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ABSTRACT

This illustrated booklet provides a rationale and overview for the twenty-nine coordinated mathematics and science units in the MINNEMAST program for kindergarten through third grade. The rationale for the program cites both the historical association of mathematics and science and pedagogical advantages. The goals of the project are to provide both mathematical and scientific knowledge, and to emphasize the development of tools for learning by emphasizing methods of acquiring knowledge rather than memorization of facts. Eight clusters of threads are woven through the curriculum; three of these are related to processes (observation, generalization, and linking of observations with generalizations), and five to subjects (real numbers, geometry, formal concepts of science, scientific topics, and the links between science and mathematics). This volume presents a chart showing the relationship of these threads to individual units, a statement of skill development goals for each grade level, and brief descriptions of the individual units. (SD)

OVERVIEW

MINNEMAST

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT
UNIVERSITY OF MINNESOTA

MINNEMAST **COORDINATED MATHEMATICS–SCIENCE SERIES**

KINDERGARTEN

1. WATCHING AND WONDERING
2. CURVES AND SHAPES
3. DESCRIBING AND CLASSIFYING
4. USING OUR SENSES
5. INTRODUCING MEASUREMENT
6. NUMERATION
7. INTRODUCING SYMMETRY
8. OBSERVING PROPERTIES

FIRST GRADE

9. NUMBERS AND COUNTING
10. DESCRIBING LOCATIONS
11. INTRODUCING ADDITION AND SUBTRACTION
12. MEASUREMENT WITH REFERENCE UNITS
13. INTERPRETATIONS OF ADDITION AND SUBTRACTION
14. EXPLORING SYMMETRICAL PATTERNS
15. INVESTIGATING SYSTEMS
16. NUMBERS AND MEASURING

SECOND GRADE

17. INTRODUCING MULTIPLICATION AND DIVISION
18. SCALING AND REPRESENTATION
19. COMPARING CHANGES
20. USING LARGER NUMBERS
21. ANGLES AND SPACE
22. PARTS AND PIECES
23. CONDITIONS AFFECTING LIFE
24. CHANGE AND CALCULATIONS
25. MULTIPLICATION AND MOTION
26. WHAT ARE THINGS MADE OF?
27. NUMBERS AND THEIR PROPERTIES
28. MAPPING THE GLOBE

THIRD GRADE

29. NATURAL SYSTEMS

For additional information, a price list and orders, write to:

MINNEMAST Director
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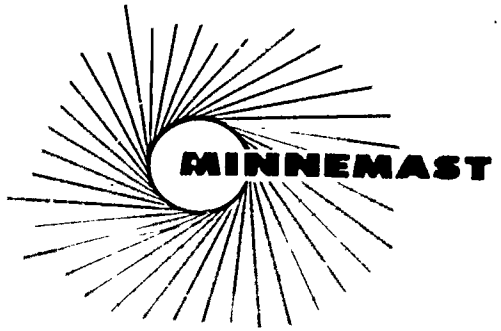
720 Washington Ave. S. E.
Minneapolis, Minnesota 55414

OVERVIEW



Minnesota Mathematics and Science Teaching Project
University of Minnesota Minneapolis, Minnesota

The Minnesota Mathematics and Science Teaching Project developed its materials under a grant from the National Science Foundation.

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MINNEMAST
AT
WORK

MINNEMAST

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT

The first elementary curriculum development project to design a coordinated mathematics and science curriculum for the elementary schools.

WHY a coordinated mathematics and science curriculum?

1 The first reason is purely pedagogical. Teaching mathematics and science together is easier than teaching them separately. It is natural to teach mathematics with applications and illustrations from science, and to teach science when you can make use of its mathematical framework. The description of Newton's law of gravity or of the growth rate of a plant is so simple and precise in mathematical terms, that words seem cumbersome by comparison.

Similarly, the abstract idea of vectors or of the real number system can be made much clearer through physical illustrations from the sciences. This argument, supported by countless examples of the mutual reinforcement of science and mathematics, is most compelling in the classroom, as any teacher will agree. Furthermore, it is very closely related to the second reason, which is of an historical nature.

2 Mathematics and science have relied heavily on each other throughout the course of their common development. The very backbone of much of theoretical science has evolved, in a sense, as a branch of applied mathematics and would not exist today without it.

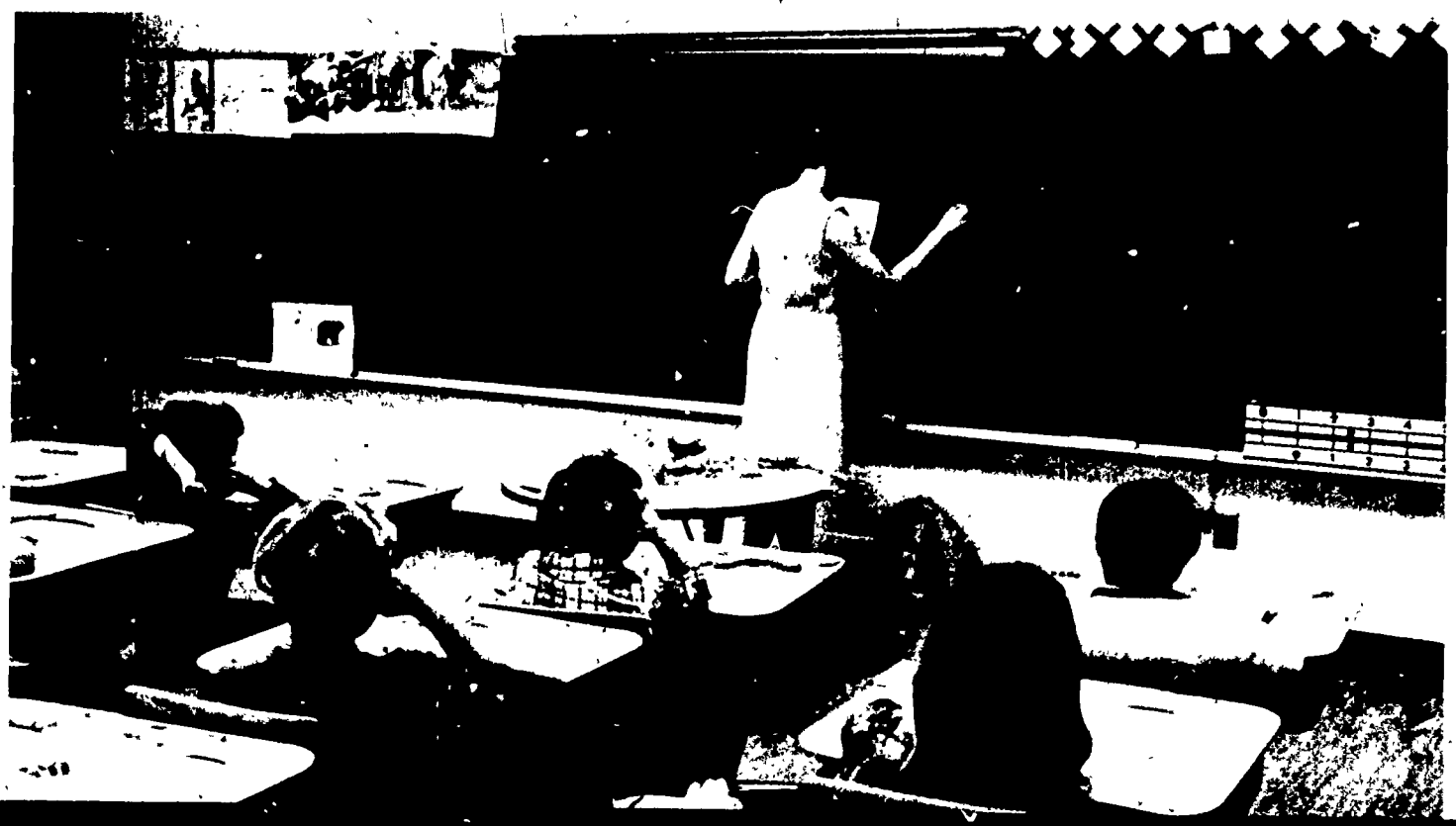
By contrast, the dependence of mathematics on science is not quite so explicit, for mathematics in its purest form is basically independent of science. The impact that science has made on mathematics,

however, is by no means negligible. We know that many branches of mathematics would not be as advanced as they are today were it not for the impetus that has been provided by science.

3 These two reasons in support of a coordinated curriculum -- one pedagogical, the other historical -- in turn suggest a third, which is somewhat philosophical.

This third reason hints at the deeper relationship between the two subjects. It is simply that the boundaries between science and mathematics are not always very well defined. Many aspects of the two disciplines overlap so closely that they are of equal importance to mathematicians and scientists.

It may well be that thinking about math and science as distinct disciplines is not necessarily the most fruitful approach for the mathematician or the scientist, to say nothing of the layman. It seems quite reasonable to avoid making a strong distinction in the mind of a child learning the elements of these subjects. Breaking the bonds that join math and science together, for the purpose of presentation to a child, probably harms that child's appreciation and understanding of both subjects as much as it weakens the creative union between the two.



Because we live in a world which is changing more rapidly than at any previous time in history, it is impossible to predict accurately what it is a child will need to know. It is imperative, then, that we give him the tools for lifelong learning, so that he will be equipped to solve problems as they arise.

IN THIS CHANGING WORLD . . .

In the past, teaching often has concentrated on memorizing facts, very few of which were retained. Our belief is that the students should be trained in the processes of mathematical and scientific thinking.

The processes of science can be classified under the several headings of observation, experimentation, generalization -- though many labels may be used.

The emphasis of this program is to provide children with activities that help them solve problems using both mathematical and scientific techniques. The activities are also designed to encourage recognition of new problems which will require additional experimentation and investigation.

