gave generously of his time to check the accuracy of the science units.

Mrs. Karen Alexander and Miss Christine Hooper assisted with stories and poems. Their sense of fun added a light touch to our pedestrian efforts. Mr. William Kritzmire did most of the art work and the recordings.

Mrs. Leda Fahrenkrog most ably performed the role of executive secretary to the project.

Theodore Sands
Charles Hicklin

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*The appendices are quite bulky and are not included in this copy of the report. Copies of the appendices are available on loan and can be obtained by writing to the project director.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

It is becoming increasingly clear that many of the problems which have concerned educators in the field of the gifted have an underlying common denominator, that of appropriate instructional materials. Regardless of the type of program, the instructor must face the ineluctable question of what to teach, and one of the prime factors in determining this is the availability of appropriate instructional materials. Whether one operates within the context of enrichment or acceleration, homogeneous or heterogeneous grouping, in the end all programs must solve the problem of obtaining suitable instructional materials. At its best, instruction of the gifted must include the early introduction of activities, concepts, and skills which are usually encountered at a higher grade, the development of concepts and thought processes of a higher order than those usually developed in less able students, and individualization of instruction.

No two gifted students are "gifted" in the same way. Ideally, any gifted program should give the individual student an opportunity to develop his talents and skills at the pace and the level of learning commensurate with his ability. Even in a so-called homogeneous class there is a wide range of abilities. No two students bring to a particular field of study the same experiences, skills, and fund of knowledge. Fliegler (1961) has stated it well, "Variability is the essence of existence, and whether total or partial segregation is practiced, heterogeneity is the constant protean characteristic of life. At best, there is only relative homogeneity."

Two of the operational characteristics of individualization of instruction are that the instructor analyzes the needs of the student and arranges for learning experiences which promise to meet those needs. Obviously these learning experiences entail a variety of instructional materials: books, records, equipment, and illustrative objects. The wider the range of choice, the more effectively a teacher can individualize the learning experiences of the student.

Several administrative arrangements which attempt to bring together the individual student and a particular appropriate learning experience are already in use. The ungraded classroom, the teaching resource center, individual projects, and use of programmed materials are such attempts. Without appropriate materials, however, these arrangements are empty showcases.

It is a truism that the wider the range of choice of instructional materials, the more effectively the teacher can individualize the learning experiences of the student. The allocation of federal funds for the establishment of curriculum materials development centers and the development of new curricula by national committees in mathematics and the sciences are testimony to the increasing realization of the importance of this function. These materials, however, have not been designed with the special needs of the gifted as their objective. If we accept the proposition that gifted students are capable of using higher thought processes with greater skill than other students of the same chronological age, it should follow that materials designed for achieving such greater skill should be available to teachers.

Providing individualized learning experiences for the gifted presents distinct problems; in the early primary grades, the problem has special characteristics. There are few instructional materials which attempt to develop basic concepts and at the same time require the use of higher thought processes. An instructional program based on materials which have as their objective the attainment of knowledge of facts, terms, principles, classes, and methodology cannot be considered adequate for the gifted. The authors take the position that instructional materials which are designed for use with the gifted should induce in the learner such skills as: analysis, prediction, verification, extrapolation, and at later stages, synthesis.

Teachers of gifted children encounter a further handicap in their search for materials. Most instructional materials dealing with basic concepts in science, social science, and to a lesser degree in mathematics, are not designed for use with early primary students. Too often these materials assume experiences and understandings which the primary grade student, even though gifted, does not have. For instance, a gifted child whose hobby is chemistry cannot go beyond descriptive data if he does not have some understanding of atoms and molecules. The usual materials dealing with atoms and molecules often make too many assumptions about past experiences and learnings to be useful for primary grade students.

At the primary grade level, there are several special factors which should be taken into account in preparing instructional materials for the gifted. First, the capacity of the child to learn is not limited by his ability to read. Reading becomes a mediating factor in the development of concepts and the use of higher thought processes only if the instructional strategy relies on the written word as the means of communications. However, "non-reading" means can be used to communicate with the child. Therefore many of the concepts which are currently treated in a written format need to be recast into a form not requiring reading, if gifted primary students are to be introduced to basic concepts.

Secondly, these classroom materials should be as self-instructional as possible. Given a teacher-student ratio of twenty-five or more students per teacher, it is unrealistic to expect even a dedicated and experienced teacher to be able to improvise twenty-five individual curricula. The alternative is for the teacher to devote the major portion of her time to teaching the standard curriculum to all her students and to assign supplemental work to the very able and the very slow learner. Past experience with this type of enrichment has not been promising. The report of the Southern Regional Project for Education of the Gifted (1962) says:

> "The concept of 'enrichment' as a means of providing for gifted children has fallen into disrepute among educators. The claim by given school administrators that this medium, long recognized as an administrative pattern coordinate with 'grouping' and 'acceleration,' is their preference has been proven in the usual instance to be a bulwark behind which scarcely anything desirable has in fact transpired."

While the problem may be less acute with a class where differentiated grouping is practiced, the challenge of individualizing instruction still exists. If the teacher is the primary source of questions and explanations, the individual is tied to whatever group the teacher happens to be teaching. Even in a so-called homogeneous group, there is need for individualization of instruction.

The essence of individualized instruction is that it not be tied to group learning. A possible solution to the problem is to assign a different role to the teacher. Instead of being a purveyor of information and the creator of learning experiences, she might better play a role of motivator, evaluator, and arranger of learning experiences. To play this role, the teacher must have available a variety of instructional materials which can achieve acceptable teaching objectives by interaction between the individual student working independently and the instructional materials.

The authors take the position that the operational reality of primary reliance on "enrichment" in the public schools is likely to continue for the foreseeable future. Therefore, if gifted programs are to be expanded and improved, a pre-requisite will be availability of instructional materials which will not require the teacher's attention or participation for more than a few minutes at a time. Nor must the use of the materials in the class require special training on the part of the teacher.

We do not mean to imply advocacy of the present status quo in the public schools, but rather take the view that if the objective is to improve the instruction of the gifted in the present, materials which lend themselves to individualized instruction must be devised. Given the pattern of instruction of most public schools, individualized instruction will depend on a large measure on the use of materials which approach a self-instructional design.

Serious doubt can be raised about attempts to provide for the gifted (or other students) by requiring the teacher to play a different role from the ones currently in practice. Too often these attempts suffer from the fallacy of attempting to bring about change in behavior without providing the operating conditions which would facilitate such change. While there is merit in identifying new patterns of instruction and exhorting teachers to use them, the impact on classroom behavior of teachers through such an approach has been disappointing.

A more promising alternative is to concentrate on the development of instructional materials which require a minimum of dependence on the classroom teacher to bring about the desired objective. Too often we ask teachers to adopt new strategies of teaching without providing the instructional material necessary to put them into practice.

Problem

This project has addressed itself to the problem of developing instructional materials in a self-instructional format for use with gifted students in the early primary grades. Specific objectives of this project have been:

1. To create and test a sequence of instructional experiences which would enable a gifted student while working independently to develop concepts which were considered basic to a discipline but not usually encountered in the early elementary grades.

2. To develop these concepts in a way which would require the bringing into play higher thought processes such as translating, interpreting, extrapolating, applying, analyzing, and evaluating.

3. To identify a strategy of instruction which would enable such materials to be used in the public schools with a minimum of teacher attention and participation; require no special training of the teacher; and be adaptable to the current patterns of administrative arrangements for instruction of the gifted.

CHAPTER II

OUTLINE OF THE PROJECT

This project produced forty-four self-instructional lessons dealing with atomic structure, nature of molecules, and measurement. The self-instructional lessons were presented to the child in the form of taped instructions with accompanying illustrative material and a workbook. Each child operated a small battery-powered tape recorder and listened through individual earphones to a taped lesson carrying approximately fifteen minutes of voice recording. At certain critical points in the instructional sequence, the child was given a criterion task which indicated whether or not the instructional objective in a given sequence of instruction had been attained.

