DOCUMENT RESUME

ED 127 187 SE 021 224

AUTHOR Vogt, Elaine E., Ed.
TITLE Comparing Changes: MINNEMAST Coordinated Mathematics - Science Series, Unit 19.
INSTITUTION Minnesota Univ., Minneapolis. Minnesota School Mathematics and Science Center.
SPONS AGENCY National Science Foundation, Washington, D.C.
PUB DATE 71
NOTE 172p.; For related documents, see SE021201-234
AVAILABLE FROM MINNEMAST, Minnemath Center, 720 Washington Ave., S.E., Minneapolis, MN 55414

EDRS PRICE MF-$0.83 HC-$8.69 Plus Postage.
DESCRIPTORS *Curriculum Guides; Elementary Education; *Elementary School Mathematics; *Elementary School Science; Experimental Curriculum; Graphs; *Interdisciplinary Approach; Learning Activities; *Mathematics Education; Primary Grades; *Process Education; Science Education; Units of Study (Subject Fields)
IDENTIFIERS *MINNEMAST; *Minnesota Mathematics and Science Teaching Project

ABSTRACT

This volume is the nineteenth in a series of 29 coordinated MINNEMAST units in mathematics and science for kindergarten and the primary grades. Intended for use by second-grade teachers, this unit guide provides a summary and overview of the unit, a list of materials needed, and descriptions of five groups of activities. The purposes and procedures for each activity are discussed. Examples of questions and discussion topics are given, and in several cases ditto masters, stories for reading aloud, and other instructional materials are included in the book. The focus of this unit is on experimental activities related to the prediction and observation of change. One section is related to the growth of plants, a second to duration of time and clock reading, and a third to other functional relationships. The construction of graphs by plotting ordered pairs is introduced. The final section of the unit concerns the measurement of volume and weight. Also included is a bibliography listing related books and films. (SD)

COMPARING CHANGES

MINNEMAST

UNIT 2

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT

MINNEMAST COORDINATED MATHEMATICS-SCIENCE SERIES

Grade	No.	Title
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
FIRST GRADE	8.	OBSERVING PROPERTIES
	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
SECOND GRADE	15.	INVESTIGATING SYSTEMS
	16.	NUMBERS AND MEASURING
	17.	INTRODUCING MULTIPLICATION AND DIVISION
	18.	SCALING AND REPRESENTATION
	● 19.	COMPARING CHANGES
	20.	USING LARGER NUMBERS
	21.	ANGLES AND SPACE
	22.	PARTS AND PIECES
THIRD GRADE	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
	29.	NATURAL SYSTEMS

OTHER MINNEMAST PUBLICATIONS

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MINNEMAST RECOMMENDATIONS FOR SCIENCE AND MATH IN THE INTERMEDIATE GRADES
(Suggestions for programs to succeed the MINNEMAST Curriculum in Grades 4, 5 and 6)

COMPARING CHANGES

UNIT 19

MINNEMAST

MINNESOTA MATHEMATICS AND SCIENCE TEACHING PROJECT
720 Washington Avenue S.E., Minneapolis, Minnesota 55455

MINNEMAST

DIRECTOR	JAMES H. WERNTZ, JR. Professor of Physics University of Minnesota
ASSOCIATE DIRECTOR FOR SCIENCE	ROGER S. JONES Associate Professor of Physics University of Minnesota
ASSOCIATE DIRECTOR FOR RESEARCH AND EVALUATION	WELLS HIVELY II Associate Professor of Psychology University of Minnesota

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

Third Printing
1971

COMPARING CHANGES

This unit was developed by MINNEMAST on the basis of experiences of the many teachers who taught an earlier version in their classrooms.

DOUGLAS I. MARVY
Research Fellow
University of Minnesota

GEORGE J. RABEHL
Research Fellow
University of Minnesota

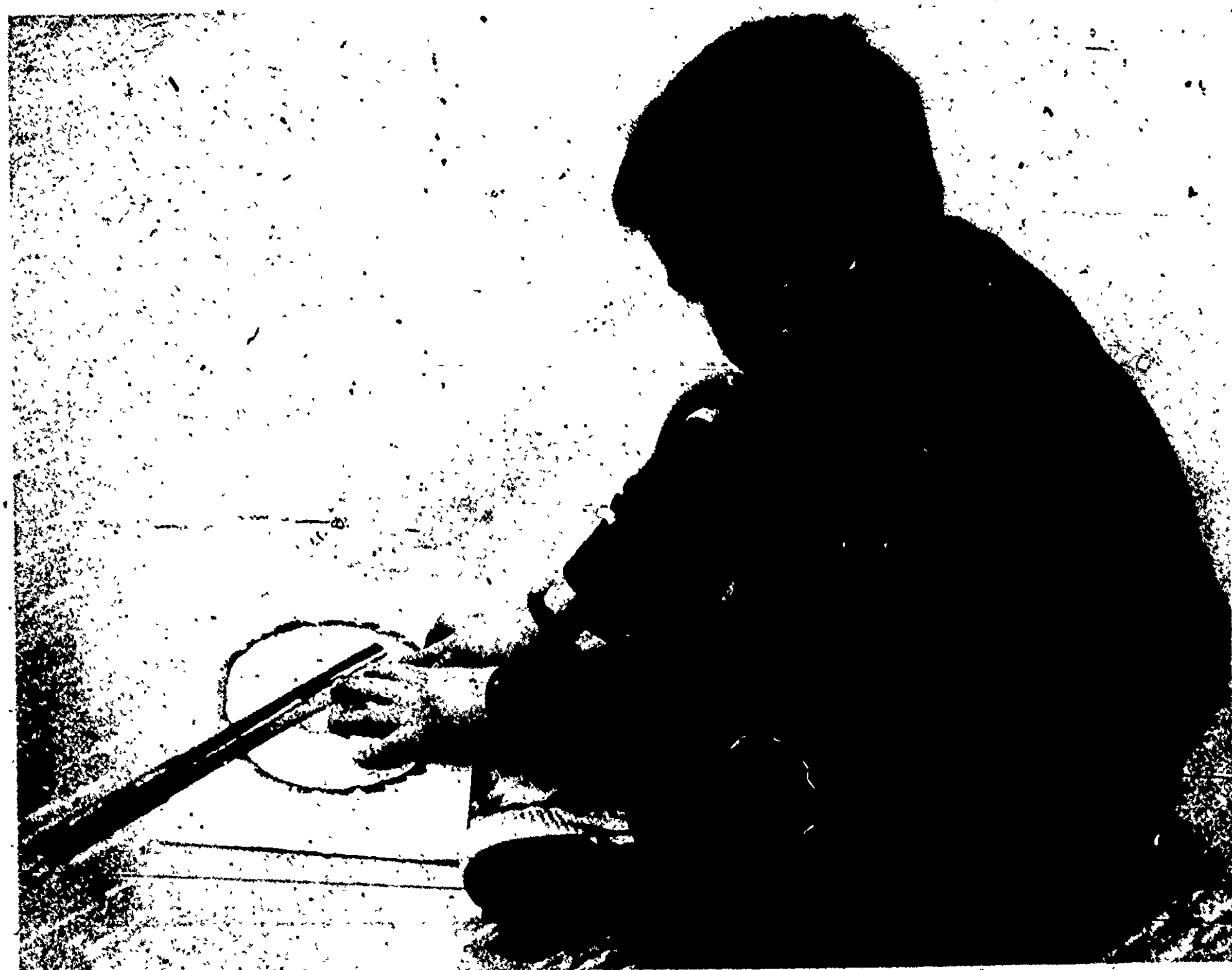
ELIZABETH W. REED
Assistant Professor of Biology
Minnemast Staff