GOALS OF THE COORDINATED PROJECT

MINNEMAST was the first project to work on a coordinated mathematics and science curriculum — a program in which science and mathematics, although sound in themselves, have their interrelationships exploited to the fullest. This was in accord with the recommendations of the Cambridge Conference and of the American Association for the Advancement of Science.

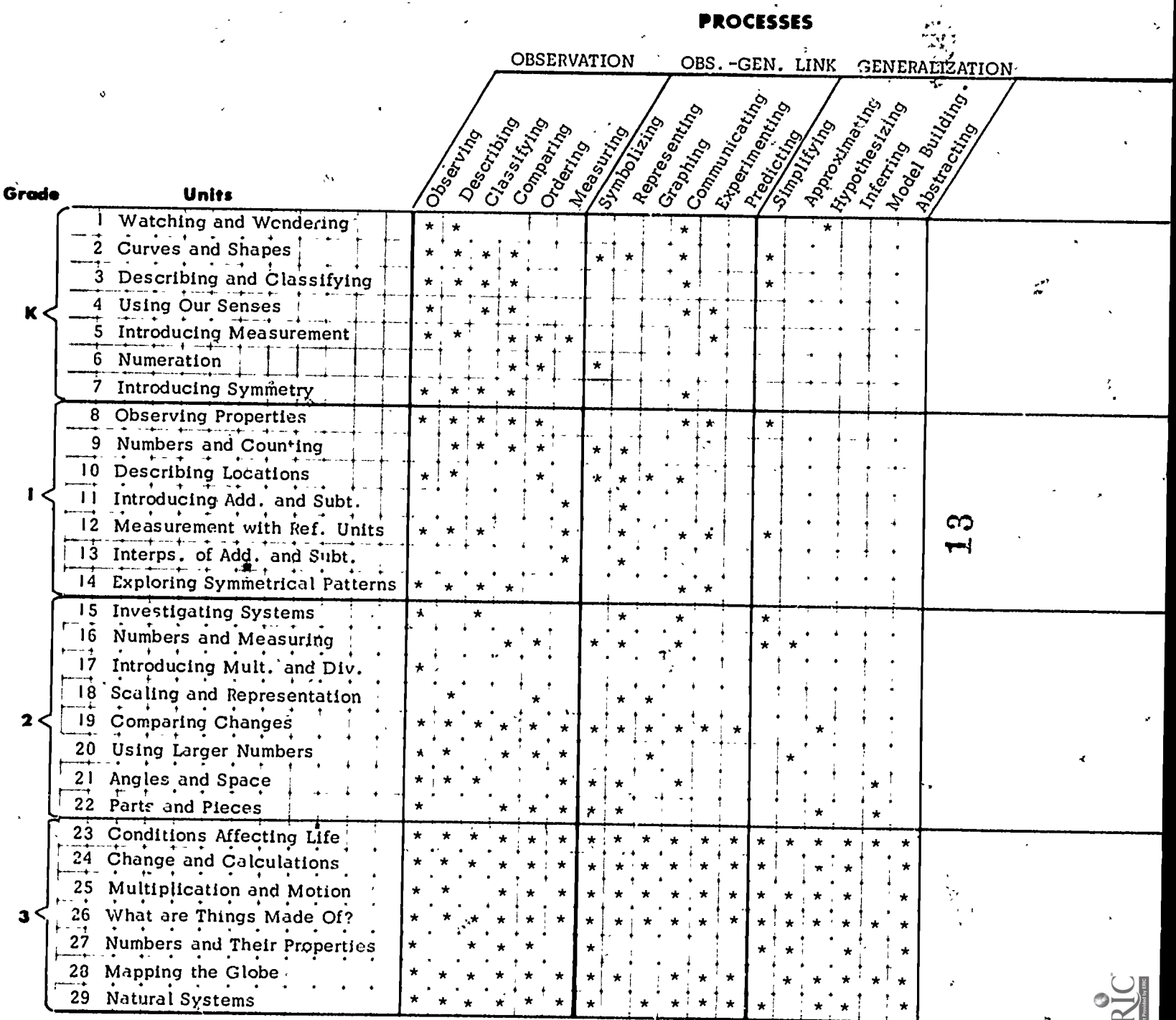
We were, first of all, concerned with mathematics and science. Our primary responsibility was to do justice to both disciplines. We do not mean to imply that mathematics and science are one and the same. Clearly, biology and algebra are separate entities, regardless of any academic connection between them. Curricular integration is a means to improve education, not an end in itself.

To develop the two subjects adequately, while taking every advantage of the many connections between them, requires that we communicate to the children the characteristic spirit of each subject as well as the essential union between them. The perfect synthesis never clouds the nature of its component parts; rather, it makes them clearer and more meaningful.

MINNEMAST materials are oriented toward the child rather than the teacher. Traditional curricula are based on the idea of teaching children what it is felt they will need to know as adults. MINNEMAST aims at teaching the tools for life-long learning by emphasizing methods of acquiring knowledge rather than rote memorization of facts.

MINNEMAST presents mathematics and science in the context of creative learning processes. Children are given the experience of discovering the underlying laws of math and science. The curriculum attempts to lead the children to discover the intrinsic rewards of learning. Children enjoy working with their classmates and teacher in experimenting, predicting, and discovering answers to their questions.

THREADS THAT WEAVE THROUGH THE CURRICULUM



SUBJECTS

MATHEMATICS — Math-Science — SCIENCE

Real Numbers . Geometry — Formal Concepts — Topics

	Number Line	Number Theory	Arithmetic	Continuity	Prob. & Stat.	Sets & Groups	Shapes Config.	Euclidean Geom.	Topology	Symmetry	Dimension	Transformations	Functions	Systems	Interaction	Change	Reversibility	Invariance	Space	Time	Matter	Force & Field	Life
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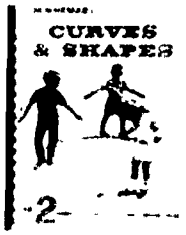
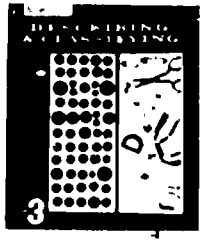
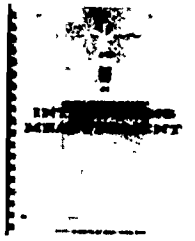






GRADE SKILLS

In KINDERGARTEN the children are introduced to a way of looking at the world around them. They are encouraged to watch and to wonder about it. Their observations include that of symmetrical patterns.

They learn to classify objects according to properties they have observed and to make qualitative comparisons, such as greater than, less than, appears to be the same as, before, after. They learn that properties of members and number of members of sets remain the same even when the sets are rearranged.

Using the basic concept of one-to-one correspondence, the children first learn to pair objects in one set with objects in another set, then with tally marks, and finally with number words.

In FIRST GRADE the children continue observing, describing and classifying objects by their properties. Many patterns of symmetry are explored. Their work with sets includes the concepts of intersection and union, and the set interpretation of addition and subtraction.

The number line is introduced. This model of the real number system will be used throughout the MINNEMAST program. The children work with a number line as they learn to make quantitative measurements of length, area, volume, and duration.

The children learn to use an addition slide rule working with numbers up to 100. They learn the place value system and add and subtract 2-digit numbers without regrouping.

They work with spatial relations and describe locations in terms of frames of reference.

Units 21 and 22 not pictured here.

In SECOND GRADE the children investigate the world around them by experimenting with systems of interrelated objects or substances.

They work with numerals up to 999, with fractions and with negative numbers. In measuring length and weight, the children discover the advantages of using fractional units for greater accuracy. The children add and subtract 2- and 3-digit numbers, and learn to check their own results through approximation. They are introduced to graphing and they review place value notation.

Using several algorithms, the children learn to multiply, finding products of whole numbers up to 6×6, and to divide small whole numbers. They work with parallel scaled number lines and locate points for some non-integral numbers. The children work with Cartesian products.

The children learn to make and interpret scaled diagrams and models. They learn to measure and record on graphs some changes that occur in their environment, such as in plant growth and temperature variation. Some properties and uses of angles are introduced.

Units 27, 28 and 29 not pictured here.

In THIRD GRADE the students continue working with numbers, investigating their properties and their relations to geometry and measurement. Science activities provide further practice with basic arithmetic ideas and algorithms and extend the children's understanding of the real number system.

The students study the relation of the slope of a line on a graph, speed and multiplication. Work with geography and projective geometry bring out the invariance and transformation features of the function concept in mathematics. Biological and earth-science activities are presented in the context of the systems concept. The students develop simple graphing and mathematical skills in describing these natural systems. The observable properties of matter are investigated in a chemistry unit. The third-grade student begins working independently on some written materials.

An effort was made to reach a convenient pause in the progression of certain subjects in science and mathematics. The writers avoided initiating work that was not likely to be reinforced in the higher elementary grades.

MINNEMAST

COORDINATED UNITS

The K-3 curriculum includes 29 coordinated mathematics and science units. These units are sequential, covering the first four years of a child's education. MINNEMAST attempted to develop a coherent, systematic curriculum rather than separate units of instruction.

The kindergarten materials are a very important part of the program. It is in these that we try to build the child's natural curiosity, encouraging him to ask questions, to take the time to explore his environment, and to try to find answers to his questions, as well as to develop new questions. The units seek to instill in the child a lifelong interest in thinking and learning.

Where school systems have no kindergarten, teachers of first grade could select lessons from kindergarten units. Because the children are more mature, these lessons would require less time at the first-grade level.

The coordinated K-3 curriculum provides a firm foundation on which the children can build as they follow other mathematics and science non-coordinated curricula in fourth grade and later. Special emphasis is placed on the actual handling of materials by the students, which

leads to a fundamental understanding of concepts, as opposed to rote learning. Through actual experience the children see how math and science serve each other and how closely interrelated they are. The staff feels that mathematics and science taught as totally unrelated subjects could not provide so good a preparation as the children get through this approach.