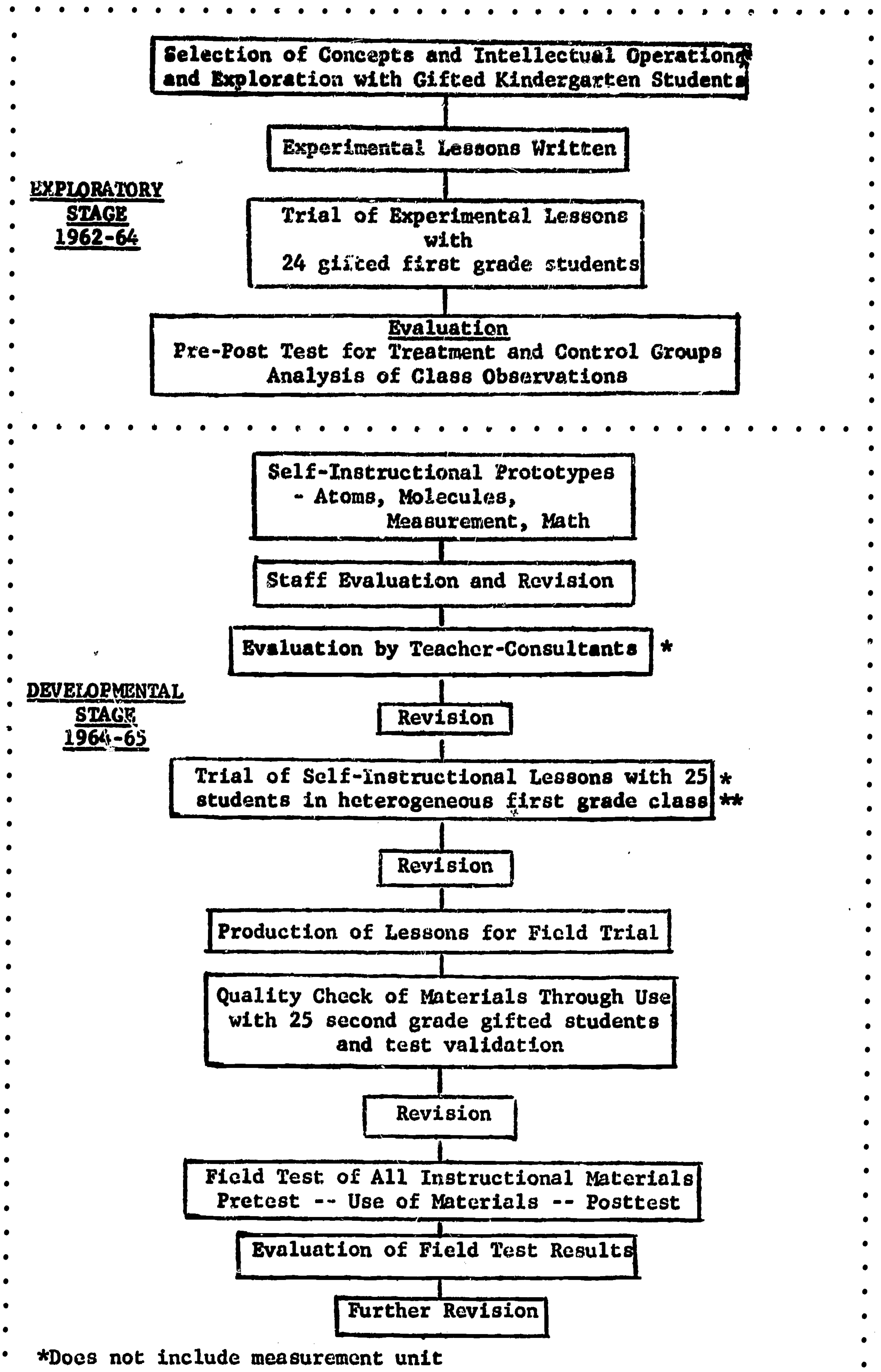
In addition, the project generated a set of instructional materials dealing with sequences and mathematical abstraction. The math lessons required the teacher to give directions.

The project was conducted in several phases. Exploratory work was done with a kindergarten class of gifted pupils in the school year 1962-63. Development of the units of instruction was started in the fall of 1963. Figure I shows the sequence of procedures used to produce the instructional materials of the project.

Selection of Concepts and Thought Processes

The concepts around which the lessons are organized were chosen on the basis of usefulness in leading to other learning. In choosing the science concepts the question was asked, "What concepts are most essential for understanding the nature of our physical environment?" After extensive consultation with specialists in physics and chemistry, concepts

OUTLINE OF PROCEDURES



*Does not include measurement unit

**Does not include mathematics materials associated with the nature of the atom and the molecule were identified as best meeting this criterion. Measurement was chosen as a topic because of its importance to a wide range of intellectual activities. Measurement was of particular interest because though children in the early elementary grades are introduced to measurement as an operation, little or nothing is done to identify and treat measurement as a concept. In mathematics the criterion was that the concepts should lend themselves to activities which would require the child to perform certain intellectual processes which are fundamental to mathematics. Though considerable attention was given to the choice of concepts, no claim of exclusiveness is made for these particular concepts. These concepts seemed appropriate to the objectives of the project; other concepts might be equally useful and appropriate for use with gifted first grade students.

A preliminary analysis of the concepts and intellectual operations involved in the proposed units of instruction raised the question of teachability. Piaget (Inhelder and Piaget, 1958) suggests that the child up to about seven years is in a preoperational stage of intellectual development and lacks understanding of certain basic relationships between objects. To achieve the objectives assigned to the experimental lessons would require of the child not only to manipulate concrete operations but also to recognize symbolic representations of these operations and to establish relationships between the symbolic representations and concrete events. This latter mode of operation Piaget attributes to the adolescent stage of intellectual development.

Could gifted first grade pupils carry out this latter mode of operation given appropriate experiences? Before lessons could be written, an assessment had to be made of these and other questions. Information was also needed about what kinds of experiences might move a child to the desired levels of intellectual operations.

A start had been made on these questions in 1962-63 with classrooms of gifted kindergarten pupils, established for research purposes in the Metcalf Laboratory School on the Illinois State University campus. During this exploratory stage the children's reactions to tasks requiring the use of symbols and the classification and analysis of data were studied. A number of experimental teaching units were written and tried. A beginning was made on the construction of paper and pencil achievement tests for evaluation of the exploratory instruction. This work provided information and insights for the next phase, a more structured trial of experimental lessons with students in a first grade class.

Trial of Experimental Lessons in Class

During 1963-64 lessons were organized and tried in one of the experimental gifted classes in Metcalf Laboratory School. Twenty lessons were organized around the theme "Let's Find Out." These lessons required the pupil to gather data through use of all five senses, to classify, to hypothesize, and to verify. These lessons required children to use chemicals, test tubes, magnifying glasses, magnets, filters, and simple balances.

Experience with these lessons revealed that with few exceptions the children could use equipment of this type to collect data. It was apparent that they also could classify, derive hypotheses from data, and carry out simple experiments to test their hypotheses.

Twenty-two lessons, each thirty to forty-five minutes long, were developed in energy, force, gravity, and atomic structure. These lessons served as further sources of information about what these children found difficult, what they already knew, and what experiences needed to be supplied. The following samples of the kinds of data which observation of these lessons produced is taken from the class log and observers' notes:

> S--- thinks legs are a sense. B-- and S-- and several others wanted to know how we knew so much about atoms if our senses didn't tell us. M--- kept insisting there was equipment for seeing atoms.

This observation led to drastic revision of the sequence of instruction and the inclusion of a series of experiences designed to illustrate how one can infer characteristics of unseen entities by their behavior.(See Atom Lesson 3, Appendix A.)

The observation record of a lesson dealing with creation of a model of a water molecule contains the following:

> When asked, N-- knew what the pegs and balls stood for. K--, on the other hand, thought the pegs represented molecules. N-- corrected him by saying they stood for energy.

Reference in the classroom to "green atoms" and the "red atoms" indicated that there was some danger of confusing the characteristics of the model with those of the atom or molecule. To prevent this attribution of particular characteristics of the model with the thing they represented, a variety of models were used in the revised version to represent atoms and molecules.(See Molecules Lesson 1, 2, and 4, Appendix B.)

The performance of the class with these lessons indicated a high level of conceptualization and the ability to apply what had been learned. For example, the children had been given lead nitrate, $Pb(NO_3)_2$, and potassium iodide, KI. Before mixing them together, they were asked to predict what would happen. The following remarks were recorded:

S-- "Might blow the cork off."
Teacher-- "Why?"
S-- "Happened when we put vinegar and water together."
G-- "Might bump together and get all mixed up."
T-- "Might make a molecule."
S-- "Already has molecules."

After the class had observed a nail change color when put into a solution of copper sulfate, A. L. explained what had happened by saying, "The molecules had broken up into atoms, and the atoms had changed places." (See Molecules Lesson 7.) In another lesson, the question was asked if all atoms were the same size and if they were all alike. The class arrived at the conclusion that neither could be because they knew all things were made of atoms, and as B-- said, "If all atoms were alike and like apples... , whole world would be apples."

The experience with the experimental class produced hypotheses of what gifted first grade pupils might be expected to learn about atomic structure, the nature of molecules, and measurement. Equally important, it was the experience with the experimental class which led to the realization that a self-instructional format was needed for use in the public schools. The conditions which led to this judgment are explained in the following section.

Creation of Prototypes of Self-Instructional Lessons

During the phase in which the experimental lessons were being tried in the Metcalf experimental class, the classroom teacher and project personnel worked as a teaching team. Project personnel briefed the teacher on the objectives of the lesson, identified and explained the concepts involved, supplied technical information, and suggested materials and activities which might be used. The classroom teacher drew up her own lesson plan and taught the lesson.