HOWARD T. STACKPOLE
Research Fellow
University of Minnesota

EDMUND C. BRAY — Assistant to Director Curriculum Materials Development

ELAINE E. VOGT — Editor

JACK KABAT — Art Director
SONIA D. FORSETH — Associate Art Director



CONTENTS

Complete List of Materials for Unit 19

(Numbers based on class size of 30.)

total number required to teach unit	item	lessons in which item is used
100	* kernels of sweet corn	1
30	* small paper cups or 4-oz. plastic containers	1
70	labels for names (or tape)	1,8,16
4-5	pounds of sand	1
4-5	pounds of soil	1
1	* roll of plastic wrap	1,16
1	1/8 cup of popcorn (optional)	1
3-4	paper bags	1
1 set/group	2 onions, 2 small jars of water, toothpicks	2
1 set/group	4 potatoes, preferably beginning to sprout	2
1 set/group	spring scale or beam balances (from Unit 16)	2
1 set/group	* 1 clear plastic bag, 6" x 8"	2
1 set/group	2 small pots for sand or soil, with saucers	2
1 set/group	* 20+ wax beans, 2-3 soaked overnight	2
1 set/group	1 plastic shoe box or pan for soil	2
1 set/group	* 10 row markers, e.g., craft sticks	2,15,25,26
1	* roll of ticker tape ("tape")	3,4,5,6,7, 13,14
15-30	rulers with centimeter scales	3,4,5,6,7, 9,13,14,27
	paste or cellophane tape	3,4,5,6,7, 13,14,20
30	scissors	3,4,5,6,7, 10,13,14
30	* Cray-Pas	5,6
10	* paper trays	8,9,15,16, 25,26
40	* tapered cups ("U-shaped")	8,9
40	straight pins	8,9
20	* 12-oz. containers, 10 tall, 10 short	8,9
1	* roll of masking tape	8,9,10,25, 26
100	sheets of newsprint to protect desks	8,9
15	* "bob" for 42 inch pendulum	8,9,22,23
1	* tablespoon of food coloring	9
1	bottle of bubble blowing liquid	9
30	* medicine droppers	9,15,16,22, 26
30	* strips of blotting paper (1 cm. x 10 cm.)	9
30	* jumbo (2") paper clips	9
5-7	Alka-Seltzer tablets	9
30	* souffle cups	9,16,25,26

1	* roll of adhesive centimeter tape	9,15
1	roll of paper towels	9,15,16,22, 25,26
1	wall or kitchen clock with second hand	10,11,12
1	* demonstration clock face	10,11
30	** white, tagboard clock faces	10,11,12
30	* brass fasteners	10,11
1	* box of small paper clips	10,11,16,21
6	** time lines	10,11
30	sheets of newsprint	10,11
6	* thin candles, cut to be 10" tall; matches	12
30	* lumps of Plasticene or clay	12,21,25,26
1	piece of cardboard, 17" x 24"	12
1	kitchen timer	12
12	sheets of paper, 2 colored	12
18-20	cylindrical objects: 1 large (e.g., wastebasket), variety of small objects	13
30	boxes of crayons	15,20
30	* plastic cylinders, 4" in length	15,16,22,25, 26
30	* marbles	15
1	* pound Navy beans	16
[illegible]	box or pan to store cylinders	16
12	* beam balances (from Unit 16)	16,21,23,25, 26
1	large piece of tagboard	17
1	red marking pen	17
30	small (3" x 5") cards	17
30	1-inch cubes, *mirrors, masking tape and glue	18
30	*** sets of Minnebars	20
30	*** addition slide rules	20
120	* paper cups	21,23,25,26
30	* 8-oz. plastic containers	21,22,25,26
30	* 8 18-inch lengths of string	21,22,25,26
60	rubber bands	21
6	* pieces of irregular lead	26

* kit items as well as

** printed materials available from Minnemath Center, 720 Washington Avenue S.E., Minneapolis, Minn. 55455

*** available from The Judy Company, 310 North Second Street, Minneapolis, Minnesota 55401

Notes on Seed and Plant Experiments

(Lessons 1 and 2)

It is best to buy seeds from a reputable seed company, though some teachers have had good results with dried corn and beans purchased at grocery stores. Whatever your source of supply, pre-test your seeds at home, so that you can get others if necessary. Soaking the dry seeds overnight will speed up germination. Soaking for longer periods does no harm but children have to be more careful in planting so they do not break off the sprout.

Besides corn and bean seeds, you will need a few whole potatoes and whole onions. In some parts of the country such products are treated with growth-inhibiting chemicals, so look for signs of sprouting before you buy. The local Farmers Market should be a good source for viable potatoes and onions if you cannot find any at your grocer's.

Some children have never seen a bean plant or even a bean pod and have no idea how beans grow. Some children have seen only dried bean seeds, or frozen or canned green beans that have been cut in pieces. It will be interesting to the children if you let a few wax bean plants grow to maturity. The plants will first flower and then bear beans in pods.

Consult the MINNEMAST Handbook, Living Things in Field and Classroom, for other useful information about plants.

BIBLIOGRAPHY OF BOOKS, FILMS

BOOKS ABOUT PLANTS — for the teacher

Baker, Samm Sinclair; The Indoor and Outdoor Grow-it Book; Random House, N.Y., 1966. Many interesting ideas for classroom use.

Minnemast; Living Things in Field and Classroom; 1967.

— for the children

Fenton, Carroll Lane and Herminie B. Kitchen; Plants that Feed Us; E.M. Hale and Co., 1961. Good illustrations. An interesting and unusual book on cultivated plants that would tie in with social studies.

Jordan, Helene J.; How A Seed Grows; Thomas Y. Crowell Co., N.Y., 1960.

Podendorf, Illa; The True Book of Plant Experiments; Children's Press, Chicago, 1961.

Selsam, Millicent E.; Seeds and More Seeds; Harper and Brothers, 1959.

Selsam, Millicent E.; The Plants We Eat; Wm. Morrow and Co., 1955. Interesting material about domesticated plants.

Zion, Gene; The Plant Sitter; Harper and Brothers, N.Y., 1959.

BOOKS ABOUT TIME — for the children

Hart, Jane; Let's Think About Time; Hart Publishing Co., N.Y., 1965. Second graders can read this material.

McGinley, Phyllis; Wonderful Time; J.B. Lippincott and Co., Philadelphia, 1966. Poetry about time, motivates thinking about time.

Reck, Alma Kehoe; Clocks Tell Time; Charles Scribner's Sons, N.Y., 1960. Descriptions of many kinds of clocks on a simple level.

Rockcastle, Verne; Keeping Time; Cornell Science Leaflet, Volume 59, Number 3, 25 cents. Address: Building 7, C.U. Research Park, Ithaca, New York, 14850.

Ziner, Feenie; The True Book of Time; Children's Press, Chicago, 1956. Makes effective use of time lapse photography and revealing closeups to give children a new approach of the marvels of plant growth.

FILMS

Cecropia Moth; Martin Bovey Film Producer. The life cycle of a cecropia moth is presented with great clarity. This is a creative film showing the development of the moth in parallel with the blooming of different plants throughout a summer...beautifully done.

What Plants Need for Growth; Encyclopedia Brittanica Films, 1150 Wilmette Avenue, Wilmette, Illinois 60091. Simple laboratory experiments are performed to illustrate the basic needs of plants--how water, light, minerals, air and warmth affect plants and to show how plants react to favorable and unfavorable conditions. Children are encouraged to set up similar experiments and to care for plants of their own.