The project attempted to provide a smooth transition from third grade of MINNEMAST to other upper elementary materials. An effort was made to reach a convenient pause in the progression of certain subjects and to recommend how MINNEMAST objectives could best be continued in the intermediate grades (4-6).

If your school or your district is not presently employing the MINNEMAST Curriculum, we heartily invite and encourage you to examine it and to consider its adoption. A pamphlet, Questions and Answers about MINNEMAST, and a price list will be sent free upon request. Any of our publications may be purchased singly. Many are useful and rewarding at levels other than those indicated in our sequential arrangement.

OTHER MINNEMAST PUBLICATIONS

The 29 coordinated units and several other publications are available from MINNEMAST. Other publications include:

STUDENT MANUALS for Grades 1, 2 and 3, and
printed TEACHING AIDS for Kindergarten and Grade 1.

LIVING THINGS IN FIELD AND CLASSROOM
(MINNEMAST Handbook for all grades.)
A description of the Handbook is included in this Overview. Available on order.

ADVENTURES IN SCIENCE AND MATH
(Historical stories for teacher or student.)
A description of this booklet is included in this Overview. Available on order.

QUESTIONS AND ANSWERS ABOUT MINNEMAST
Sent free with price list on request.

OVERVIEW
(Description of content of each unit.) Available on order.

MINNEMAST RECOMMENDATIONS FOR SCIENCE AND MATH IN THE INTERMEDIATE GRADES
(Suggestions for programs to succeed the MINNEMAST Curriculum in Grades 4, 5 and 6.)
A description of this booklet is included in this Overview. Available on order.

For additional information, a price list and orders, write to:

MINNEMAST Director
Center for Curriculum Studies
University of Minnesota
Minneapolis, Minnesota 55455

Kindergarten

Unit 1
WATCHING AND WONDERING

Kindergarten children are encouraged to watch, to wonder, and to seek their own answers to questions through discovery and testing.

In their first days of kindergarten the children are learning to be explorers. "Pretend you are an explorer for your family," the teacher tells her class. "When you get home your mother and father will ask what you saw in the classroom. What will you tell them?"

The children explore their classroom, the school building, and the neighborhood. They make observations about animals, the weather, shadows, and night and day.

Each child is encouraged to discuss and question his own wonderings and to develop ways of finding answers to his questions. The activities provide interesting experiences that expand his powers of observation and his verbal skills of communication.

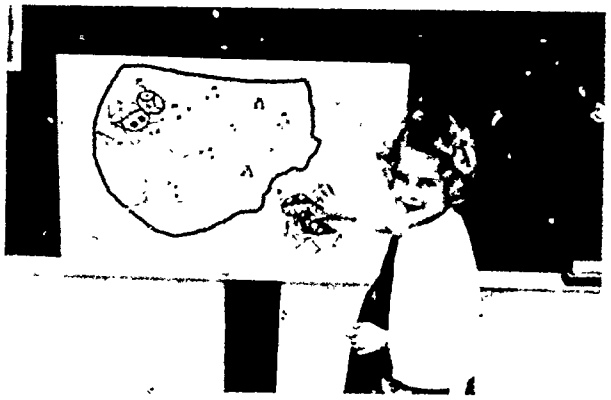
Unit 2
CURVES AND SHAPES

The kindergarten children continue their observations. Here they observe geometric patterns. They become acquainted with some properties of shapes and curves, emphasizing that a curve may enclose or bound a region in a plane.

The children find, identify and construct many curves. Through games and stories, they learn to determine whether curves are open, closed, simple or non-simple. The circle, square, triangle and rectangle are treated as four simple closed curves.

The children learn to classify and sort curves according to certain properties. A branched diagram called a "concept tree" makes their sorting easier. The children transform curves made of yarn into different types of curves. They also see that a curve can be made to look different without changing the type of curve it is.

This unit consists of four parts; each is taught at a different time during the school year. The activities provide the children a great deal of practice in developing their skills of observation and classification.



Unit 3
DESCRIBING AND CLASSIFYING

The concept of set is developed for the kindergarten children and they apply it to many groups of familiar objects.

The children observe objects, describe their properties, and then classify them according to certain properties. They sort many classroom objects, property blocks, and various biological objects. They compare sets by placing the members in each set in a one-to-one correspondence, and they find that sometimes one set will have more members than another.

Two points are emphasized: a set remains the same set after rearrangement, and the number of members of a set does not change under rearrangement or substitution. The activities on conservation of set and set comparison form a basis for later counting.

Unit 4
USING OUR SENSES

"Tell me something about this," the teacher says to her class as she shows the children a flower.

"Yes, it is a flower. But can you tell me more about it? What color is it? What part of your body tells you that?" Then she asks the children to touch and smell the flower and to identify which sense they use to acquire their information.

The children have been using their senses since the day they were born; they have been watching and wondering and making observations since the day they started kindergarten. Now the teacher leads them to discover the part each of their senses plays in making these observations.

First the children explore the properties of familiar objects, and then test their awareness with unfamiliar "mystery objects." Stories, riddles, and games are used for reinforcement and pleasure.

Unit 5

INTRODUCING MEASUREMENT

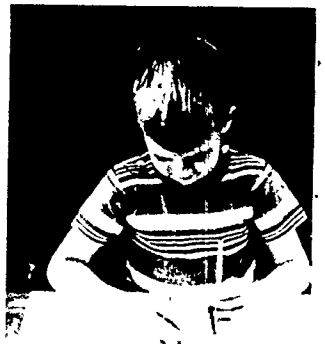
Since all measurement is essentially a series of comparisons of two objects, it is appropriate that a child's first formal work with it should involve making direct comparisons. The length of one object is greater than, less than, or appears to be the same as the length of another.

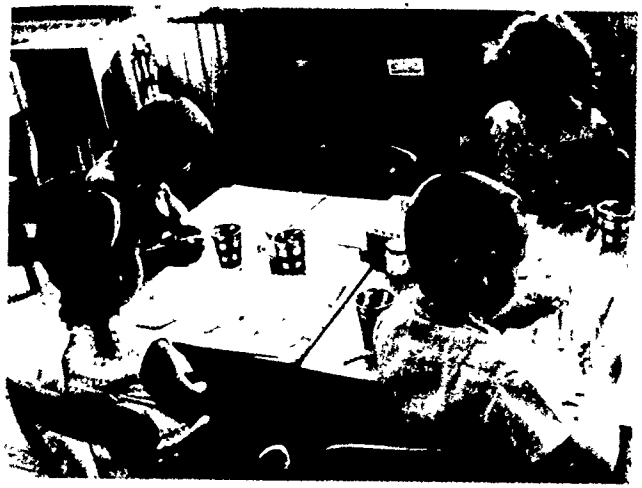
Length, area, volume, and time duration are introduced as properties that can be compared. From these comparisons an order is determined. All the work is qualitative, i.e., non-numerical.

The children first see a need to measure a particular property. Then they develop methods of comparing each of two objects using that property. Areas inside closed curves of yarn, for instance, are compared by the number of children who can stand on the region inside the yarn. Next the children order three or more objects by comparing two at a time using the transitivity principle. They play games arranging paper cutouts by area or boxes by volume, and watch plants arranged in order of time since planting.

The children meet situations involving the variability and invariability of a particular property under changing conditions, such as length of pencils, strips of crepe paper, and Slinky toys.

Measurement is an activity that cannot be assigned to either science or mathematics exclusively. The concepts of length, area, volume, time order, and time duration, and the ideas and language of binary comparison, ordering, inequality and invariance -- basic to both the scientist and the mathematician -- are introduced in a qualitative manner in preparation for a quantitative, numerical approach.





Unit 6
NUMERATION

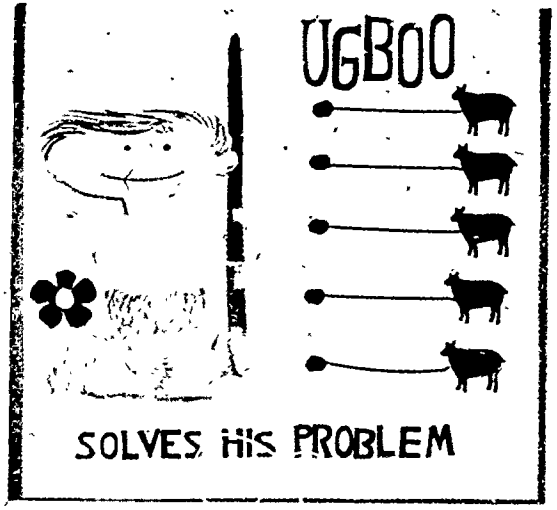
"Here is Ugboo. He lived a long, long time ago. This is the way he counted: 'One -- two -- many.' He did not know any other way to count more than two. At that time no one knew how to count more than two."

Ugboo's problem introduces the children to a method of representing the number of members in a set. Ugboo needed a way to be sure that he brought back as many sheep each night as he had taken to pasture in the morning.

The children first use a set of objects, then tally marks, and finally numerals to represent the number of objects in a particular set.

The first lesson involves ordering activities; in following lessons the children construct and use equivalent sets of objects and tally marks for representing numbers. Minnebars represent number by length. By comparing the various bars, children can perform pre-counting, pre-addition and pre-subtraction exercises. The children use numeral cards and also count aloud in many activities. Because of the emphasis throughout the unit on one-to-one correspondence, counting now becomes an intelligent process, not just a verbal recitation.

An optional lesson in printing numerals appears at the end of the unit.