This pattern of operation revealed a number of problems which, while solvable in a laboratory school situation, promised to be serious obstacles in the public schools. The problems arose from the level of subject matter understanding required of the teacher, the nature of the illustrative and manipulative materials required to develop the concepts, and the strategy of instruction required to induce higher thought processes.

It was the judgment of the experimental classroom teacher, buttressed by instructors in the University course in science for elementary teachers, that the content of the proposed lessons was beyond the training of most first grade teachers. Experience in the experimental class indicated that this judgment was right. The amount of help given the classroom teacher by the subject specialist was more than could be expected under even optimum conditions in the public schools.

The implication of this situation was that though there was evidence that gifted children could learn advanced concepts and use higher thought processes, it was questionable if these results could be replicated in the public schools with the same approach.

An additional cause of concern was the availability of appropriate materials. Though special care was taken to confine illustrative materials to items of common use, the nature of the subjects taught seemed to require materials which were not readily available to first grade teachers. Many of the items, while fairly common, are not found in the first grade classroom, e. g., magnets, magnifying lens, vinegar, soda, metals, and chemicals, and are not obtainable on short notice. It was apparent that there was a need to supply all items required for instruction.

Lastly, there was the matter of teaching strategy. Given a body of content which was relatively unfamiliar to the teacher, it seemed unlikely that public school teachers without extensive special training could present the material in a way which would encourage their students to employ higher thought processes. It was these considerations which led to the decision to cast the material in a self-instructional format.

Creation of Self-Instructional Lessons

In the summer and fall of 1964, forty-four self-instructional lessons dealing with atomic structure, the nature of molecules, and measurement were written. The following guidelines were assigned as necessary conditions in writing each lesson:

1. Sensory experiences. Wherever possible, abstractions and symbols were to be associated with an appropriate sensory experience.
2. Operational definitions. The student should be given the opportunity to perform an operation and then be told the word or words which denote the behavior.
3. Participative activities. Each lesson should actively engage the student in manipulation of illustrative materials and overt behavior related to making inferences, solving problems, or predicting.
4. Programming principles. The instructional material should embody the following techniques derived from programming principles: identification and statement of objectives in behavioral terms, presentation of information in small steps, careful sequencing, immediate confirmation, self-pacing.

The lessons were arranged so that they could be used in a variety of ways. The teacher was supplied with a teacher's manual (see Appendix A., B., C.) and a complete set of materials. The manual and the materials enabled the teacher to use them in a variety of ways. The teacher could assign the materials as complete self-instruction and restrict her role to merely scheduling the use of the materials. A more effective use was to allow the student to use the materials independently and later discuss the lessons with him. Some teachers have used the materials as a basis for group instruction, with the teacher acting as instructor. Other teachers have used the materials as a basis for class instruction.

Evaluations by Teacher Consultants

The advice of the public school teachers who were to use the experimental materials was sought during the stages when the instructional material was being written. These teachers, acting as paid consultants, evaluated a prototype of the atom and mathematics units in the summer of 1964. The consultants filled out evaluation forms (see Appendix D) and were also encouraged to voice their reactions in a group discussion in which their suggestions were tape recorded.

An analysis of data collected from this evaluation session led to extensive revision of both content and format, especially in terms of pacing, vocabulary, and manipulation of illustrative materials. The revised lessons were tried with a regular first grade class in the Metcalf Laboratory School, then revised again. In order to obtain data for validation of test items, and also to obtain a final check on the materials before their placement in the public schools, all lessons were used with a class of gifted second grade pupils in Metcalf Laboratory School.

Field Trials in Public Schools

The lessons were then put into production for trial in the public schools. The field trial was carried out in twenty-one first grade classrooms located in sixteen different elementary school attendance centers in the Bloomington Public Schools and in McLean County Community Unit District # 5 schools. The latter included attendance centers in Normal, Towanda, Hudson, and Carlock, Illinois. Twenty-one teachers were involved with one hundred ten pupils at the start. The field trials began in November, 1964, and continued until May, 1965, with the units taken up in the following order: Math, Atoms, Molecules, and Measurement. For experimental design purposes (see Chapter III) two groups were selected in the public school trials with group A starting instruction immediately and group B delaying instruction.

Project personnel did not teach in the classroom or direct the use of materials with individual pupils. The role of project personnel was limited to observation in the classroom, answering teacher inquiries, and replacing faulty material and equipment. Day by day schedules for use of the project materials within the time allotted for the total unit was left to the teachers.

Selection of Pupils and Teachers

In both school systems pupil selection was done by means of a preliminary screening test followed by individually administered Stanford-Binet Intelligence tests. One district used a group mental abilities test in the spring of 1964 as a screening instrument; in the other school system the screening test was given in the fall of 1964. By the fall of 1964 both school systems, using qualified psychological examiners from Illinois State University and the public school systems, had identified a pool of ninety-two subjects who scored 124 or above on the Stanford-Binet scale. (See Table I.) Teacher selection prior to the beginning of instruction resulted in the addition of eighteen more subjects for a total of one hundred ten subjects.

TABLE I

FREQUENCY DISTRIBUTION OF I. Q.

I. Q.	No. of Pupils	I. Q.	No. of Pupils
165 - 169	1	144 - 140	12
164 - 160	0	139 - 135	15
159 - 155	0	134 - 130	29
154 - 150	0	129 - 125	30
149 - 145	2	124	3

The selection of teachers was made by the central staffs of the two school systems. Some classes were not included because no pupils in their classroom met the formal screening criteria.

Administrative Arrangements for the Field Trial.

When the proposal for the project was conceived in the summer of 1963, the chief administrators of the two school systems agreed to furnish the necessary experimental setting. A series of meetings was held with the administrators of the two school systems, including building principals, to explain the nature of the project. Administrators designated a number of their central staff to coordinate the project. The coordinators scheduled orientation meetings for teachers and administrators. Other meetings were held with building principals to work out the details for distribution of materials.

Parent Reactions

As might be expected, the designation of pupils for special experimentation in a public school system created some stir among parents, teachers, and other patrons of the school and the community. An initial story in the local press marked the awarding of the grant. An accompanying story reported progress of the exploratory phase of the project in the Metcalf Laboratory School.

The parents of the children to be included were notified by individual letters with a general description of the project. In the fall of 1964, parents' meetings were held in some, but not all, schools. At these meetings project personnel explained the materials which the children would be using. The follow-up questionnaire (see appendix E) sent out in the spring of 1965 revealed that parents were aware of their children's activities in the project. In most cases, they were aware of the subject content of these materials.

There was very little negative reaction from parents of children who were not selected. As the experiment progressed and became routine in the various classrooms, curiosity subsided. Some of the teachers extended the use of these materials to the entire classroom, and the experimental lessons became part of the regular class routine.

CHAPTER III

CONTENT OF INSTRUCTIONAL MATERIALS

One of the distinguishing features of the experimental instructional materials is the depth of treatment and the level of abstraction called for in the development of concepts by first grade pupils. An analysis of the concepts and the way in which they are developed suggests that they require of the learner a high level of abstraction. In the lessons that deal with atomic theory and molecular structure, the pupil is required to develop a mental construct of the atom and the molecule by means of symbols. The relationships between the symbol and the thing it represents are established by analogy. Once the characteristics of the parts are identified, the child is required to establish the relationship between the parts which form the atom and the molecule. In addition the child is asked to apply theory to explain or predict change.

In the measurement unit measurement is treated as a concept as well as an operation. The child is given the opportunity to identify the elements which are common to all measurement and to apply the concept of measurement to a variety of measuring operations.

The sequence and mathematical abstraction units ask the child to perform operations which are based on the abstraction of generalizations from a body of data and to apply the generalization by extrapolating or predicting.

In the section below is presented a representative list of the concepts treated in the experimental units and activities which required higher thought process for successful completion.

ATOMS

Concept	Activities Involving Higher Thought Processes
The smallest part a whole can normally be divided into is an atom.	The child takes a whole apart, selects a part, which is then treated as a whole and taken apart. After this process is again repeated, child is asked if the smallest part he sees might be broken down into an even smaller part.
	Child is asked to identify the way in which two lessons which teach a similar concept are alike.
Observations can be made in many ways.	Child is given three samples of unknown liquids and asked to identify the liquids by a variety of observational techniques.
The center of an atom is a place called the nucleus.	The child is given an example of an atom which is constructed incorrectly, asked to identify the error and to correct it.
An electron moves around the nucleus of the atom.	Child is shown a picture of the Bohr atom model and asked how the model might be improved so it would more closely resemble a real atom.
Objects with the same charge repel.	Child is shown pictures of charged atomic particles and asked how the particles will behave towards one another.
Attraction and Repulsion.	Child is asked to compare the ways in which magnets and atomic particles are similar.
Electrons are held in their orbits by the attraction of unlike charges.	Child is shown a model of an atom, which on spinning throws its electrons to the outer limit of the atom model. Electrons of the model are maintained at this limit by wires. The child is asked what the wires stand for in the real atoms (the attractive force between the positive nucleus and the negative electron.)