Wonders of Plant Growth; Churchill Films, D.C. Heath and Co. An eight year old girl and a six year old boy plant different kinds of seeds and observe their growth over a period of weeks. Plant growth from roots, stems, and leaves is also shown. The children in the film work independently.

NOTE: The films are not referred to in the lessons, but the children will benefit a great deal from seeing them. When you obtain the films, show them during the teaching of Section I. They will reinforce and extend the concepts being developed in that section. The Cecropia Moth, for example, will show the children that animals, as well as plants, change with time.

INTRODUCTION

In previous MINNEMAST units the children have had experience in observing and describing some changing and unchanging properties. In this unit we want them to focus their attention on the way two changing properties in a system are related to each other. The children are guided to discover the relation between two changes by setting up a number of experiments. In an early experiment the children plant corn. They observe that there is a change in the height of their plants that is related to the change in the number of days since planting. Similarly, as they drop marbles into a container of water, they see that with each change in the number of marbles, there is a change in the height of the water, and that there is a relation (or rule that operates) between the two changes.

Relations between changes like these are called functional relations. If measurements of the changes can be made, the relation can be vividly shown on a graph. Therefore the children are given experience with several different methods of graphing the changes. (The stages in the development of graphing skills are outlined on the next page of this introduction.)

But even where measurement is difficult or impossible, the relation between changes can still be investigated by observation and/or experimentation. For example, the children do an experiment where they let one potato sprout in the light and another in the dark. It would not be difficult for them to measure and compare the longest sprout on each potato, but it would be impossible for them to measure precisely how much light (or heat) each potato received during the growing period. In such a case, the children can still observe the rule (the functional relation) that operated. They can make a fairly accurate statement saying that the potato that had less light had the longer sprout, or that there is a relation between darkness and the rate of growth.

The concept of functional relations is emphasized at this point in the curriculum because it is basic to man's attempt to understand the world around him. Ability to recognize and interpret the relation of one change to another and to express that relation in concise form is an important aspect of scientific and mathematical investigation. The limited understanding which the child acquires now will aid him in his attempts to explain his environment. His understanding will gradually be extended as his studies continue.

To bring out the advantage of graphing in helping to visualize functional relations and to record and communicate data, the children are given many opportunities to plot their measurements on grids. Stages in the development of this skill in this unit are given below.

Stages in the Development of Graphing

1. Paper strip lengths, measured by direct comparison, are used to represent plant heights vs. roughly equivalent time intervals. Example: Each child cuts a strip of ticker tape each day to correspond to the height of his growing corn plant. He pastes these unnumbered lengths of tape side by side on a grid where the intervals mark the number of days since planting.

2. Paper strips measured by direct comparison are then measured with a centimeter scale, and the numerical measurement is communicated. Example: Each child keeps a record in centimeters of his plant's daily height. He exchanges this data with his neighbor, and both are able to cut and paste strips to the right lengths from the data.

3. A strip marked with a centimeter scale is used for measurement, cutting out one of the steps above. Example: Each child cuts strips marked off in centimeters to correspond to his plant's daily height. When he pastes these numbered strips on a grid, he (and the others) can see that it gives the plant height vs. days since planting.

4. The length data is plotted on a grid without pasting on paper strips. The appropriate length is measured on the grid paper with a centimeter scale. Example: Each child marks off the daily height of his plant in centimeters above the number of days, which are marked off along the horizontal axis.

5. Coordinates are added to the vertical axis. Example: X-axis is now numbered on the grid lines, instead of in the spaces between them. Y-axis now only represents centimeters, where previously it marked off those measurements.

6. Ordered pairs are plotted. Example: Child collects his data, gathering a record of two variables. He then plots it by "going over," to find the first coordinate, "going up" for the second coordinate, and marking the point at the intersection of the two grid lines.

Some of the early activities lend themselves particularly well to the earlier stages of plotting. In later activities, various stages are suggested as appropriate, but you should use your own judgment, moving to more advanced stages as soon as you feel your class is ready. Stage 6 is developed in Section 4 and will be reinforced repeatedly in later work. The work in plotting is intended to give the children skill in graphing but, more important still, to emphasize the functional relations depicted by the graphs.

Many functional relations involve a measurement of the duration of an event. Therefore the unit includes several lessons which review the determination of duration and its association with clock reading. It is suggested that you use these lessons as indicated in the unit plan on page 6, but carry the activities of Lesson 11 (Twelve-Hour Clock -- Minutes, Hours) on throughout the balance of the year, increasing the complexity as your class progresses.

This unit includes several activities involving functional relations where measurement of a time interval is not a factor. Examples are found in Lesson 15, in which the change of depth of water is associated with the number of submerged marbles, and in the series of lessons relating the weight of an object to its volume -- found by water displacement. The lessons on weight and volume illustrate not only functional relations which are independent of time measurements, but also lay a foundation for work on density to be developed later. Density itself should not be discussed at this time.

NOTE: For a brief summary of the unit objectives, turn to page 163.

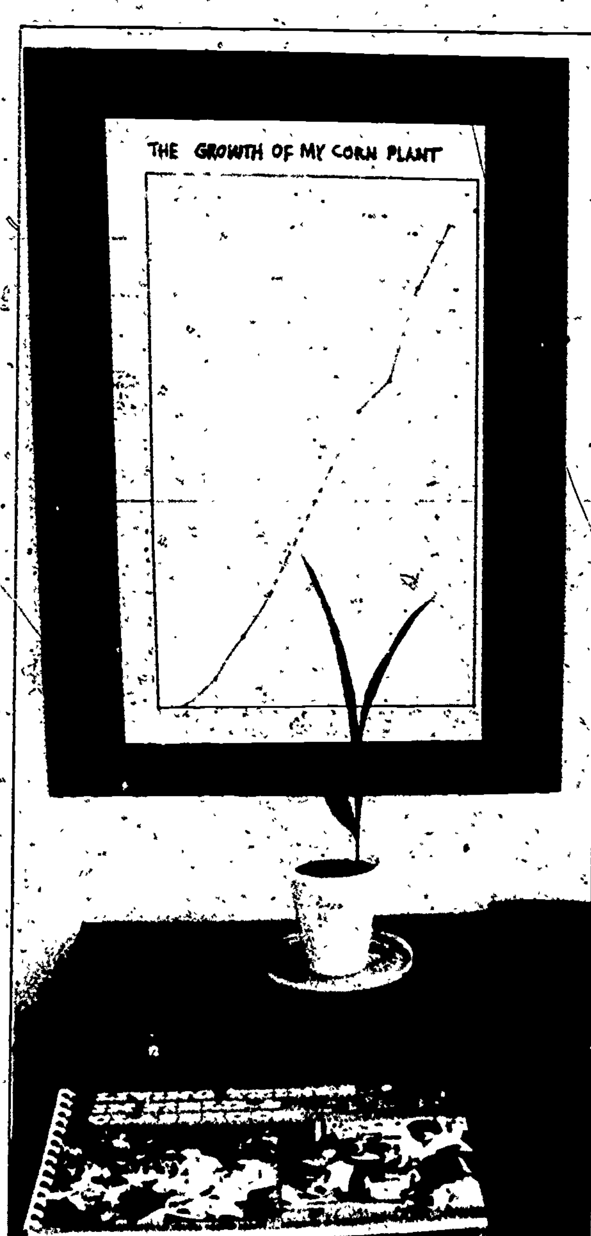
NOTES ON TEACHING THE UNIT

Some of the activities of Section 1, Plants, will extend over many days, though often requiring only a very few minutes each day. However, some things in this section should be done on certain days of the week. The lessons of Section 2, and ensuing sections, are to be carried out concurrently with Section 1, on days when the plant activities do not require much time or have been completed. The lessons of Sections 2 through 5 need not be done on particular days, but their sequence should be maintained unless you feel that some are not necessary for your class.