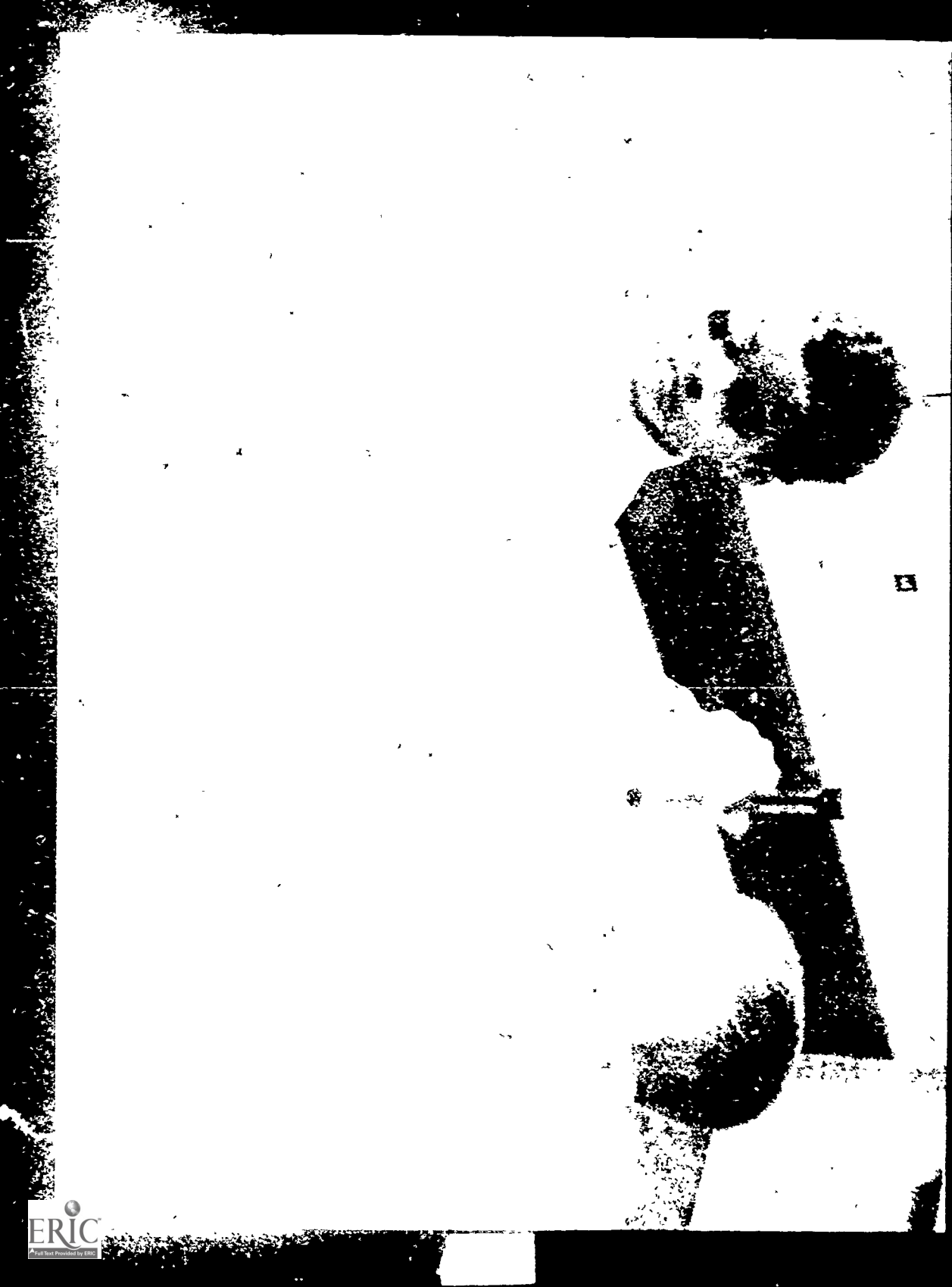


Unit 7

INTRODUCING SYMMETRY

The children observe symmetric patterns existing around them -- both man-made patterns and those present in the natural world. Most of the lessons involve observations and manipulations of a variety of objects. Art activities that demonstrate patterns of symmetry help to make this unit a very exciting one for the teacher and children.

The activities illustrate three kinds of symmetry. Rotational symmetry is exhibited by objects that can be rotated part way and still look the same. Two examples are a starfish and a paper star. An endless picket fence illustrates translational symmetry, in which a pattern is repeated indefinitely. A finite pattern is shown by a paper doll chain. Bilateral symmetry, which is also called mirror or folding symmetry, is illustrated with figures such as butterflies and leaves.



Unit 8
OBSERVING PROPERTIES

In the context of exploring their new first-grade environment, the children continue describing objects, grouping objects into sets and subsets, and ordering sets according to number of members.

Two new set concepts are union and intersection. The children put together two sets, such as red blocks and green blocks, and learn that this combined set is a union. They sort objects according to two properties, such as white objects and round objects, and learn that the white round objects are in the intersection of the two sets.

When the children start to classify objects according to three properties, their teacher reads them a story that shows the desirability of using a tree diagram for classification by more than two properties. The need for a reference or control object becomes apparent when the children observe and compare several properties of an object.

The children have many opportunities to experiment with changing properties. They inflate and deflate a painted balloon, watch an ice cube melt, plant seeds and observe the growth rate of plants, study the life cycle of a meal worm, and recognize their own changing sizes.

The children discover that some properties of an object can be changed while the identity of the object remains unchanged. They find that some changes of properties are reversible, while others are irreversible.

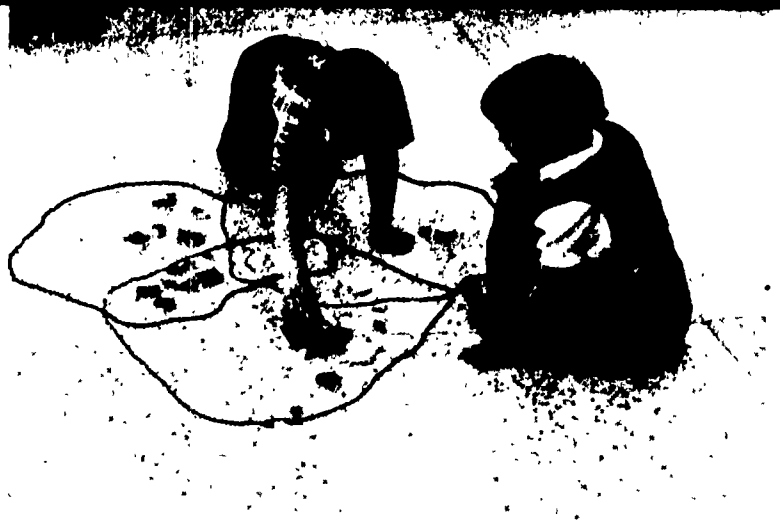
Unit 9
NUMBERS AND COUNTING

The concepts of comparison of sets, numbers, numerals, and counting, which were introduced in kindergarten, are reviewed in first grade.

The children collect two sets of objects, such as rocks, seeds, nuts, leaves, or shells. Several objects are used so that the children cannot tell at a glance which set has more members. First the children compare their two sets by one-to-one correspondence. They discover that sets which are in one-to-one correspondence have the same number property.

Next they see that a reference set, such as tally marks on paper, can represent a set which is to be compared with another set. A story, "Tal's Aching Back," shows the usefulness of a reference set when the sets to be compared cannot be brought side by side for matching by one-to-one correspondence.

In another story a set of words replaces the tally marks and counting becomes the pairing of a set of words, in a given sequence, with the objects in the set to be counted. The last word paired gives the number of objects in the set. The story helps the child realize what he is doing when he counts.



The numerals for 0 through 20 are taught by rote and then established by practice. Practice in counting and writing numerals is related to activities with sets of objects. The children order sets by the number of members to help clarify the abstract idea of number.

Unit 10

DESCRIBING LOCATIONS

The children locate buried treasure, help South Pole explorers record their journey, and find their own desks on a classroom map in a few of the activities of this unit. They learn to make and read a variety of simple maps and to describe verbally (without pointing) where something or someone is.

Two mathematical concepts are involved in the techniques of describing locations. One, the concept of describing a location by using a frame of reference, provides a foundation for later mathematics work with coordinate systems and graphing — an important part of the MINNEMAST curriculum. A reference frame is some particular arrangement of objects, in relation to which we describe some other object's position or location. Reference frames need not be physical objects — points and lines may be used.

The second concept is the idea of a location as a point or set of points. A more exact location can be given by describing a point or set of points, such as "at the intersection of line AB and line CD" or "ten feet due north of the flagpole."

The unit introduces the ideas of a point, line, line segment and intersection and union of sets. The unit provides many opportunities to connect the mathematics and science work with art, social studies and language skills.

Unit 11

INTRODUCING ADDITION AND SUBTRACTION

The children are introduced to addition and subtraction of the counting numbers through experience with sets of objects. Addition is interpreted as the process of determining the number of members in a set formed by joining disjoint sets. Subtraction is interpreted as the process of removing members from a set and determining the remainder. This set interpretation applies to the positive integers.

The number line is introduced to the children at this time. The number line is a model of the real number system. It provides a simple way to obtain correct answers for all addition and subtraction problems the first-grade child will encounter. The number line will be used throughout the MINNEMAST curriculum.

To introduce the number line, the teacher draws two long horizontal lines on the chalkboard to resemble a street map. On the map she places a cut-out figure of a dog named Skip, and marks his house with the numeral 0. The story, "Skip's Trip," provides an address scheme which introduces the labeling on the number line. As Skip moves along from house to house the children put the correct numeral on each house.

Other activities of the unit illustrate the notion of place value and the decimal system of numeration for numbers up to 100. Rectangular arrays and simple fractions are introduced. Some of the worksheets use examples from nature showing food and habitat of animals, and seeds and fruits of plants.