All atoms are made from the same kind of parts.	Child is given a variety of objects which represent atom parts (electrons, protons, neutrons). He is to arrange these parts so as to construct models of a number of different atoms.
The atoms of an element are all alike.	Child is provided with pictures which represent atoms. He is to select the pictures which represent elements (all the same kind of atoms).

MOLECULES

Concept	Activities Involving Higher Thought Processes
Symbols are used to represent things.	Child is given several symbols and told to match them with other symbols which stand for the same objects.
Atoms join to form molecules.	Child is given two symbols which stand for atoms and asked to join these two symbols together. Child is then asked to name the new entity.
Atoms form molecules by sharing electrons.	Child is provided with a manipulative model of a molecule. The atoms of the molecule model are joined with other atoms of the model with mechanical snap fasteners. The child is then asked what the snap fasteners represent. (electrons)
A collection of molecules composed of two or more kinds of atoms which are uniform in arrangement is called a compound.	The child is given several groups of atoms, some of which are uniform in arrangement and composition and others which are varied in their arrangement and composition. The child is then asked which groups represent compounds.
The properties of a substance identify the substance.	The child is given a description of the physical characteristics of an object and asked to identify the object.
All samples of identical compounds have the same kind and arrangement of atoms.	Child is given pictures which represent the atomic structure of a variety of substances. He is to identify which substances have identical properties.
Atoms can be arranged in a variety of ways to form different molecules.	Child manipulates symbols for atoms to form molecules. (The symbolic manipulation is followed by a chemical experiment which confirms their symbolic manipulations.)

The combination or separation of atoms and molecules may result in the release of energy.	Child is provided with mechanical models which release energy when they are separated. Child is asked to indicate the similarity between the mechanical models and chemical reactions.
An increase of energy increases the motion of atoms and molecules.	Child is asked to explain evaporation using this concept.

MEASUREMENT

Concept	Activities Involving Higher Thought Processes
The amount of space an object occupies is called its volume.	Child is shown pictures of solids, liquids, and gases and asked to determine if the concept of volume applies to them.
	Child is asked to determine why water from one container will not fill another container of exactly the same size which contains some marbles.
	Child is asked to determine volume of air in a sealed bottle which has water, air, and marbles in it and compare the volume of air with that of the water and marbles.
The amount of space an object takes up is independent of its orientation.	Child is asked to determine if the volume of a set of blocks in a given position changes as the position of the blocks is changed.
An object displaces a volume of liquid equal to its own volume.	Child makes a measuring cup using a given cube as a standard. Uses cup to discover that differently shaped solids can have the same volume. Uses cup to measure volume of an irregularly shaped object.
A unit of measure can be any convenient and appropriate object.	Child is asked to use three different objects as a unit of measure, and asked to decide if other objects might be used.
Area and shape are separate	Child is given four square regions to manipulate and asked to determine if the different resultant shapes have the same area.

The most important characteristic of a standard unit is its constancy.	The child is asked to decide what is most important about an inch.
A standard unit is a convenience and a convention.	Child, having measured in various sized units, is asked to evaluate their convenience.
The greater the mass of the nucleus of an atom, the greater is the gravitational attraction.	Child is shown pictures of groups of atoms and is asked to identify which would weigh most.
The standard units of measurement need to be kept at a constant temperature.	Child is asked to identify from several alternatives what would happen if the standard units were kept at varying degrees of temperature.

MATHEMATICS

Concept	Activities Involving Higher Thought Processes
Sequences have a first term but no last term.	Child is given a pattern and asked to decide if it can be extended indefinitely.
A sequence of figures may be an alternating sequence if a property of the figures alternates.	Child is given a pattern and asked to extend the sequence. Child is asked to abstract and state the quality which alternates in the sequence.
In periodic sequences all the terms repeat in a predictable fashion.	Child is shown a period sequence and asked to choose an appropriate set of symbols from several to continue the sequence.
A sequence can be based on the quality of <u>increasing</u>.	Child is asked to abstract and state the quality of <u>increasing</u> from a sequence of figures.
Sequences may have terms that change in a predictable pattern but are not necessarily periodic sequences.	Child is asked to abstract and state the quality of motion from a sequence of figures.

Figures are alike if there is at least one property in common.	The child is asked to identify figures which are not identical but have at least one property in common. The child is asked to describe the property which is common to the figures he chose.
Figures are alike if there is at least one property in common, and they are still alike if they have more than one common property.	The child is asked to indicate that figures may be alike in more than one way by connecting lines between appropriate figures and by verbalizing the concept.
Identical figures are alike in every way. Identical figures are also like figures because they are alike in at least one way. However, figures that are alike in at least one way are not necessarily identical.	Child is given a group of sets of identical figures and is asked to match them in terms of like figures. Later the child is asked to identify their identical likeness.
Rectilinear figures are figures that are entirely made up of straight line segments. Curvilinear figures are figures that are entirely made up of curved lines.	The child is asked to pick one figure from several on the basis of its non-rectilinearity. Child then explains why the rectilinear figures are alike. After abstracting the idea of rectilinearity from the figures, the child is told that mathematicians call figures made of straight line segments, rectilinear.
Figures can be classified according to the number of lines that compose them.	Child is asked to choose from a set of figures one that is unlike the others. The basis for choice is number of lines in the figure. Child is asked to explain his basis for choice.
Figures can be classified according to the number of angles they contain.	Child is asked to choose from a set of figures one that is unlike the others. The basis for choice is number of angles. Child is asked to explain his basis for choice.
Figures can be classified according to length of lines.	Child is asked to choose from a set of figures one that is different. Basis for choice is length of lines. Child is asked to explain his criterion for choice.
Figures can be classified according to whether they are closed or open.	Child is asked to choose from a set of figures one that is different. Basis for choice is open (or closed) figure. Child is asked to explain basis for his choice.

CHAPTER IV

EVALUATION

Introduction

The teaching materials that were developed for this program represent a fundamental departure from typical first grade instructional procedures in science, measurement, and mathematics, both with respect to the goals of the instruction and the means chosen to achieve these goals. It was essential from the beginning, therefore, to include in the project provisions for gathering information to determine the effectiveness of the special instructional material.

The evaluation activities were concerned with providing information pertinent to three principal questions. First, did the instructional material produced in the project enhance the learning of scientific concepts considered to be fundamental to further study of science? Second, were the cognitive objectives achieved with minimal inter-classroom variations? Third, were the cognitive objectives achieved with minimal undesirable incidental effects?

The primary source of information about the attainment of cognitive objectives was a series of paper and pencil achievement tests constructed specifically for the project. Information about variations in classroom procedure and incidental side effects was obtained from teacher evaluation sheets included as part of the evaluation package for the units in mathematics, atomic structure, and measurement. Additional information was obtained from an extensive questionnaire completed by participating teachers during the course of two consultation meetings held near the end of the complete program of instruction and questionnaires mailed to parents after completion of instruction. Samples of these measuring devices are found in Appendix E.

Design of Achievement Tests

The first problem in the construction of the achievement tests was the specification of a universe of terminal behavior of which a test could be considered a sample. Except for the two mathematics units, the universes of terminal behavior for all units were described through the use of a two-way classification with content as one mode of classification and cognitive operations as the other. The two mathematics units were considered to involve a single common cognitive operation, abstraction.

Abstraction was operationally defined as identifying an object in a set of alternatives which has a single property held in common with a given set of objects. In the second unit, the terminal behavior was identifying elements from a set of alternatives which continued a sequence. It was assumed in the first mathematics unit that identifying an object with one property in common with a given set of objects involved perception and identification of a property held in common by the given set of objects. It was not required that the students name that property. For the second mathematics unit it was presumed that completing or adding to a sequence required perceiving and identifying the basis for the sequence. In the unit involving abstraction from a set of figures, the test was constructed to sample a variety of properties which could be abstracted: curvilinearity vs. rectilinearity, openness vs. closedness, number of angles in figures in the set, number of lines in figures in the set, and number of objects in a sub set of the given set. In the second mathematics unit in which the property to be abstracted formed the basis for a sequence, the test items sample two principal categories of sequences: monotonic and periodic sequences. The number of items in the tests was proportional to the relative lengths of the two units.

For the other units, a two-way classification was used. For the unit on atoms one mode of classification was content subdivided into three conceptual categories; cognitive operations were the other mode of classification. The first content category included concepts concerned with the divisibility of matter into components. The second content category was concerned with concepts of the structure of matter, and the structure of atoms, and with manifestations of energy associated with the structure of atoms. The third content category was concerned with concepts about models and symbols. The cognitive operations mode of classification consisted of categories of cognitive operations following the classification scheme of the Taxonomy of Educational Objectives: Cognitive Domain (Bloom, 1956). In this mode of classification seven categories were used: four from the principal classification of knowledge, two from the principal classification of comprehension, and one from the principal classification of application. The four knowledge categories were knowledge of specifics, i. e., recalling specific and isolable bits of information; knowledge of conventions, identifying as conventions characteristic ways of treating and presenting ideas; knowledge of methodology, recall of ideas about methods of inquiry in science; and knowledge of principles and generalizations. The two comprehension categories were translations, i. e., recognizing appropriate information in two forms of communication; and extrapolation, i. e., recognizing implications of specific knowledge and generalizations.