Specifically, the planting of the corn in Lesson 1 should be discussed and done on the first Thursday that the unit is used, with corn kernels you have soaked over the previous night. The activities of Lesson 2 should be done on the first Friday. One of these activities requires wax beans soaked over Thursday night. Additional pre-soaked beans should be planted each day until the first specimens have grown to the point where they have their first leaves. Then a typical bean plant from each day's planting should be dug up and the set arranged in order of the number of days since planting.

Planting the pre-soaked corn on Thursday (and the pre-soaked wax beans on Friday) insures that by Monday there will be sufficient growth of the plants to permit the first measurements. Worksheets are provided only for recording the measurements of each child's corn plant. (The development of other plants can be recorded on the chalkboard.) The period of observation and measurement extends over three weekends, so that predictions about the probable growth can be made every Friday and checked against the actual measurements on Monday. On the first weekend, the children can only guess at what will happen to their seeds. But by the next Friday, after measuring their plants for five school days, they can perhaps make more sophisticated estimates of the amount of growth that will take place. When, on the third Monday, they have checked the previous Friday's predictions, the plants may be discarded -- but only after a full discussion of the changes that have taken place in the plants.

The suggested schedule for teaching (on pages 6-7) should be helpful in showing you how to schedule the lessons of the unit so that the two daily periods devoted to MINNEMAST can be used most effectively. It shows a plan where you start teaching the unit on a Monday and explains how to modify the plan for other starting days.



SUGGESTED TEACHING SCHEDULE

If you start the unit on Tuesday or Wednesday, do Lesson 8 that day and displace the lessons of Section 2 accordingly on the schedule -- conducting Lesson 8 or Lesson 9 on Wednesday and 9 or 10 on the following Tuesday, etc.

If you start the unit on Thursday, do Lesson 1 that day and do not start the lessons of Section 2 until the following Tuesday.

Wherever you see a blank on the right side of the page, it means the lessons of Section 1 will take up the two full MINNEMAST periods for that day. When the plants are discarded, which occurs on a Monday (the eighteenth day since planting the corn), you will have no further need for this schedule.

	Section 1	Section 2, etc.
M		Lesson 8
T		Lesson 9
W	Soak corn kernels overnight for Lesson 1.	Lesson 10
Th	Lesson 1: discussion; children plant pre-soaked corn; soak wax beans for tomorrow.	________
F	Lesson 2: experiments with potatoes and onions; children plant soaked wax beans; predictions about changes in the plants; assign a child to soak a few wax beans on Sunday night for Monday's planting.	________

Section 1, continued		Section 2, etc.
M	Lesson 3: first measurement and record of height of corn seedlings; check predictions; observe changes in other plants, making chalkboard record of growth of wax beans and of other plants, as desired; soak a few more wax beans.	________
T	Continue plant observations; measure and record corn growth; plant soaked beans; chalkboard record of beans, etc.; soak a few more beans.	Lesson 11
W	Same as T	Lesson 12
Th	Same as T and W	Lesson 13
F	Lesson 4: predicting, but otherwise same as T, W, and Th; assign a child to soak beans on Sunday night.	Lesson 14
M	Lesson 5: check predictions; plant a few more soaked beans; soak a few more.	Lesson 15
T	Continue plant observations; measure and record corn growth; plant beans; soak beans.	Lesson 16
W	Same as T	Lesson 17
Th	Same as T and W	Lesson 18
F	Lesson 6: predicting, but otherwise same as T, W, and Th; last planting of beans.	Lesson 19
M	Lesson 7: check predictions; final discussion of plants; discard plants.	________
T	________	Continue unit sequentially.

SECTION 1 PLANTS

PURPOSE

- To give the children some experience with living plants.
- To have the children observe, describe and compare changes in the plants.
- To teach ways of representing and recording the changes.
- To teach the making and reading of graphs.
- To convey the idea that graphs are "pictures" of certain relations between changes.
- To show how graphical records of relations can be used to describe and predict changes.

COMMENTARY

Lesson 1 involves planting corn kernels that you have soaked overnight to speed up germination. It is best to schedule this lesson for a Thursday, so that by the following Monday there will be enough plant growth for the children to measure. Therefore, if you plan to start teaching this unit on any other day, begin with Section 2 and return to this lesson on the first Thursday.

Lesson 2 provides some experiments the children can do to observe changes in potatoes, onions and beans. The lesson provides an excellent opportunity for the children to make up and try other experiments and they should be encouraged to do so with whatever variety of materials you can provide. The children who participate in Activity E of this lesson continue to plant a few wax beans (soaked overnight) each day for about ten days.

After the first seeds are planted and the experiments set up, daily plantings, observations, measurements and discussions will not take up much class time. Use the remaining time to teach other lessons of the unit (see Suggested Teaching Schedule, pp. 6-7), but reserve a full period or two for a final discussion of the changes just before the plants are discarded. If possible, keep the corn plants until the eighteenth day after planting (a Monday) so that the children can check the previous Friday's predictions, but dispose of other plants whenever you think appropriate.

Lessons 3 through 7 are concerned only with the corn seedlings. In these lessons each child not only has the pleasure of working with a living, changing thing and of speculating about its development, but he also is given the experience of measuring it, and recording and graphing the measurements. Each child should become aware that the height of the plant increases as the days pass, and he should see the connection between the numbers recorded in a table of plant growth and a graph made from such a table.

The child should discover that by using a graph he can "look back" to see how the plant has grown, and even venture to predict how it will continue to grow. He ought to learn that a graph is, in a sense, a picture of the relation between the height of a growing plant and the duration of its growth since planting. He should also discover that the curve that shows his plant's growth is different from that of other similar plants. This illustrates the fact that living things vary.

NOTE: In any work with plants, seeds should be tested ahead of time to determine the percentage of germination. If you test the planting procedures at home first, you will also be able to anticipate the children's problems and questions, and to make a few measurements to get an idea of how the plants will perform. You may also want to start a few extra plants in case some children are not successful with theirs. If each child plants three corn seeds in his paper cup, at least two should sprout and one can be measured, the other being kept for a spare. Needless to say, no two plants will be exactly alike, but this in itself demonstrates the variation inherent in the biological world. Seeds will germinate more rapidly and are more easily measured in sand, but soil may be easier to obtain. If so, use it. For more help and suggestions, consult the MINNEMAST Handbook, Living Things in Field and Classroom.

Lesson 1: PLANTING CORN

Conduct this lesson on a Thursday. Prepare for it by soaking overnight sweet corn kernels (three per child and a few spares) and a few kernels of other kinds of corn, such as popcorn, calico corn or field corn.

In Activity A each child will plant three pre-soaked sweet corn kernels in a small container of sand or soil in order to have at least one healthily growing plant to tend, observe, describe and measure during the next two weeks. Soaking the corn kernels speeds up germination, so that by Monday each child should have one measurable plant.

The diversity of Activity B depends on what materials you can provide. It is desirable that the children experiment by planting some unsoaked kernels of sweet corn, by planting a few other kinds of corn for comparison, by testing growth in soil against that in sand, and by seeing how a corn plant grows (1) in the dark; (2) in extreme heat and (3) in drought.

Rather full discussions precede and follow the plantings. Suggestions are given in the activities for the direction of these discussions, but the children should contribute as much as they can to each. You may also wish to have them draw pictures of what they think their seeds will become; and later of the plants as they see them.