Unit 12

MEASUREMENT WITH REFERENCE UNITS

Measurement activities in this unit include assigning numbers by the use of various standard units. Measurement involves establishing a ranking order of objects according to the magnitude of some property. Assigning numerical values to these properties requires using units of measurement. The arbitrary nature of these units is emphasized by letting the children begin by using reference standards such as paper clips, corks, and pendulums. In later activities they use common standard units of measurement such as inches, centimeters, quarts, seconds, etc.

The children measure objects and events, record values of length, area, volume, and time duration, and determine time order. In recording their results, they use the symbols > (greater than), < (less than), and ≐ (appears to be the same as) for comparing measured quantities. Other activities include work with optical illusions, counting and adding games, distinguishing perimeter, area, and volume, and getting practice with clocks and calendars. The children learn to use centimeter and inch grid sheets for the measurement of area, and they develop "clocks" as guides for counting.

Unit 13

INTERPRETATIONS OF ADDITION AND SUBTRACTION

The children review the concepts of measurement and the set and number line interpretations of addition and subtraction of the counting numbers.

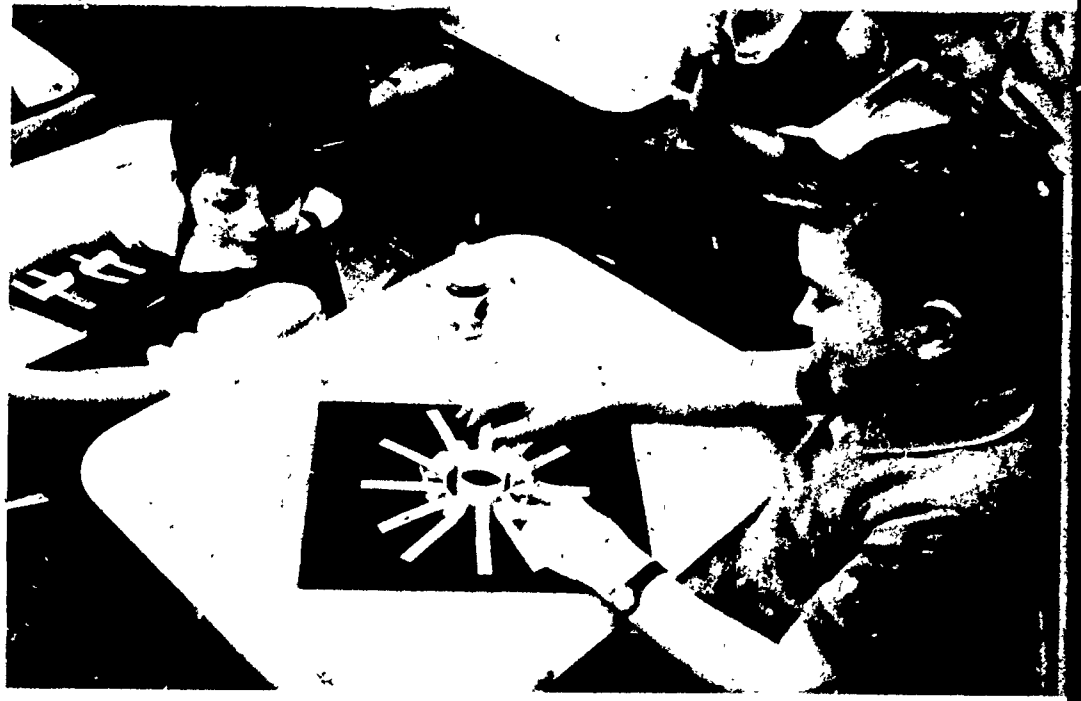
They learn to use an addition slide rule. This enables them to add and subtract larger numbers before learning the standard algorithms, and also to add and subtract numbers other than the counting numbers. Optional activities introduce algorithms for addition and subtraction of two-digit numbers that do not require carrying or borrowing.

From the activities the children discover patterns and relationships among numbers. They learn that addition is commutative, whereas subtraction is not ($3 + 4 = 4 + 3$, but $3 - 4 \neq 4 - 3$).

The children apply addition and subtraction to situations familiar to them. Some worksheets are illustrated with biologically accurate drawings of plants and animals. The theme for several of these illustrated worksheets is animal life in Africa.

Unit 14

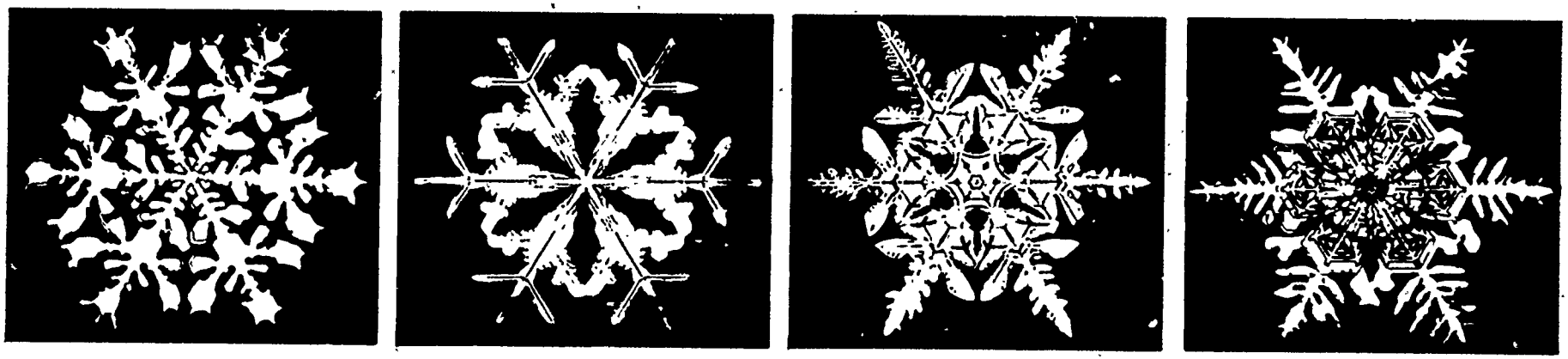
EXPLORING SYMMETRICAL PATTERNS



The children study the symmetry concepts introduced in the kindergarten symmetry unit, but somewhat more intensively. They observe symmetry in flowers and tile floors, and they construct many patterns of their own in art and craft activities.

There are activities and tests for three types of symmetry: rotational symmetry, translational symmetry or symmetry of repeating patterns, and bilateral or mirror symmetry.

As in the kindergarten unit, actual objects are used to demonstrate symmetry. The art activities make this unit enjoyable for both the children and teacher.



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Unit 15

INVESTIGATING SYSTEMS

During the kindergarten and first-grade years the children observe individual objects. Now they are introduced to the study of sets of interrelated objects or substances which are looked upon together as systems. Emphasis is placed on having the children investigate the relationships among the components of the different systems through experimentation. They work with magnets and with flashlight cells and bulbs. Their study of seed dispersal systems includes a field trip and classroom experiments. They mix colors and they observe simple chemical reactions. The children use themselves as subjects in studying eating systems.

To understand a system, the children observe some phenomenon. Then they determine experimentally which components of the system are necessary by eliminating one at a time and observing whether the phenomenon still occurs.

Common to all the activities is the basic objective of developing a rudimentary understanding of the systems concept, which is broadened in third grade. The systems concept is important because it simplifies investigations by focusing attention on limited portions of a complex environment.

The children learn that many questions can be answered through experimentation, and they gain experience in recording and interpreting data.

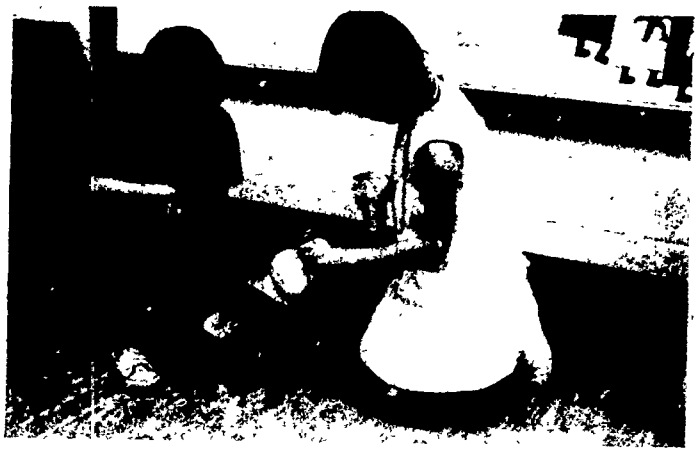
Unit 16

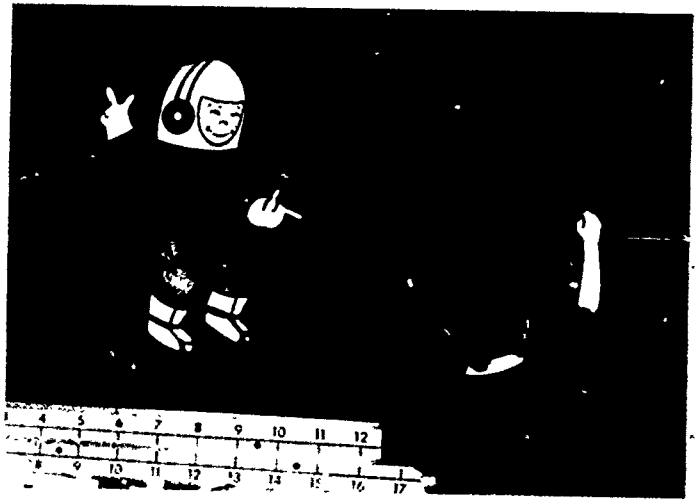
NUMBERS AND MEASURING
(Learning with Tor)

By the time they begin this unit, the children have had experiences in making simple comparisons of properties, and they have gained an understanding of part of the real number system. Here they are required to refine their comparison methods by using more precise tools for measurement, ar to consider other aspects of numeration.