Application involved recognition of specific applications of abstract principles.

In the unit on molecules, the cognitive operations mode of classification was divided into categories which identified the logical form of statements keyed as correct responses to items. The set of categories was part of a set used by Smith and Meux (1962) to classify units of classroom discourse. The logical categories used in this mode of classification were describing, designating, classifying, comparing and contrasting, explaining, and conditional inferring. Test items in the describing category required recognition of an adequate and relevant description of an event or class of events. Test items in the designating category required recognition of statements that assigned a proper name to an object, category of objects, event, or category of events. Test items in the classifying category involved recognition of the class or category into which some object or event should appropriately be placed. Test items in the comparing and contrasting category involved recognition of similar and distinguishing properties of objects and events assigned to different categories. Test items in the explaining category involved recognition of a sufficient explanation for the reason of occurrence of some phenomena or class of phenomenon. Conditional inferring involved recognition of consequences of assumption of the truth of some statement.

The categories in the content mode of classification of the unit on molecules were the same as those used in the unit on atoms.

In the unit on measurement, the Taxonomy of Educational Objectives was again used as the source of categories. In this instance, however, only three categories were used. These categories were not further subdivided. The three categories in the cognitive operations mode of classification for the unit on measurement were knowledge, comprehension, and application. In the content mode of classification, a total of ten categories composed of sets of concepts concerned with the nature of volume, the nature of area, the nature of length, the underlying basis of temperature, gravity, and the underlying basis for weight measurement were used.

In those tests in which items were constructed in the framework of a two-way classification, each joint occurrence of a content and operations category constituted a subuniverse. The definition of the universe for the atoms unit included twenty-one subuniverses; the universe of terminal behaviors for the molecules unit included eighteen subuniverses; and the universe of terminal behaviors for the unit on measurement included thirty subuniverses. The judgment of project staff members concerned with the writing of the instructional material was relied upon to determine an appropriate sampling of these subuniverses. In the case of the atoms unit, sixteen of the twenty-one subuniverses were used; in the case of the unit on molecules, fifteen of the subuniverses were used; and in the case of the measurement unit, all thirty subuniverses were used. The judgment of those on the project staff concerned with construction of the lessons was also relied upon to determine whether or not the subuniverses should be differentially weighted. On the basis of their judgment, all the appropriate subuniverses were given equal weight. For each subuniverse for the units on atoms and molecules two items were written. In measurement, in each subuniverse only one item was included.

The items in the achievement test were presented in a multiple choice format. For each item four response options were offered as well as an "I don't know" response option for those students who were unable to select an appropriate correct response. Such a procedure is considered to improve the validity of multiple choice type tests. Although the content of the units was at a rather high level of complexity as compared to typical first grade materials, no corresponding elevation of reading ability could be assumed. Consequently, the response options were presented pictorially on individual answer sheets for each item. Item stems and descriptions of response options were then read to students.

Item Selection

For each of the universes of terminal behavior described in the previous section a pool of items considerably larger than that to be used in the final test was prepared. As a means of selecting items for inclusion in the final test, items in the item pool were administered to students in two classes at the Metcalf Laboratory School. One of the classes is a second grade class of gifted children used previously as the control group in an earlier phase of the project. The other class is a heterogeneous first grade class at the Metcalf School. The items in the item pool were administered and scored by a member of the project staff. Two criteria were used to select items for inclusion in the final test: a criterion of item difficulty, and a criterion of item discrimination. The item difficulty indices permitted the appearance of a wide range of individual differences in achievement test performance. Item discrimination indices were expected to enhance the internal consistency of the tests.

Design of Questionnaires and Evaluation Sheets

In an attempt to identify classroom variations in presentation of instruction as well as the extent and kind of incidental effects of instruction, questionnaires were supplied with the evaluation packages. Rather than depend on the uncertain reliability of teacher judgment about processes inferred from student behavior, evaluation sheets were designed so that effects of instruction could be identified in terms of objectively observable overt behavior on the part of students. The possibility of judgment errors and rating biases dictated the use of categorical rather than scaled responses. Additional information was obtained about specific categories of teacher involvement by means of questionnaires. In addition, estimates of teacher attitude toward their gifted students and various elements of the instruction were obtained by the use of sentence completion items. Further information about both cognitive and emotional consequences of the instruction was obtained from questionnaires issued to parents of children involved in the project. Generally speaking, more freedom of response was permitted in these questionnaires than in the teacher questionnaires, except for those parts of the questionnaire concerned with the identification of biographical information about the parents, the extent of their knowledge about the project, and the source of their knowledge about the project.

Collection of Data

For purposes of systematizing the gathering and analysis of data, evaluation activities were considered as an experiment testing the hypothesis that scores on tests given at the completion of instruction represented the effects of the special instruction.

Protection against alternative explanations of terminal test performance was provided by a quasi-experimental design--the non-equivalent control group design (Campbell and Stanley, 1963). This design provides protection against external influences, selective differences in ability and the effects of repeated testing as explanations of terminal test performance. The schematic diagram below describes the treatment-testing sequence prescribed in the design.

$$\begin{array}{cccc} E & O_1 & X & O_2 \\ \hdashline C & O_1 & & O_2 \end{array}$$

In this diagram O_1 represents test scores obtained prior to instruction, X represents the treatment, and O_2 represents testing after instruction. E and C designate experimental and control groups. The dashed line between the two groups indicates that assignment of individuals to the two groups was not random. Assignment of intact classroom groups was random. Because it was impossible to exclude any of the selected group from instruction for reasons external to the central purpose of the project, this design was modified as follows:

$$\begin{array}{cccccc} A & O_1 & X & O_2 & & O_3 \\ \hdashline B & O_1 & & O_2 & X & O_3 \end{array}$$

The modification produces no change in protection against alternative plausible hypotheses but allows treatment to be applied in both groups. A third test provides a basis for pooling post-treatment scores. Because all pupils receive treatment in the modified design, the groups are designated A and B instead of experimental group and control group. The interval between tests was approximately four weeks. For this design and for the kind of controls desired, the indicated statistical procedure is analysis of covariance; that is, comparison of mean scores between group A and group B on test 2 adjusted for intergroup differences in mean score on test 1.

Pupil responses to the terminal tests were entered on log sheets and verified independently. These responses were then transferred to punched cards and the items were scored on an IBM 1620 data processing system. A program was written to provide test scores, item analysis data, and reliability estimates of the tests as well as means and standard deviations for all groups. In addition to group means and standard deviations, another program provided distribution statistics of total scores and subtest scores defined in terms of subtests of categories of both content and cognitive operation. With the use of these summary statistics, it was possible to construct frequency distributions for total test scores and all subtest scores. Other statistical analyses were performed using standard statistical programs.

CHAPTER V

ANALYSIS OF DATA

Introduction

Three forms of analysis produced the results reported in this chapter: first, statistical analysis of test scores; second, enumeration of categorical responses to a teacher questionnaire; third, content analysis of free responses and enumeration of categorical responses to a parent questionnaire. The statistical analysis was directed toward measurement of gains attributable to the use of the experimental materials. The analysis of categorical responses in the teacher questionnaire was directed toward the identification of variations in classroom practices in the use of experimental materials. The analysis of responses of parents was concerned with identification of parents' and children's attitudes toward use of project materials and evidence of out of school thinking or application of topics covered in the experimental units.

Evaluation of Overall Gains

Summary statistics describing test performance for pooled groups before and after treatment are presented in Tables 5.1 to 5.5. These statistics include means, standard deviations, and reliability estimates from post-treatment. In these tables, differences in the number of test scores between pre-treatment and post-treatment tests represent unreported data rather than attrition. Reliability estimates were computed using Kuder-Richardson Formula 20. No inferences can be made about the principal effects of treatment on the basis of these statistics, but they provide descriptive information useful in interpretation of statistical inferences.