Corn is a very important American crop. It is processed in many ways, some of which are familiar to children (corn bread, corn flakes, corn syrup, popcorn). Corn has an interesting history, too; and it has sometimes been used as a decoration in North and South American architecture. You may wish to take advantage of the children's interest in their corn plants by having them investigate some of these areas in their social studies (Optional Activity C) during the weeks they are observing and measuring their corn plants.

MATERIALS

-- for each child --

- 3 sweet corn kernels soaked overnight
- 1 paper cup or other small container filled to within one inch of the top with sand or soil moist enough to cling when squeezed in the hand
- tape or label for the child's name

-- for the class --

- a few soaked and unsoaked kernels of various kinds of corn
- a few containers of sand
- a few containers of soil
- plastic wrap
- a few paper bags

-- optional --

- pictures and books about corn

PREPARATION

Soak overnight the three sweet corn kernels required for each child in Activity A, and some of the other corn kernels you plan to have the children use in Activity B. Moisten the sand or soil to be used and fill the paper cups or other small containers with it before class. Select an area out of the direct sunlight where the children's plantings will thrive. Except in the experiments of Activity B, do not let the children place plants on radiators or in any locations where they will suffer from excessive heat or cold.

PROCEDURE

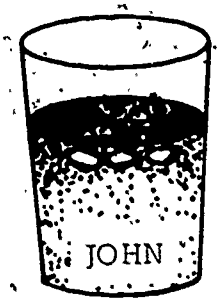
Activity A

Have the children speculate about what will grow from a sweet corn kernel, how large it will get, how long it will take to reach a certain size, and so on. Let them do most of the talking, but focus their attention on several ideas:

(1). Many things change from day to day. (2) Living things change in a way we call growing -- which means to become larger in some way. (3) Plants are alive and grow.

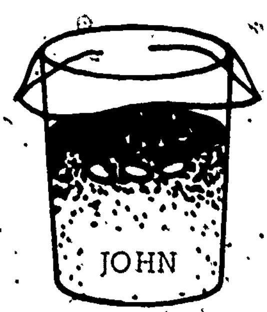
Then ask the children how they could find out how much the seeds will grow and how they will change. They should suggest planting the corn and observing the growing plants.

When the children have suggested planting, ask them to think about what would make up a plant-growing system. They should be able to say that sand or soil, water, and light or warmth are necessary parts of such a system.



Now give the children a container of sand or soil and a label. Have each child print his name or initials on the label and paste it on the container.

Show the children how to plant their seeds by pushing the seeds down about one-quarter to one-half inch below the surface of the sand, then smoothing the sand over the top. (If the seeds are buried too deeply, the seedling may take longer to reach the surface. A good depth for planting is about equal to the thickness of the seed.)



After the seeds have been planted, ask the children how they could keep the sand moist over the weekend. Then have each child place plastic wrap loosely over the top of the container so that the sand will not dry out.

On the chalkboard, make a record: Soaked sweet corn kernels planted by all students, Thursday, Jan. 5.

Now ask the children where the containers should be placed. (Lead them to choose a shelf or table out of the sun.)

Finally, ask the children to make predictions about what will happen to the seeds they planted. Have them speculate how quickly the plants may grow in the different pots and suggest factors (water, sunlight, warmth, the quality of the seeds themselves) which might affect the rate of growth.

Activity B

In this activity you want the children in each group to use as much ingenuity as they can in thinking of an experiment to do with the seeds. If the children have trouble thinking of plant experiments by themselves, ask them why you soaked the sweet corn kernels which they planted. If the children have no theories, suggest that one group plant some unsoaked seeds as an experiment. Elicit that all the other conditions of the planting must be the same.

Other suggestions:

Ask the children to speculate about how popcorn might look as it grows. Will it be as large a plant as the sweet corn? How can they find out? Have them plant some.

Many plants grow in the desert. What is a desert like? (It is hot and dry.) Do you think popcorn would grow there? How can we find out? Guide the children to plant some popcorn and place it on a radiator.

When you planted your sweet corn kernels, why did I ask you to keep them out of the direct sunlight at first? Does too much heat from the sunlight prevent the kernels from sprouting as quickly? Does it prevent them from sprouting at all? Have the children set up an experiment to find out.

How will darkness affect a seedling's growth? Have the children do some plantings and cover each container with a paper bag. They may be astonished at what happens. The corn seedlings may grow very fast at first, especially if it is warm under the bags, but later -- though they may continue to grow tall -- they will become pale and sickly from the lack of light. Do not tell the children this; let them find out by observing their experiments. No record sheets are provided for the experiments of this activity, but you can help the children keep track of what they have done by marking the containers and by writing the data on the chalkboard.

Activity C (Optional)

Reading, writing and art lessons may be used to take advantage of the children's interest in their plants. (A description of some good primary books is given in the bibliography on page viii.) The children might like to talk about their own experiences with house and garden plants, or try some plant experiments at home. See the MINNEMAST Handbook for suggestions.

NOTE: Read Lesson 2, which you will conduct tomorrow (Friday), so that you can decide how many wax beans to soak, and how many other kinds of beans, potatoes and onions you will need.

Indians Husking Corn

Lesson 2: EXPERIMENTS WITH ONIONS, POTATOES AND BEANS

Conduct this lesson on Friday. Prepare for it by soaking wax and other kinds of beans overnight.

In this lesson, the children observe changes in growing onions, potatoes and beans during two weeks. They observe some effects of environmental conditions on the growth. Small groups (four or fewer children) carry out simple experiments involving one or more of these factors. Two or more groups should be doing the same activity, but interest can be added by having each group use a different kind of onion, potato or bean. Results with the different types of plantings will be somewhat different, but not contradictory. The use of a variety of materials (either different plants, or sand in place of soil) actually will furnish a kind of insurance of some results; and variation in itself is an important characteristic of living things. The kind of potato which sprouts slowly, for example, may be better for keeping in the store, but perhaps not as good for growing a crop. These differences can be exploited in the classroom as points for discussion and speculation.

MATERIALS

Quantities specified for each activity are sufficient for only one group. Double or triple the amounts, as necessary.

- 2 onions, 2 small jars of water, toothpicks (Activity A)
- 4 potatoes, preferably beginning to sprout (Activities B, C, D)
- spring scale or beam balance from Unit 16. If beam balance is used, provide small paper clips or beans as weight units. (Activity C)
- 1 small plastic bag (Activity C)
- 2 small pots of sand or soil, with saucers (Activity D)
- 20 or more wax beans; soak 2 or 3 beans overnight to be ready for each day's planting (Activity E)
- 1 plastic shoe box or pan of soil (Activity E)
- 10 row markers such as craft sticks, plant markers or tongue depressors (Activity E)

PREPARATION

Figure out how many groups will be doing each activity and try to find a variety of onions, potatoes and beans to suit. Onions could include Bermuda, spring, white and red. Potatoes could be Idaho or Ohio. Beans could include wax, lima, navy, green, or pinto. Have the group soak two or three wax beans each night (for ten nights or so) for Activity E.