They deal with numerals up to 999, with fractions, and with negative numbers. They are introduced to base four as an aid to their understanding of base ten in our decimal place value system of notation. They also get a look at the Egyptian system of representing numbers, and do some work with U. S. coins. The intent is not to have the children master all of these concepts at this time, but to broaden their view of mathematics and measurement.

After a review of the comparison symbols, the children practice measuring and ordering various lengths, including diameters and circumferences. Then they apply measurement to another property -- weight. First the children judge the relative weights of objects by lifting them, next they compare the weights by using a beam balance, and finally by using a standard scale. In their





work with length and weight, the children discover the advantages of refining their measurements by using fractional units for greater accuracy.

A story, "Tor," about a friendly little man from outer space, strongly motivates the various activities. The children pretend that Tor is studying this unit along with them, and his questions tend to make the communication of explanations easier for them.

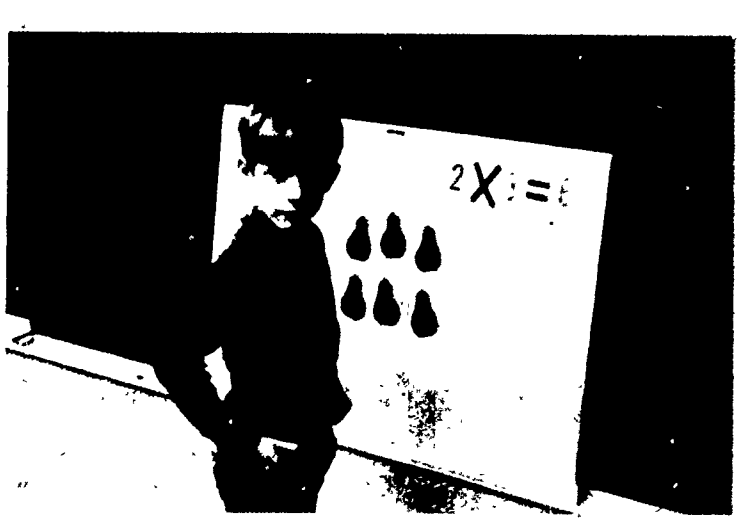
Unit 17

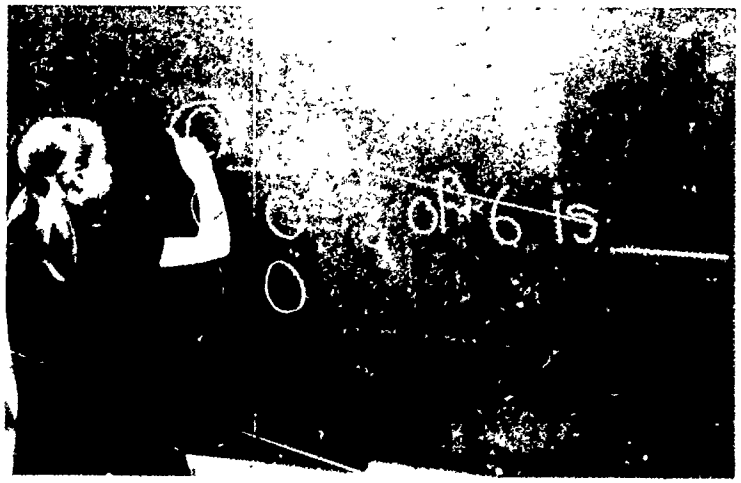
INTRODUCING MULTIPLICATION AND DIVISION
(Kangaroos and Numbers)

The children are introduced to multiplication and division of whole numbers one through six. The emphasis is on an elementary understanding of the concepts and processes of multiplication and division, rather than on computational skills or memorization of number facts.

Different algorithms are presented so that the child will learn to view the concept of multiplication in various ways: repeated addition by repeated jumps on the number line, repeated addition using combinations of equivalent sets or arrays, related scales on parallel number lines.

To introduce multiplication as repeated jumps on the number line the teacher tells her class a story about a kangaroo family that has a jumping contest along the line. Later the children work with parallel number lines. One number line represents the number of spaces jumped, and the other the number of jumps. The children know that Mother Kangaroo moves three spaces with one jump. "How many spaces will she move with two jumps?" the teacher asks. The children locate 2 on the "jumps" line and then determine by looking at the "spaces" line that she moves six spaces in two jumps.





Division is presented in a manner that makes full use of the child's conception of dividing up a set of things into equivalent subsets. This gives him an early feeling for the relationship between simple fractions and division by the counting numbers, e.g., the relationship between a half and division by two.

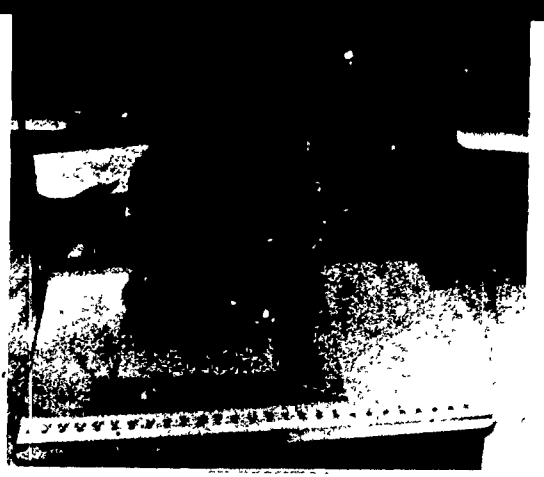
Unit 18

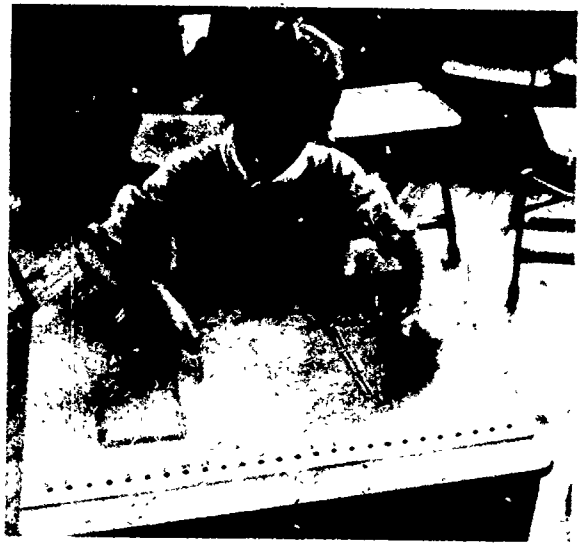
SCALING AND REPRESENTATION

The children learn that representations of an object may be larger or smaller than life size, and that objects often come in different sizes to suit different needs, e.g., clothing, furniture. They work with numerous representations — shadows, outline drawings, maps, three-dimensional cutout models, and Minnebar shapes.

The children learn to scale representations up and down using three methods. First they look at objects through magnifying and reducing lenses, observe how they appear larger or smaller and draw them as seen through the lenses. Then they use a one-to-one scale where a smaller unit corresponds to a larger unit. Finally they work with a scale using multiples of the same size units.

There is a great deal of practice with multiplication as they scale up the dimensions of a drawing on grid paper and record the computation as they go along. Computation of area is also introduced optionally for those children who are ready for it. Division is related to scaling down, but it is only presented as an interesting idea. No division computation is taught.





Making and interpreting scaled diagrams and models involve observation, description and measurement — activities fundamental to both science and mathematics, and important in everyday life. The activities of this unit are designed to develop this important representation and communication skill in children.

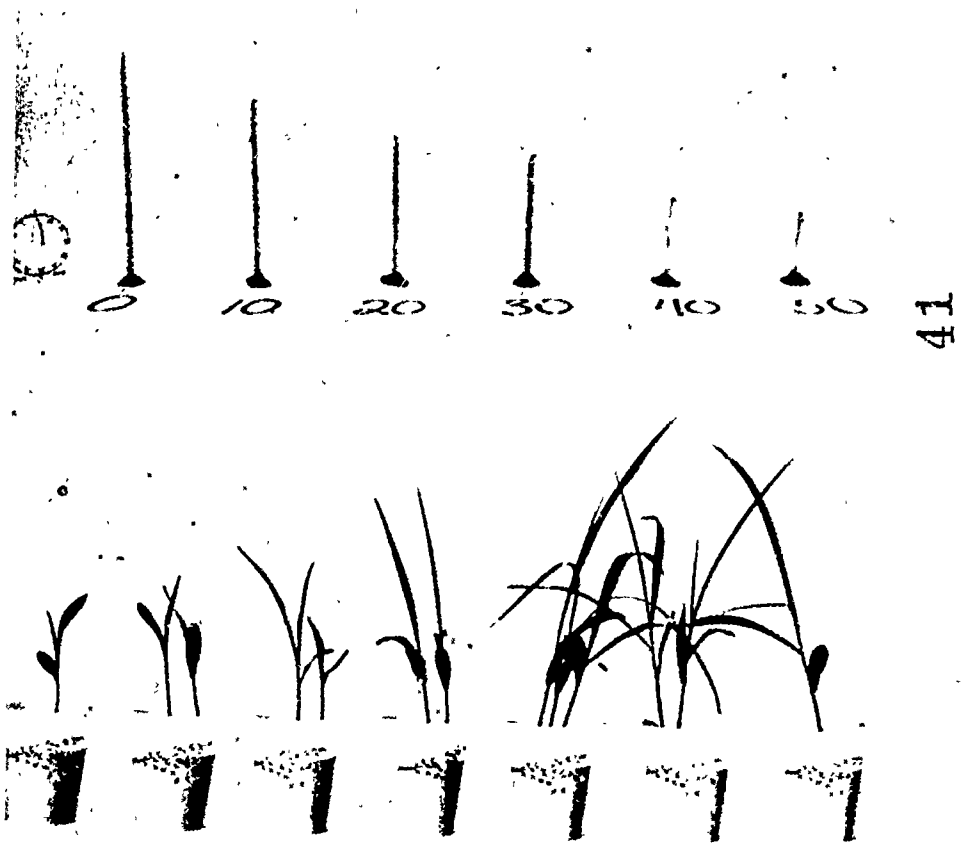
Unit 19

COMPARING CHANGES

The children's attention is drawn to many of the changes that occur in the environment, and to the relationships among the changes involved. The children are encouraged to measure and record these changes.