TABLE 5.1

SUMMARY STATISTICS FOR MATHEMATICS UNIT I
30 ITEMS

Status	N	Mean	Standard Deviation	Reliability
Post-treatment	95	14.50	5.30	.8056
Pre-treatment	108	11.90	4.17	-----

TABLE 5.2

SUMMARY STATISTICS FOR MATHEMATICS UNIT II
20 ITEMS

Status	N	Mean	Standard Deviation	Reliability
Post-treatment	98	8.76	5.08	.8680
Pre-treatment	109	6.89	4.95	-----

TABLE 5.3

SUMMARY STATISTICS FOR SCIENCE UNIT I (ATOMS)
32 ITEMS

Status	N	Mean	Standard Deviation	Reliability
Post-treatment	95	13.08	5.60	.8175
Pre-treatment	91	6.30	3.48	-----

TABLE 5.4

SUMMARY STATISTICS FOR SCIENCE UNIT II (MOLECULES)
30 ITEMS

Status	N	Mean	Standard Deviation	Reliability
Post-treatment	94	10.29	4.47	.7423
Pre-treatment	97	6.71	3.55	-----

TABLE 5.5
SUMMARY STATISTICS FOR MEASUREMENT UNIT
30 ITEMS

Status	N	Mean	Standard Deviation	Reliability
Post-treatment	89	13.30	4.08	.7160
Pre-treatment	86	10.64	4.00	-----

For four of the five instructional units prepared for use in the schools of Bloomington and McLean County Unit 5, analysis of overall gains took the form of analysis of covariance. The quasi-experimental design described in Chapter IV provided the framework for this analysis. The analysis of covariance compared mean test scores obtained by pupils of group A on Test 2 to the same scores obtained by pupils in group B, with covariance adjustments for differences in mean scores on Test 1 between group A and group B. Test 2 scores were obtained immediately after pupils in group A had used the experimental materials and immediately before pupils in group B had used them. In one of the five units, the Science Unit II, incomplete data dictated comparison of post-treatment means to pre-treatment means by the use of a t test based on repeated measures on the same pupils.

Summaries of the results of analysis of covariance are presented in Tables 5.6 - 5.9. The F-ratios reported at the ends of these tables were obtained by comparing the variances of distributions of group means about regression lines with common slopes to the variances of distributions of individual scores about the same regression lines. The values of F for three of the four units were significant at the five percent level or better: Mathematics Unit I, Science Unit I, and the unit on Measurement.

TABLE 5.6

SUMMARY OF ANALYSIS OF COVARIANCE
MATHEMATICS UNIT I N = 106

Source of Variance	Degrees of Freedom	Sum of Squared Deviations
Group regression coefficients about common slope	1	87.6916
Scores about group regression lines	102	1711.3529
Scores about regression lines with common slope b_w	103	1799.0445
Group means about regression line with common slope b_w	1	110.0412
Scores about regression line for combined groups	104	1909.0857

$F(1,103) = 6.30$

TABLE 5.7

SUMMARY OF ANALYSIS OF COVARIANCE
MATHEMATICS UNIT II N = 97

Source of Variance	Degrees of Freedom	Sum of Squared Deviations
Group regression coefficients about common slope	1	68.6499
Scores about group regression lines	93	1896.4830
Scores about regression lines with common slope b_w	94	1965.1329
Group means about regression line with common slope b_w	1	47.3734
Scores about regression line for combined groups	95	2012.5063
F(1,94) = 2.26		

TABLE 5.8

SUMMARY OF ANALYSIS OF COVARIANCE
SCIENCE UNIT I (ATOMS) N = 88

Source of Variance	Degrees of Freedom	Sum of Squared Deviations
Group regression coefficients about common regression slope	1	353.8648
Scores about group regression lines	84	1529.5336
Scores about regression lines with common slope b_w	85	1883.3984
Group means about regression line with common slope b_w	1	385.5368
Scores about regression line for combined groups	86	2268.9352
F(1,85) = 17.39		

TABLE 5.9

SUMMARY OF ANALYSIS OF COVARIANCE
MEASUREMENT UNIT N = 86

Source of Variance	Degrees of Freedom	Sum of Squared Deviations
Group regression coefficients about common regression slope	1	.1095
Scores about group regression lines	82	1214.4609
Scores about regression lines with common slope b_w	83	1214.5704
Group means about regression line with slope b_w	1	122.5277
Scores about regression line for combined groups	84	1337.0981

$F(1,83) = 8.37$

An underlying assumption of the analysis of covariance is that regression lines describing the relationship between predictor and criterion variables (Test 1 and Test 2) in the separate groups are parallel. To sustain this assumption, the variance of the distribution of group regression coefficients about common regression slopes is compared to the variance of the distribution of individual scores about group regression lines. For the Mathematics Unit I and Science Unit I the obtained F-ratios were 5.12 and 19.43 respectively. These values of F are significant at the five percent level or better, indicating that much of the difference in Test 2 scores between the two groups is due to differences in variance between pre-treatment scores and post-treatment scores . This conclusion is verified by referring to Tables 5.1 and 5.3.

When regression lines for separate groups are not parallel, the Neyman-Johnson technique provides a means of determining those values of the predictor variable (Test 1) for which there are significant differences in the criterion variable (Test 2) (Walker & Lev, 1953). The results of this analysis indicated that on Mathematics Unit I, there were no values of the predictor variable for which there were significant differences between groups in the criterion variable. For Science Unit I, the analysis indicated significant differences favoring group A for Test 1 scores higher than 11.

As part of the analysis of data, frequency distributions of pre-treatment and post-treatment scores were also obtained. These distributions are presented as percent frequency distributions in Tables 5.10 - 5.12. In these tables each x represents one percent of the total sample receiving scores in the indicated ranges on pre-treatment tests. Each o represents one percent of the total sample receiving scores in the indicated frequencies on post-treatment tests. Inspection of these frequency distributions suggested that changes due to treatment may have had the effect of changing the shape of the score distribution rather than significant shifting of mean scores. Further analysis was performed to test the hypotheses that the shapes of the distributions of Test 1 scores for groups A and B were the same and that the shapes of the distributions of Test 2 scores for groups A and B were different.

TABLE 5.10

PRE- AND POST-TREATMENT FREQUENCY DISTRIBUTIONS
MATHEMATICS UNIT I
30 ITEMS

24-26	
21-23	ooooooooooo xxx
18-20	oooooooooooooooooooooooo xxxxxxxx
15-17	oooooooooooooooooooooo xxxxxxxxxxxxxxxx
12-14	ooooooooooooooo xxxxxxxxxxxxxxxxxxxxxxxx
9-11	oooooooooooo xxxxxxxxxxxxxxxxxxxxxxxxxxxxx
6-8	oooooooooooo xxxxxxxxxxxxxx
3-5	oooo xxxxx
0-2	o x

TABLE 5.11

PRE- AND POST-TREATMENT FREQUENCY DISTRIBUTIONS
MATHEMATICS UNIT II
20 ITEMS

18-20	o xx
15-17	oooooooooooooo xxxxxx
12-14	oooooooooooooooooooooooo xxxxxxxxxxxx
9-11	ooooooooo xxxxxxxxxxxxxxxxx
6-8	ooooooooooooooooo xxxxxxxxxxxxxxxxxxx
3-5	ooooooooooooooooooo xxxxxxxxxxxxxxxxxxxxxx
0-2	oooooooooooooo xxxxxxxxxxxxxxxxxxxxxxx

TABLE 5.12

PRE- AND POST-TREATMENT FREQUENCY DISTRIBUTION
SCIENCE UNIT I (ATOMS)
32 ITEMS

24-26	ooooooo
21-23	oo
18-20	oooooooooooooooo x
15-17	ooooooooooo
12-14	oooooooooooooooooo xxxx
9-11	ooooooooooooooooooooooo xxxxxxxxxxxxxxxxxxxxx
6-8	oooooooooooooooooo xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
3-5	ooooo xxxxxxxxxxxxxxxxxxxxxxxxx
0-2	xxxxxxxxxxxxxxxx

The Kolmogorov-Smirnov test provides a means of comparing two score distributions when other characteristics than the mean are of interest (Siegel, 1956). The test is available as either a one-tailed or a two-tailed test. The two-tailed test is sensitive to any kind of difference in the distributions from which two samples are drawn--differences in mean, variance, or skewness. The one-tailed test is used to decide whether or not the scores of one group are "better" than the scores of the other. To apply the Kolmogorov-Smirnov test, a cumulative frequency distribution is constructed for each sample of observations, using the same intervals for both distributions. For each interval, one step function is subtracted from the other. The test then focuses on the largest of the observed deviations, symbolized by D.

In this instance, separate distributions were constructed comparing group A performance to group B performance on Test 1 and group A performance to group B performance on Test 2. The test was used for those units for which the analysis of covariance produced non-significant or equivocal results; that is, the two mathematics units and Science Unit I. The two-tailed test was used to identify any differences between group A and group B on Test 1. The one-tailed test was used to identify differences between group A and group B on Test 2. Critical values of D for the conditions existing in the field test are given by Siegel. For the one-tailed test, values of D are converted to values of chi-square with two degrees of freedom, which are then referred to a table of critical values of chi-square. This procedure retains the quality of control provided by analysis of covariance.