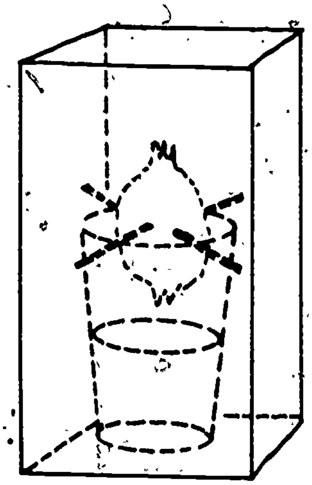
PROCEDURE

Activity A

Group A prepares the two onions. One onion is set above water in a jar in the light and the other is set up in the same way, but kept in a dark place or under a cardboard box or paper bag. Usually within twenty-four hours small roots will begin to appear on the onion kept in the light. The children doing this activity should make a drawing or other record of the onions right after they have been set up, and another after roots appear. There is a lot of root growth before the top develops. If a child should want to place an onion upside down over water, let him try that, too.

If necessary, use toothpicks to hold onions in place.

Onion over Water in Light



Onion over Water in Dark

Activity B

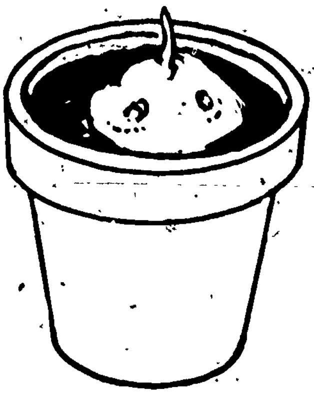
Group B uses whole potatoes. One potato is placed on a table or shelf in the light. A second potato is placed in a dark drawer or cupboard. Within a few days the young sprouts on the potato in the drawer will be longer and paler than those on the one in the light. Only a few of the sprouts will develop. Drawings or other records should be made of several stages of development.

Activity C

Group C uses pieces of potatoes. Cut several cubes about one inch in size, with at least one eye in each cube. Leave the skin on. One piece should be exposed to the air and one should be enclosed in a plastic bag. Keep the latter out of direct sunlight or strong heat. The exposed piece will turn dark faster, shrivel and lose weight due to evaporation. Have the children weigh the pieces with the spring scale or beam balance immediately. Then have them weigh the pieces after several days. The two weights should be recorded so that a comparison of weight changes can be made. Any changes in appearance should also be described.

Activity D

Group D prepares two pots of moist sand and plants a piece of potato (with one or two eyes) in each pot. The eye should be above the sand level. After a record has been made, both pots are to be watered, and one placed in good light. The other should be nearby under a small box or light-proof bag. Within two or three days the sprouts on the piece in the dark will probably be longer and paler than those on the one outside, and sometimes roots will appear on the surface of the one in the dark, especially if the soil is kept quite moist.



Activity E.

Group E is to make a series of plantings of beans to compare plants that have been growing for different lengths of time. The children should prepare a tray of soil and plant in it each day two bean seeds which have been soaked over the previous night. They should mark each row with the date on a craft stick stuck in the soil. (The extra seed is planted to increase the likelihood that at least one plant will develop for each planting.) Care should be taken to cover the beans with no more than one-fourth inch of soil or an amount about equal to the thickness of the bean. The soil should be kept fairly moist and two beans put to soak each night for the next day's planting. Each large container should be labeled with the name of the bean planted in it (wax, lima, navy, pinto, etc.).

Wax Bean Plants

At the end of the first week, reports can be made to the class by each group. These reports can be continued over the next week if interest is sustained.

When some of the beans of Group E have their first leaves, one of the seedlings from each day's planting can be dug up a and the whole series arranged in order of the number of days since planting. The stages of development can be observed and discussed, and the root structure studied. (Let some plants continue to grow so the children can see they produce first flowers, and then a new generation of beans.)

Suggestions for Discussions:

In Lesson 1 the children defined what they thought were the essentials for a plant-growing system. In Activity A of this lesson, one onion had only one element (water) which was considered necessary. The children should discuss what happened to the onion thus deprived, as well as to the onion that had two elements (water and light). They should compare the growth of the two onions and speculate further about the absence of soil: Would planting in soil, with water and light have made a difference? Consult Group D.

The children who did Activity B should note that one potato had none of the essentials of a plant-growing system, not even light. They should discuss how the light affected growth of the sprouts and try to explain why the potato in the dark sprouted faster. (It probably was warmer inside the drawer or cupboard.) Did the potatoes perhaps have water within them? Let Groups C and D contribute to this.

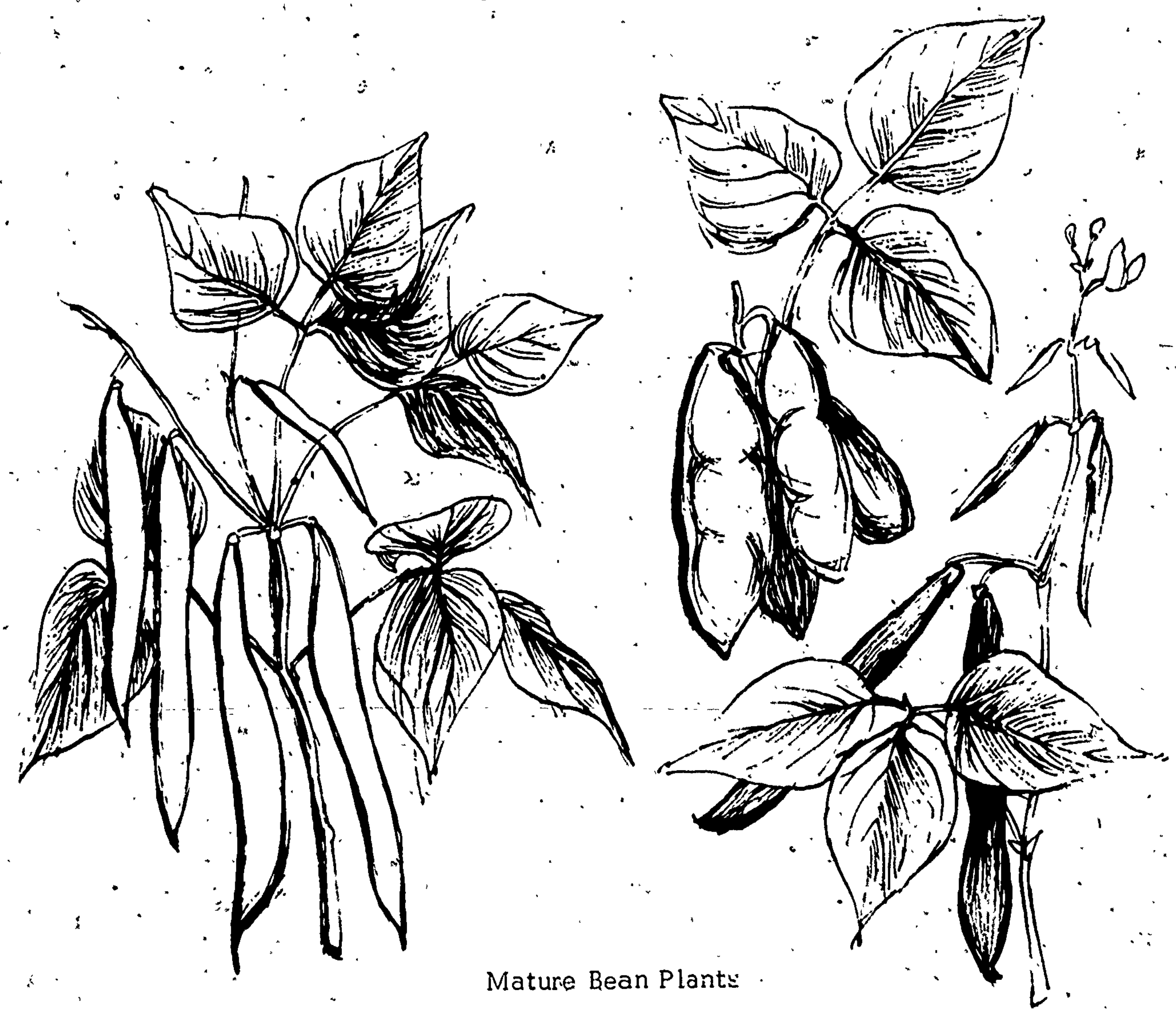
Group C was not trying to grow anything. Their discussions should concern how the exposed piece of potato dried up and discolored more quickly than the piece protected by the plastic bag, and why. And chiefly they should be concerned with comparing the changes in weight of these partial plants.