Experiences with plants, volume and weight, and temperature changes lead the children to explore relationships among variables and to represent them graphically. For example, the children discover that the height of a plant is related to the amount of time that has elapsed since it was planted. Then they learn to represent, on a graph, this relationship between height of plant and time. This introduces the idea of a function as an association or relationship between two variables.

By experimenting and measuring, the children discover different kinds of functions. They get some feeling for the usefulness of these discoveries in attempting to understand the world. Learning to interpret the dependence of one variable upon another, and to find regularities and laws in natural and abstract systems, comprises much of the work of scientists and mathematicians.



Unit 20
USING LARGER NUMBERS

This unit presents the standard algorithms for addition and subtraction of two- and three-digit numbers, and provides experience in manipulation of these larger numbers.

The activities develop the children's computation skills and extend the concept of the number system. To develop the algorithms the children first use a place-value chart on which they manipulate counters to give concrete representations of the addition and subtraction methods. The counters are made so that a 10-piece is ten times as large as a 1-piece and a 100-piece is ten times as large as a 10-piece. After they have had sufficient practice in regrouping the counters, they learn to work with numerals in the chart instead of counters. They learn to record the process on paper in condensed form, rather than to use a place-value chart and counters or numerals. Thus they arrive at the standard algorithm.

Games provide a fun and challenging way of practicing addition and subtraction skills. Activities with graphing reinforce work done in previous units and also present computational problems in a new setting. The children practice the techniques of approximating answers and checking their own results — not only to give them a sense of numbers and size, but also to develop independence and confidence in working with numbers.

In the last section of the unit, the children learn to use different instruments to measure and study the components of weather. In working with weather measurements, it is necessary for the children to do a great deal of computation using the skills acquired in the rest of the units.

Unit 21
ANGLES AND SPACE

This unit concentrates on geometry concepts — an important part of the elementary curriculum for several reasons. Geometry is the study of spatial relations and concepts that are important in the application of science. The study of geometry helps to develop logical thinking and extends the concepts of measurement and numbers. An understanding of dimension, gained from studying geometry, is basic to understanding the three-dimensional universe.

The unit reviews the concepts of point, line and line segment and introduces the concept of ray. The children discover a simple definition of angle (two rays with a common origin) and learn to measure angles. They use a clock face protractor that differs from the traditional 180° protractor. The children are introduced to the word "mag," which means "the measurement of the angle." The word was coined by MINNEMAST to eliminate confusion between the concept of angle and the measurement of angle. One can talk about the mag of an angle just as one talks about the length of a line segment or the weight of a mass. The children look for angles in and out of the classroom and practice measuring them. They experiment with light beams and mirrors and discover interesting facts about light and its reflection.

The children study polygons and review many set and classification concepts. They also study similar triangles and congruent figures and play with polygons to see what relationships exist among shapes and what repeating patterns can be found in designs consisting of polygons.

To make a transition from two-dimensional to three-dimensional shapes, the children work with flat shapes (for example, squares) and put them together with tape to form three-dimensional shapes (for example, the cube). Finally, tney make various open-ended investigations with solid figures (polyhedra).

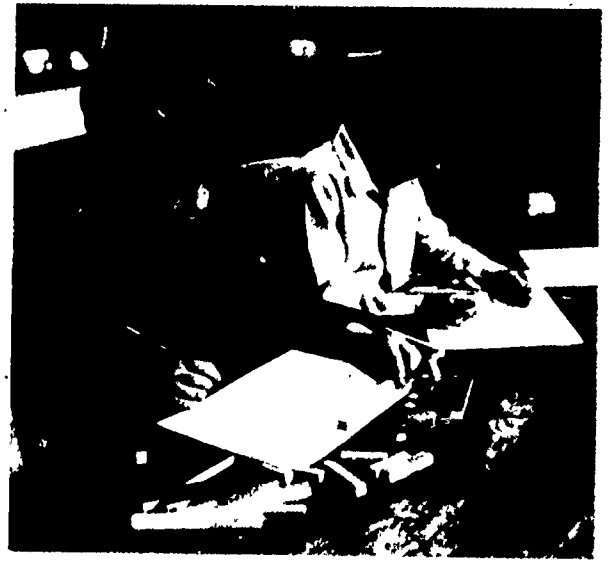
Unit 22

PARTS AND PIECES

This unit expands the student's understanding of the real number system by formally introducing the set of rational (or fractional) numbers. Fractions are taught because they are a part of the real number system — that set of numbers which can be put in one-to-one correspondence with points on a line. A need for fractions is generated by creating situations for which the whole numbers are not sufficient. The children begin their work using physical objects to represent parts of wholes. In later work they view fractions as points on a number line.

Rational numbers have a property not shared by any set of numbers thus far considered in the curriculum. This property is known as density and means that between any two rational numbers there is always one more rational number. Although the children may not grasp the idea of an infinite set of rational numbers between any two other rational numbers, they do learn that there are "many, many" points between any two points on the number line.

Two distinct types of measure are introduced to facilitate the children's understanding of density. One is the "counting measure," which refers to "how many" or the number of parts into



which an object is divided. The other is the "amount measure," which refers to "how much" or the overall quantity of material under consideration. The concepts of weight, length, magnitude of angle, time, and area are developed as amount measures. Students often work in small groups while carrying out the activities.

Unit 23
CONDITIONS AFFECTING LIFE

In this unit the children study three environmental conditions that profoundly affect life. These are moisture, light and temperature. The children learn how these conditions and their effects can be detected and measured. They investigate the effects of these conditions on the growth of plants and on the behavior of animals, and they also consider the part these conditions play in determining where plants and animals normally live.

The children begin their studies by taking a field trip to observe plants and animals in a natural setting and to discover what conditions of moisture, light and temperature cause living things to be in these places. Eventually these considerations reveal the necessity for designing controlled experiments. The children begin to realize the relation between field and laboratory investigations.

The MINNEMAST "systems" thread develops the concept that an investigation of a phenomenon or problem can frequently be simplified by concentrating attention on certain objects and their interrelationships and eliminating others. The systems used in this unit are taken from nature and are somewhat more complex than in previous units.

The systems thread provides situations in which the children (1) select relevant elements to observe, (2) discover relationships among these elements, and (3) verify the relationships by testing. For example, the effect of temperature on the breathing rate of goldfish is investigated. The children focus their attention on a system that includes a goldfish, ice cubes for lowering the temperature of water, a thermometer for measuring the water temperature, and a pendulum for timing the breathing rate of the fish. They discover that the rate of breathing is reduced as the temperature is lowered. This discovery is checked when the temperature of the fish is lowered still further.

Unit 24
CHANGE AND CALCULATIONS

The children set up a computer to work addition and subtraction problems. The computer is set up with desks, using the children as components. Algorithms for addition and subtraction are developed with heavy emphasis on the place value system. The children review T notation for expressing place value. In T notation, the one's place is named T^0 because no groups of ten have been made. The ten's place is named T^1 because the elements have been grouped by ten just once. The hundred's place is T^2 because the elements have been grouped by tens twice.

First the computer accepts "T-pieces." Later the children program numerals into the computer. And finally, the vertical forms for addition and subtraction are developed.

The children also work with measurement systems of length, volume and time duration. These systems contrast the place value of the base-ten numeration system because the measurement units for length and time duration are not regular, i.e. 12 inches = 1 foot, 3 feet = 1 yard, etc.

The students work with two other systems: a pouring system and a balance beam system.

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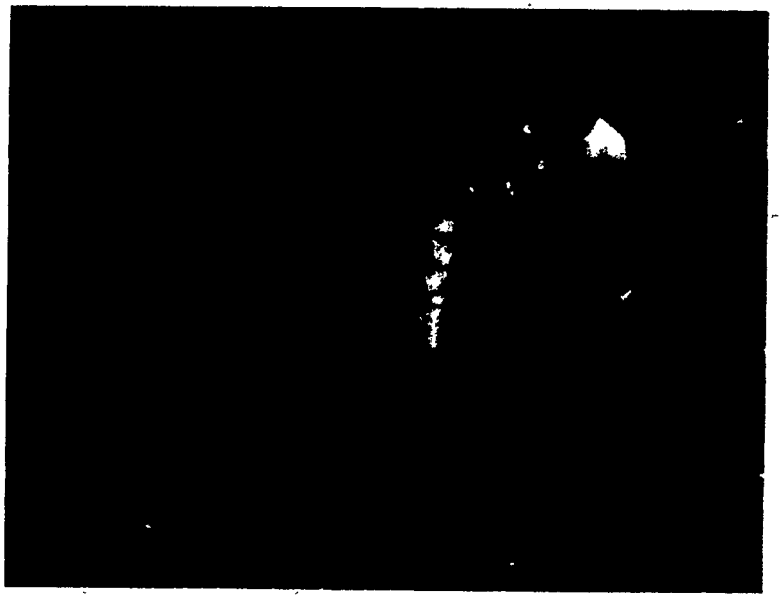
This work is done independently with minimal help from the teacher. By pouring water from one measured tube into another or balancing a meter stick, the children generate ordered pairs. They graph these pairs on grids and use them to predict new states of their systems.

Unit 25
MULTIPLICATION AND MOTION

This unit relates the concept of motion and graphs of speed to multiplication. The children explore motion and gather their own data through a series of races, both on foot and with battery-operated toy cars. The children become familiar with some of the problems involved in measuring speeds and gain more experience in collecting data in experimental situations. The children graph the data they collect and then find that they can compare relative speeds by comparing the slopes (steepness) of the lines representing the motion. They discover that the steeper the slope of the line, the faster the speed that line represents.