From the Kolmogorov-Smirnov two-tailed test, it was apparent that there was no difference between group A and group B score distributions on Test 1 of Mathematics Unit I, Mathematics Unit II, or Science Unit I. Consequently, any differences between the groups on Test 2 can be attributed to treatment. The value of chi-square for the one-tailed test on Mathematics Unit I was 2.42, a non-significant value. For Mathematics Unit II, the obtained value of chi-square was .38, also non-significant. For Science Unit I, the obtained value of chi-square was 4.36. With two degrees of freedom, the probability of random occurrence of a value of chi-square that large is less than .001. Hence, for Science Unit I, although the results of analysis of covariance were equivocal, the Kolmogorov-Smirnov suggests that the use of experimental materials produced significant changes in score distribution.

In the unit on molecules, because appropriate data were not available for analysis of covariance or analysis of variance, assessment of gain was made by use of a correlated t test between pre-treatment scores and post-treatment scores for the pooled groups. The mean difference between pre-treatment and post-treatment scores was 3.527. The corresponding value of t with 90 degrees of freedom was 8.324. The probability of a random occurrence value of t this large is less than .001. Consequently, differences between post-treatment scores and pre-treatment can be attributed to the treatment.

Teacher Treatment of Experimental Materials

An attempt was made to collect data which would indicate how teachers treated the experimental materials. Answers to these questions were sought by the project personnel:

1. Were the materials self-instructional?
2. Were all pupils exposed to the same treatment between pre- and posttests?
3. In what ways, if any, did the teacher supplement the instruction provided by the experimental materials?
4. Were portions of the experimental materials incorporated into the regular curriculum?

In the spring of 1964 a questionnaire designed to elicit data on teacher treatment of the experimental materials was sent to the nineteen teachers in the project (two of the original twenty-one teachers had withdrawn--one for reason of health, the other for administrative reasons). Returns were made by seventeen teachers. The questions asked and teacher responses are listed in Table 5.13.

TABLE 5.13

TEACHER RESPONSES TO QUESTIONS ABOUT
TREATMENT OF EXPERIMENTAL MATERIALS
N=19

QUESTIONS	RESPONSES		
	ATOMS	MOLECULES	MEASUREMENT
1. What action did you take when tapes and/or instructions were inadequate?			
A. No assistance	5	6	6
B. Assist at specific points	9	9	6
C. Read text to group	4	4	4
D. Read text to individuals	5	5	3
E. Other	2	2	2
2. To what extent was the content of the experimental material extended beyond the standard taped instruction?			
A. No extension	10	11	10
B. Encouraged projects	4	2	3
C. Students reported to class	4	4	6
D. Project materials taught to entire class	7	1	2
E. Other	3	1	2
3. What review procedures did you follow to help establish concepts included in the experimental lessons?			
A. None	7	10	10
B. Activities explained	7	4	5
C. Review after each lesson	6	5	5
D. Review at end of unit	9	7	8
E. Other	0	0	0
4. What procedures did you use to evaluate the learning progress of students?			
A. Checked for completion	12	13	13
B. Checked booklet	9	9	8
C. Questioned students	12	10	10
D. Checked tape quality	2	2	2
E. Other	0	0	0
5. What use did you make of the teaching materials?			
A. Read teacher's manual	17	16	17
B. Listened to tapes	11	10	9
C. Tried activities	5	4	3
D. Consulted references	4	3	4
E. Other	0	0	0

The role of the teacher is of particular concern because of technical failures in tapes and recorders which are known to have occurred during the critical treatment phase of the project. All tapes and recorders were checked before shipment to the experimental classes. However, after the tapes were in the classrooms where they were interchanged between recorders, it was discovered that some tapes played well with only a particular recorder. Under these circumstances, it was possible for a child to get a tape which was difficult to hear or understand, and in some few cases, unintelligible.

This unanticipated technical difficulty created a situation which placed the teacher in a critical role. On the one hand, if the teacher assumed the attitude that the materials were supposed to be completely self-instructional and did nothing to correct technical failures in the tapes or recorders, pupils would not be fully exposed to the experimental treatment as assumed in the experimental design. At the other extreme, some teachers might have disregarded the self-instructional format completely and personally taught the experimental material. Should this have happened, a teacher variable would have been introduced which would have made any conclusions questionable. Another alternative role would be for the teacher to read the script to the pupil(s) who had difficulty understanding a poor tape. In this case the material could still be considered self-instructional because the teacher was merely assuming the function of the tape recorder. In addition a teacher might explain, review, and/or summarize the lessons.

Teacher responses to questions one, two, and three suggest that the materials were used in an essentially self-instructional pattern. The majority of the teachers did not attempt to extend the project materials beyond the taped instructions. For Science Unit II (Molecules) and the Measurement Unit, ten of the seventeen teachers felt the units to be self-sufficient. The Science Unit I (Atoms), which was the first of the self-instructional units, was viewed as self-sufficient by seven teachers. Those teachers who attempted to help their students evidently limited their activities to supervising and explaining the use of illustrative materials, and reviewing and summarizing the concepts included in the lessons. From an analysis of the responses made on the questionnaire and in written progress reports, as well as responses of teachers in personal interviews, it can be concluded that no teacher in the project assumed primary responsibility for teaching the experimental units.

Were all pupils exposed to the same treatment between pre- and post-tests? The answer is a qualified "no." The responses to question 1-A indicate that at least five teachers did nothing to correct deficiencies in the tapes. For the Science Unit II (Molecules) and the Measurement Unit, at least six teachers offered no help in case of technical difficulty with tapes or recorders. If the teacher did not take the initiative to spot defective tapes and recorders, there was no way for project personnel to correct the deficiency. Thus it should be assumed that in at least five classrooms some children missed all or portions of one or more lessons.

In addition to exposure to differences in tape quality and use, pupils received varying degrees and types of supplemental instruction from their teachers.

In what ways, if any, did the teacher supplement the instruction provided by the experimental materials? Relatively few teachers reported that they encouraged study in related topics: four teachers did so in the Science Unit I (Atoms), two in Science Unit II (Molecules), and three in Measurement. Only one teacher used group discussion as a supplementary teaching activity. A few checked students' booklets for appropriate responses; seven teachers in Science Unit I (Atoms), four in Science Unit II (Molecules), and five in Measurement. The same number of teachers in each unit supervised and explained activity portions of the experimental lessons.

Reviewing the material was by far the most common supplemental activity used by the teachers. Twelve teachers reviewed either individual lessons or the total unit with their pupils for Science Unit I (Atoms); ten teachers did this for the other two units. Actually three teachers in Science Unit I (Atoms) and Measurement (and two in Science Unit II (Molecules)) chose to review both after each lesson and after the unit was completed.

Were portions of the experimental materials used in instruction of the entire class? Almost half the teachers chose to share some of the experimental materials with their entire class. In the Science Unit I (Atoms), nine teachers either encouraged pupils who were in the project to report their learnings to the class or actually taught some of the contents of the experimental lessons themselves. For Science Unit II (Molecules), five teachers employed these procedures, and for the Measurement Unit the number of teachers was seven.

Teacher cooperation

Special comment should be made of the high level of cooperation received by the project from the participating teachers. Although they were not specifically requested to do so, a substantial majority of the teachers took time to determine whether their students had finished the taped lessons and completed the required activities, and most of them went on to check the booklets to determine whether students had made correct responses to the questions. All the teachers reported that they read the teacher's manual, and a large majority listened to some of the tapes prior to use by their students.

Teacher comments in personal interviews revealed considerable interest in the illustrative materials and a desire to experiment with them in instructing non-gifted children.

Informal interviews with teachers corroborated the responses made by teachers in the questionnaire. In the interviews an attempt was made to discover if there were any significant activities which might come under the category "other" which were not reported in the questionnaire. No significant activities were identified.

Pupil and parent reactions to project material

After all children in the project had completed use of the experimental materials, an attempt was made to collect data by means of a questionnaire sent to all parents which might answer the following questions:

1. Did children in the project react negatively to the experimental materials?
2. Did children give evidence out of school of thinking about topics covered in the experimental materials?
3. How did parents react to their children's use of project materials?

A summary of results of the questionnaire sent to parents is listed in Table 5.14.

TABLE 5.14

SUMMARY OF RESULTS OF PARENT QUESTIONNAIRE

QUESTION	RESPONSE
Total questionnaires delivered	89
Total questionnaires returned	79
Parents unaware their child was using project materials	0
Felt their child did not care for project materials	8
Child asked parent to tell teacher of dislike for materials	4
Child asked for books related to topics in project	22
Parents making written comments *	51
Written comments which were favorable	42
Written comments which were unfavorable **	9

* The comments were made in response to the following statement on the questionnaire: "Use the space on the back for a description of anything your child seemed to learn by using these special materials or any examples of the application of what was learned."

** Five of these concerned one classroom situation.

Did children in the project react negatively to the experimental materials? As measured by parent's perception, the answer is no. Only eight parents reported that their child did not care for the experimental materials. Most parents who wrote comments indicated a high level of interest among their children for the project materials. The following sample comments are typical of the majority of the responses:

> "L-- thoroughly enjoyed the special program. She talked much more about this work than the regular curriculum."
>
> "M-- was very intrigued by the recorder and wanted one of his own thinking that one from a store would come equipped with the same material he was studying."