Group D should discuss what the deprivation of light did to the potato that had every other essential for growth, try to find out why it thrived, and compare its growth with that of the potato that had light.

The children who did Activity E should make records of the growth of the beans. If various kinds of beans were planted, the growth of the different kinds should be compared. The results with different kinds of beans will vary somewhat, but will not be contradictory.

The general conclusions about the plant experiments should be that plants vary a great deal in their growth. Some seem to thrive (at least for a while) under conditions which would not be at all favorable to others. Some kinds of plants grow faster than others, though given the same conditions. Even samples of the same kinds of plants vary considerably in the way they grow. The children should especially note that the duration since planting (or since setting up an experiment) has a relation to the changes in the plant.

NOTE: Plan on conducting Lesson 3 next Monday. This first instruction in observing the changes in the plants, and in measuring and recording measurements, will probably take up the entire MINNEMAST time for that day. But, after that, arrange for a set time each day for observation and measurement. This should not require more than a few minutes per day for the next two weeks, or until such time as you decide to hold a final discussion and discard the plants.



Mature Bean Plants

Lesson 3: MEASURING AND RECORDING HEIGHT OF CORN SEEDLINGS

Begin this lesson on Monday, providing there is available for each child a corn plant at least a half-centimeter tall. Measurement should be made and recorded in two ways: (1) by cutting a paper strip the height of the plant and mounting it on Worksheet 1, the record sheet; and (2) by measuring the height in centimeters with a ruler and entering the measurement on Worksheet 2, the record table. The children will probably need help with the measuring and recording for the first time or two, but later they should be able to do these things themselves. For consistent results, the plants should be measured at about the same time each school day.

Corn Plants Growing in Sand

MATERIALS

- 1 corn seedling in container for each child
- Worksheets 1 and 2
- roll of ticker tape
- rulers with centimeter scale (at least one for each two children).
- cellophane tape or paste
- scissors
- small pieces of yarn or string

PROCEDURE

Activity A

Distribute the plant containers and have each child remove the plastic wrap from the top. Allow some time for the children to examine the plants, as they are usually quite excited about the emergence of the young seedlings. After that, ask for suggestions about determining how tall each plant is, which is the tallest, and so on. Visual comparison of the plants, use of paper strips, and use of a ruler are all likely suggestions.

If germination has been successful, each container will have two or three seedlings but provide some of your spares, if necessary. Have each child select his most vigorous plant to measure and indicate which one it is by marking the side of the container nearest to it with a crayon or pencil, or by tying a piece of yarn or string loosely around the base of the plant. Save the other seedlings to use in case of accident and also to demonstrate that, even in the same pot, the plants will vary in size and growth rate.

Next ask for suggestions about recording the height of the selected plants, so that the measurements will not have to be remembered from day to day. Again there are several suggestions the children might make. But say that you have decided they should record the measurements in these two ways:

1. Every day each child will cut off a paper strip to match the height of his plant that day. He will then paste these strips in place on Worksheet 1, the record sheet.

2. Every day each child will measure his plant's height to the nearest half-centimeter with his ruler. The plant's height will be entered in the table on Worksheet 2.

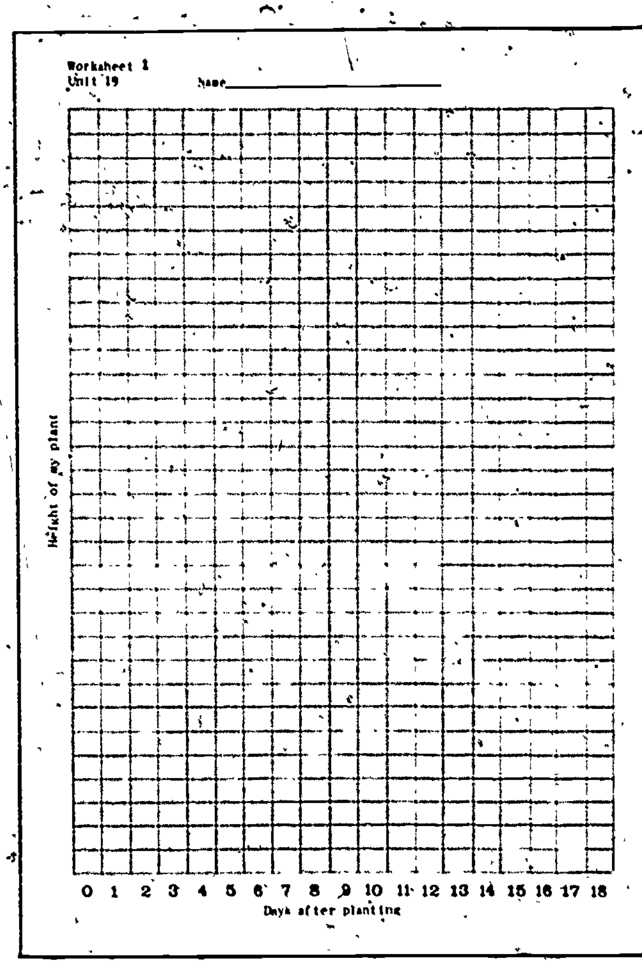
After the children have briefly discussed measurement and comparison, show them how to measure with the paper strip. With one hand, hold the strip vertically beside the plant with one end touching the sand. Fingers of the other hand can be used to mark off the place on the strip that the top of the seedling reaches. Holding the fingers pinched together to mark this place on the strip, move it away from the plant, and snip the strip just below the fingers. Explain that you have moved the strip away from the plant before using the scissors in order to avoid cutting the plant. (You may prefer to have the children mark the strip with a pencil, instead of with their fingers. Or two children might need to work together -- one child holding the strip and the other marking it.)

Now each child should cut his own strip to the height of his plant. Have the name of the day (or the calendar date) and the time of day written on the strip. Next have the children mount the strips on Worksheet 1, but first ask, "Where should we paste them? How many days has it been since we planted the seeds?" If the planting was done on Thursday, Monday is the fourth day. "Day 0" is the day of the planting. It is now "Day 4." The strip, therefore, shows how tall the plants are on the fourth day after the children planted the seeds. (For contrast with the worksheet, have the children color the tape with crayon, if you wish.)

Worksheets 1, 3 and 5 are identical except for the worksheet number.

Worksheet 2 spreads over two facing pages in the student manual. Each child should remove the pages and cut and paste them together as indicated.

All worksheets on which corn growth records are kept are used again and again throughout this section. They should be collected after each daily recording so they will not be lost. You may wish to display some different ones each day, along with the plants they describe.



Worksheet 2
Unit 19 Name

Days since planting	4	5	6	7	8	9	10
Date							
Clock time							
Height of plant							
Predicted height, in centimeters							

Paste Here

Second half of Worksheet 2. Tear out and paste to first half.

Cut Here

11	12	13	14	15	16	17	18

Next show the children how to measure the plants' heights with the centimeter ruler. The ruler is set, zero end down, on the sand beside the plant and a reading of the height is made. (If MINNEMAST rulers are used, you may ignore the length below zero or have the children very carefully push this length into the sand.) If a plant's height falls between two numbers on the ruler's scale, a child should record the plant's height to the nearest half-centimeter ($1\frac{1}{2}$ cm, etc.)