The relationship of multiplication to constant speed motion is made obvious when the children examine the increase in the slope of a line. They learn to name the slopes as y number of units up per x units over. They discover that when the car travels the same distance each second, it is going at a constant speed. The graph of a constant speed is a straight line, and represents a multiplication relationship. For example, if the car travels 3 feet per second, it will go 6 feet in 2 seconds, 9 feet in 3 seconds, 12 feet in 4 seconds, etc. For each second traveled, the car covers 3 feet, so the slope of the graph increases in multiples of 3.



The children use a multiplication chart with lines of slopes one (up per one over) through nine (up per one over) to find the products of integers from zero through ten. The unit also reviews other embodiments of multiplication, such as repeated addition, arrays and Cartesian products.

Unit 26

WHAT ARE THINGS MADE OF?

Children who have been in the MINNEMAST program since kindergarten have had a great deal of experience in observing and describing the properties of objects. They have given qualitative and quantitative descriptions of properties. This unit brings in a new consideration — the students now focus on the properties of the material of which an object is composed rather than on the properties of the object itself.

The lessons are designed to teach some of the ways a material may be identified by its properties. The children learn to test metals and minerals for the property of hardness. They find out how to separate inks and food colorings into the component colors. They learn to identify some minerals by the property of crystal shapes and by the property of shape retention after cleavage. Finally, they use solubility and chemical reaction as properties that a material may have.

Science and mathematics are well coordinated in this unit. The mathematical concepts include intersection of sets, measurement of angles, and measurement and graphing of weight and volume.

The concluding lesson of the unit gives the children opportunities to use their experimental skills in identifying a variety of unknown white substances.

Unit 27

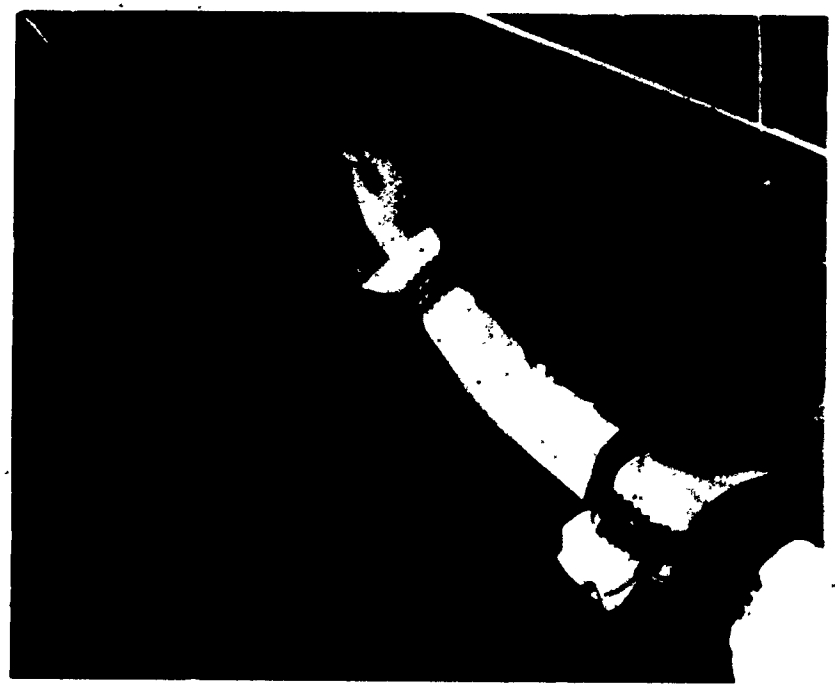
NUMBERS AND THEIR PROPERTIES

In this unit the students work independently — reading, following instructions and completing the worksheets with a minimum of help from the teacher. The students study factors, products, and multiplication sentences and learn to apply some properties of multiplication by 0, 1, 5 and 9 to multiplication problems where those numbers appear as factors.

Worksheets, class discussions and games provide practice with addition, subtraction and multiplication skills.

The students first practice multiplication using rectangular arrays. They partition a large array into smaller arrays and find the total number of elements in the original array by adding the number of elements in each smaller array. Rectangular arrays are used to develop an algorithm for the multiplication of whole numbers. Eventually a vertical algorithm for multiplying two-digit numbers is developed.

Worksheets and story problems extend the concept of a Cartesian product that was introduced in Unit 25. The story problems give the students experience with the multiplicative relation of Cartesian products and with the idea of finding all possible combinations of the members of sets. The distributive property of multiplication is also reviewed.



Unit 28
MAPPING THE GLOBE

The students are introduced to some of the basic notions of topology — the study of the properties and behavior of objects when transformed by twisting, stretching or bending. The topologist looks upon the objects being deformed as sets of continuous points on a curve or in a two-dimensional region. The continuity of points on a line is a characteristic of the real number system as well, for real numbers can always be represented as the points on a line. Also, continuity is at the heart of the fundamental theorems of calculus. Thus, in studying the deceptively simple and intuitive properties of curves and surfaces as they are deformed, the children are being introduced to the ground work of higher mathematics.

The children learn about these ideas by working with one to one transformations of various objects and sets. Many activities are included that children can appreciate, such as distorting a checkerboard, in which case it is found that under a certain kind of transformation (deformation), measurable properties, such as area and length, change; topological properties, such as order and connectedness, do not. Examples are also drawn from comparative anatomy and from map making and projecting. Thus, this unit integrates basic ideas in geometry and mathematics with other sciences such as biology and geography.

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Unit 29
NATURAL SYSTEMS

Unit 29 is the final MINNEMAST unit. The children who have gone through the four years of the MINNEMAST program have been equipped with basic skills in observation, measurement, classification and setting up simple controlled experiments to test their speculations. They have had experiences with the systems approach which helps them study nature by narrowing down and focusing their attention on one phenomenon at a time.

Three natural systems are presented here, and each requires a different method of investigation. A plant's water-transport system is investigated through controlled experiments. The children find that water enters the plant through the roots, is carried up to the leaves through tubes in the stem, and then goes from the leaves into the air in the form of water vapor. An open-ended discussion leads them to consider plants in relation to their environments.

A group of animal locomotion lessons involves a different kind of investigation. The children have to depend on close observation of living things, and on the basis of their observations they are able to make certain generalizations about locomotion on land, in water and in the air.

The final natural system they investigate is one involving erosion. Here they begin with an observation of the natural phenomenon and go on to work with models of the system they build and experiment with in the classroom. They find that the erosion system is affected by variations in soil type, slope and water flow.

All these investigations require the children to define a system in terms of their particular need. They see that a system is no more than man's way of looking at things, and that one can make his own decisions as to what the system is to include for his experimental purposes. He can limit the system or broaden it, but the purpose of his investigation should always govern what he includes or what he leaves out of a system.

Teaching Aids

Two separate booklets are available in the MINNEMAST curriculum. These are not units, but can be used as teaching aids for class enrichment. Descriptions of Adventures in Science and Math and Living Things in Field and Classroom follow.

ADVENTURES IN SCIENCE AND MATH

These true stories of science adventures and adventurous scientists illustrate familiar aspects and processes of science; they also include some interesting episodes in the history of mathematics. Particular stories have been selected not merely for their quality as stories but also because they bear on major topics: the birth of the scientific method, varieties of research approaches, the role of instruments in the development of science, mathematical notation, and simple calculating devices. Moreover, in these pages the reader will discover examples of observation, description, measurement, classification, experimentation, deduction, and hypothesis making — recurring themes in he MINNEMAST curriculum.

The use of this material is best left to the discretion of the teacher. Much will depend on the abilities and interests of the individual classes to be taught. Most students will not be able to read these stories by themselves. Thus, it will be most practical for the teacher to read to the class. On occasion, a story might be combined with a demonstration or an experiment as, for example, in the case of Anaxagoras or Archimedes.

LIVING THINGS IN FIELD AND CLASSROOM

This handbook is designed as a general aid, to be used by teachers of all the elementary grades parallel to their work with the sequential MINNEMAST units. It provides many suggestions for the study of living plants and animals through coordinating work in the classroom, the out-of-doors, and the library.

It is hoped that pleasant early experiences with plants and animals will help develop a sensitivity and respect for life, and also a sense of the interdependence of living things — that is, an ecological point of view, basic to the solution of so many environmental problems of the times.

The handbook provides simple how-to suggestions for setting up a classroom garden and zoo, including recommendations of particular kinds of plants and animals that have proven their hardiness under the adverse conditions likely to prevail in a classroom. The book gives suggestions on how to use to best advantage those occasions when children bring things to school. Discussion guides and extensive identification aids are provided. The classroom museum is presented as a meaningful grouping of exhibits around a central idea, rather than as a miscellaneous collection of natural objects.

Field trips are an important aspect of work with living things. The handbook gives detailed instructions for conducting many sorts of trips, some very simple and short (for example, 10 minutes in the schoolyard) and some more complex. There are also suggestions on what to look for and what kinds of questions to ask that will encourage curiosity and lead to further exploration.

The handbook includes an extensive bibliograph including both children's books and teacher's references. The bibliography is classified by subject matter, and is subdivided into information, identification, activity and story categories.

While this manual was designed particularly as an aid for MINNEMAST teachers, it serves as a valuable reference book for all elementary teachers.

MINNEMAST Recommendations for Science and Math in the Intermediate Grades suggests courses of study in mathematics and science that will best continue the MINNEMAST objectives for children who complete our K - 3 coordinated curriculum. To prepare this booklet, the staff examined all of the leading math and science curricula for the intermediate grades. They offer several alternatives for your consideration. It may well be that another program not mentioned in this booklet may suit a local situation better. Failure to mention any particular curriculum should by no means be construed as a criticism of it. This helpful booklet is available at modest cost.

For additional information write to

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