"He was sorry the project ended."

Did children give evidence out of school of thinking about topics covered in the experimental materials? There is evidence that at least fifty-one of the eighty-nine pupils convinced their parents that they were thinking about topics covered in the project. A sample of parents' comments follows:

> "My child wanted me to get some books for him on one or more of these subjects. ... Subsequently, at intervals, he would volunteer information about such things as molecular composition and seemed interested when we added such facts as molecular weight ... ."
>
> "New words have appeared in her vocabulary that upon questioning I found they were in the special materials."
>
> "Our child ... was stimulated to look up information in the encyclopedias he has here at home.
>
> "S-- and her brother were having an argument about who had the largest glass. Steve's was taller but S-- told him hers could hold just as much because hers was bigger around so they emptied them both and she did show him that hers held more."
>
> "He explained how rubber got on the track at Indianapolis Speedway. Rubber molecules came off on the track faster as the tires got hotter."

How did parents react to their children's use of project materials? Of those parents who volunteered information, a substantial majority (82%) reacted very favorably. To be sure, the wording of the statement inviting comments did not encourage negative comments. Nevertheless some negative comments were made; but these cannot be viewed as a measure of the total negative feeling which might have existed. Most of the negative comments stemmed from children's frustration over poor recording quality of the tapes. A typical comment was "If the tapes were clear, everything was fine, but when she couldn't understand them she was upset--extremely so initially."

The majority of the comments, however, indicated a high level of acceptance of project materials by both parents and pupils. Typical of the comments made by parents are the following:

> "We have been literally amazed at the knowledge J-- has gained and hope very much he can continue this work next year."

> "I am glad J-- had a chance to be part of this program, and she enjoyed it too."

> "We feel she learned that math and science can be fun and exciting, not drudgery as so many students consider them."

> "I feel that it broadened his reading knowledge. . . ."

CHAPTER VI

CONCLUSIONS

The experimental work of this project indicates that intellectually gifted first grade pupils can learn content which requires use of cognitive operations typically encountered at more advanced stages of cognitive development, and that they can do so through the use of self-instructional materials which require a minimum of teacher assistance. The learning was accomplished with no sacrifice of technical accuracy of the content and with minimum adjustment in vocabulary. The instruction was presented to nonreaders with no discernible interference with the acquisition of basic skills or adverse emotional effects.

The performance of pupils with the self-instructional materials of the Measurement Unit and Science Unit I (Atoms) confirms the findings made in the exploratory and developmental stages of this project, i. e., that gifted children, when provided with appropriate instructional materials can master intellectual operations which use symbolic representations of concrete experiences to a higher degree than is usually required in the primary grades.

The results of this project strongly suggest that a fruitful means of differentiating the curriculum for gifted children is by means of self-instructional materials which are specifically designed to induce higher thought processes in the user.

These conclusions are based primarily on the performance of pupils in Science Unit I (Atoms) and the Measurement Unit. Gains made from use of Science Unit II (Molecules), while statistically significant, cannot, because of restrictions imposed by the research design, be attributed solely to the use of the experimental materials. Mathematics Units I and II, which were not self-instructional, did not produce statistically significant gains in test performance as assessed by analysis of covariance.

Analysis of results for the Measurement Unit and Science Unit I (Atoms) leads to the conclusion that these units were effective teaching units. Science Unit II (Molecules) appears to be promising, but needs further testing.

Self-instructional Format

The findings of the exploratory and developmental stages with reference to the need and efficacy of self-instructional materials were generally borne out by results of the field trial. Self-instructional modes of instruction are adaptable to the instruction of first grade gifted children. The children in this project were capable of operating a tape recorder and following directions given by means of a recording. In the Measurement Unit and Science Unit I the workbooks and manipulative and illustrative materials held the attention of the users sufficiently to bring about statistically significant gains in learning. The results with Science Unit II (Molecules), while inconclusive, are sufficiently encouraging to warrant further investigation.

The teachers began the use of project material with the Mathematics Unit which involved considerable individual attention with students and teacher application of instructional patterns. While students were furnished worksheets for individual use, teachers were directed to question the student concerning his answers. Teachers in the project were almost unanimous in their opinion that extra work for gifted children could not be introduced into the first grade without serious burden on the teacher, particularly where the number of gifted children ran as high as nine. Even when only one student was involved, the teacher was reluctant to part from her traditional pattern of instruction to use this material individually in the manner prescribed.

Science Unit I was the first self-instructional unit to be used. Instructions, explanations, and questions which would normally be expected to come from the teacher were supplied by a tape recording. Some of the tapes did not give a clear playback. Thus some of the teachers bypassed the tape recorders and read the instructions to the students as they performed the manipulations either as a group or individually. Some teachers apparently preferred this even when tapes were of adequate quality. During Science Unit II some of the technical difficulties were cleared up; however, some tapes were still of poor quality. As stated above, more teachers were willing to rely upon the tape recorders for this unit. In the final unit on Measurement the tape recordings reached their highest technical perfection, although they left much to be desired. As the technical quality of recordings improved, there was an increased willingness of teachers to accept the self-instructional pattern of instruction.

Introduction of Advanced Content

Experience during the field trials leads to the conclusion that the self-instructional format facilitated the introduction of advanced materials. One of the assumptions made during the developmental stage of the project was that the average classroom teacher could not be expected to have mastered the subject matter necessary for teaching certain concepts which their pupils were capable of understanding. This is not to say that teachers were not capable of learning this information. Rather the hypothesis is presented that in addition to special training courses or institutes for teachers, self-instructional materials may be an effective means of gaining acceptance for new curriculum materials. It is significant that as the content of the units became more technical and advanced, teachers were more willing to use the materials in a self-instructional pattern. There is some evidence that the materials were used by some teachers to enrich the regular curriculum in their classes.

Teacher Reaction To Use Of Project Material

Teacher attitudes toward the self-instructional material were ambivalent. On the basis of personal interviews, one can conclude that with few exceptions teachers would welcome materials of this nature. On the other hand, the materials go counter to certain deep-seated practices and attitudes of first grade teachers. Several teachers testified in both questionnaires and personal interviews their concern about the teaching of the concepts involved in the units to first graders. At the end of the project some teachers were still concerned or convinced that the first grade curriculum should be restricted primarily to acquisition of basic skills--particularly in reading; however, no teacher gave any evidence of the interference of these materials to the acquisition of such skills on the part of pupils involved in the project. In fact many said that the tapes led to the learning of words which would not normally be part of first grade vocabulary.

All teachers testified that they felt that some or all of their pupils learned a surprising amount of material from the self-instructional use of project materials. Many expressed deep dissatisfaction with the science curriculum ordinarily furnished for the first grade and were fully convinced that most children in the first grade could probably learn more science than they presently are offered.

The experimental materials were generally well received by both pupils and parents. Only eight instances of negative feelings toward the materials were reported. The comments made by parents indicate a high level of interest in and support for this type of instruction. There is evidence that the materials did have some effect on the children's thinking out of school and that they used some of the concepts in formulating models to explain phenomenon in daily life.

Plans For Further Development

The instructional materials developed in this project require further testing and development. The experience to date indicates that the self-instructional format is basically sound, but needs refinement, especially in the use of tapes and in the format of the tests used in evaluation.

It does not seem practical to use battery-powered recorders in public schools. Much of the trouble with tapes stemmed from the different speeds at which the various tape recorders operated. However, there is no reason to believe that a better quality tape recorder with a constant speed drive could not be used successfully. The most promising, and economical, solution seems to be the use of pliable plastic phonograph records.

The evaluation instruments, while producing reliable data, were difficult to administer. Suggestions from teachers are on hand which indicate how the tests could be improved in format and content.

As can be expected, this project has raised more questions than it has answered. The first question centers around correction of obvious faults. What results could be obtained by replicating the field trial with improved materials: use of records to insure good sound reproduction; use of revised tests; use of revised lessons? The lessons have been revised during the summer (1965) and teacher suggestions for improvement have been included. A number of the lessons have been rewritten to include more activities requiring higher thought processes.

A group of questions is raised by the population. What results could be obtained with pupils selected on multiple criteria, e.g., teacher judgment, reading readiness, science aptitude, maturity, creativity, as well as I. Q.? Are the materials appropriate for use in grades other than the first? What modifications of instruction would be required? Can these materials be used with benefit with a heterogeneous class?

A number of questions are raised by the role of the teacher. Would teachers use materials of this type as a routine procedure, i.e., outside of the context of an "experiment?" What is the effect of materials such as these in changing the teacher's perception of the learning ability of gifted and other children? What effect does working with materials such as these have on the teacher's perception of curriculum for first grade children?

The materials with which to investigate these questions exist in the revised Science Unit I (Atoms), Science Unit II (Molecules), and the Measurement Unit.

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