Each child's measurement of his seedling should now be recorded in the table of Worksheet 2. The row for days represents days after planting the seeds. The blank boxes are to be filled in each day with numbers that represent the height measurements.

Each succeeding day, allow a few minutes for the measuring and recording of the plant height.

Optional Activities

1. An optional project which you can do if you have a suitable camera -- especially a Polaroid camera -- is to take a picture of one (the same) plant each day, and make a display of the photos. Put grid paper behind the plant. Mark, with chalk, the spot where the camera and pot are placed. Be sure to use the same plant and to take the picture at the same distance, angle and time each day.

2. As you can see, the records the children will be keeping are numerical tables and height graphs. Days are numerically recorded as "Day 1," "Day 2," etc. You might like to make a large class display bar graph, which would record the day of the week below the day number. This could be a bit fancier -- you might draw a picture of the plant instead of recording its height by length of a strip. Use a plant you set aside to measure, or one of the children's.

Lesson 4: PREDICTING CORN GROWTH

Conduct this lesson on Friday. The children should measure their corn plants and record the data, just as they have been doing each day, but today they should do some predicting, too. The coming of the weekend provides an excellent opportunity to introduce the idea of trying to predict what the heights of the plants might be on Saturday, Sunday and Monday. (In Lesson 5 the children will see that Monday's prediction can be checked against Monday's measurement, but that Saturday's and Sunday's measurements can only be estimated from the graph.)

MATERIALS

- the same as for Lesson 3

PROCEDURE

After the children have made their daily measurement of the plants, ask them to look at Worksheet 1 where they have recorded their measurements with paper strips. Ask them what the plants will be doing on Saturday and Sunday when there is no school. The children probably will say that the plants will be growing.

Ask the children to look at their paper strips and see how much the plants have grown so far, and how much taller they think the plants will be on Saturday. There should be some discussion at this point, since records of different plants will not be the same, but the children should see that most plants grew a little taller every day and probably will continue to do so on Saturday, Sunday and Monday.

Ask each child to predict how tall he thinks his plant will be on Saturday by making a pencil mark on the worksheet wherever he expects the top of the paper strip will be. This mark should be in the column just to the right of the Friday measurement. Have each child similarly indicate how tall he thinks his plant will be on Sunday and on Monday. (No entries of the predictions should be made on Worksheet 2.)

Make sure the plants have been adequately watered for the weekend, but do not wet the sand so much that water remains on the surface. If there is a danger that the plants might dry out, place plastic covers over them rather loosely, leaving a little opening for some ventilation. Remove the plants from window sills if there is a chance they will be too cold there.

Mature Corn Plant
Grown Under
Optimal Conditions

Lesson 5: CHECKING THE PREDICTIONS

Conduct this lesson on Monday, the eleventh day since the planting of the corn kernels. When the children make their regular daily measurement of the corn plants, be sure they first compare their new strips for Monday with their predictions for that day, and then paste them in the appropriate column of Worksheet 1, leaving two blank columns for Saturday and Sunday.

Activity C of this lesson requires more predicting by the children. It is hoped that they will come to realize that data from previous measurements are useful in making the predictions about growth.

Activity D shows the children the advantage of the centimeter record for communicating the results of measurements. This is Stage 3 in the development of graphing (outlined on pages 2 and 3 of the introduction to the unit).

MATERIALS

- the same as for Lessons 3 and 4, plus:
- Worksheet 3 (the same as Worksheet 1, but used here for predicting only)
- Worksheet 4 (a sheet of centimeter scales to be cut into tapes)
- Worksheet 5 (same as 1 and 3, but used for mounting centimeter tapes)

PROCEDURE

Activity A

When the children make this Monday measurement, they may be astonished that the plants have grown so much. Displaying a graph, ask:

HOW DOES IT HAPPEN THAT THE MONDAY MEASUREMENT IS SO MUCH LARGER THAN THE FRIDAY ONE? (It includes two extra days' growth -- Saturday's and Sunday's.)

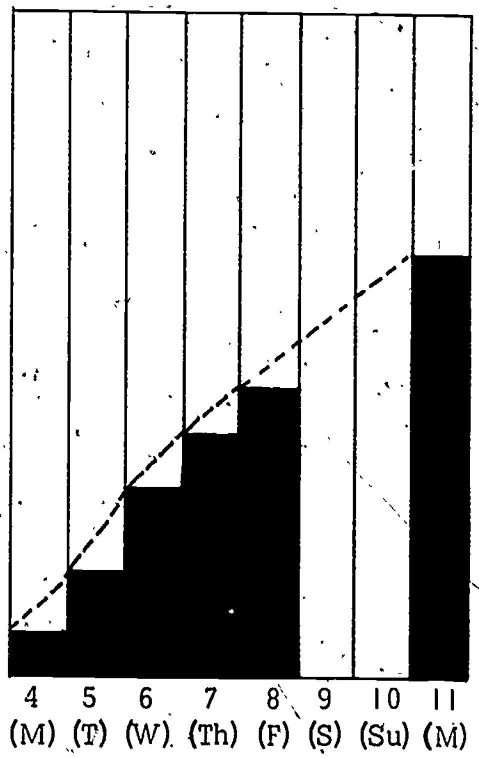
As a matter of general interest, conduct a survey about the accuracy of the predictions that the children made for Monday. You will probably find there was a great range.

HOW DID WE CHECK OUR PREDICTIONS FOR MONDAY? (By comparing the predictions with the Monday measurements.)

It is important here that a distinction be made between a prediction that can be checked by direct measurement (the Monday one) and those that cannot be checked by direct measurement (the Saturday and Sunday ones). In the next activity the children will see that they can only estimate from a graph what the Saturday and Sunday heights were.

Activity B

The children will see the need here to "look back" to estimate the growth on Saturday and Sunday. Show them how to dot a line (free-hand) connecting the tops of all the pasted strips. This line will naturally bridge the Saturday and Sunday gaps in the record.



Ask the children whether they can tell from their graphs how tall their plants were on Saturday and on Sunday. They should suggest that the places on the dotted line that are above the Saturday and Sunday columns, Days 9 and 10, ought to show these heights. (This is interpolation, whereas their predictions were extrapolation, but do not use these words for the children.)

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Activity C

Here the children have another opportunity to predict growth. Ask:

WHAT WILL THE CORN PLANTS BE DOING BETWEEN NOW AND TOMORROW? (They will be growing, getting larger and taller.)

HOW TALL DOES EACH OF YOU THINK HIS PLANT WILL BE BY TOMORROW? BY THE DAY AFTER THAT? BY NEXT WEEK?

HOW COULD WE KEEP A RECORD OF ALL OUR PREDICTIONS?

Lead the discussion to the idea that each child could mark his predictions on a worksheet by putting a mark where he thinks the top of his plant (the top of his tape) will be on that day. Suggest that such predictions could be made for each day.

Have the children use Worksheet 3 for their predictions. Tell them to make crayon marks for each of the next seven days, predicting how tall they think their plants will be. The crayon mark for each day should be made where each child thinks the top of his measuring tape will be on that day. The children may find it helpful to their predictions to pencil in marks showing where the tops of the tapes were on previous days; but let them know that they will have an opportunity each day to change the remaining predictions if they think they can improve them. They can make each new set of predictions with a different color of crayon to differentiate between them.

After a few days, the children should realize that their more complete actual records are helpful in making better predictions. However, toward the end, the growth of the corn seedlings may slow down, and the children may discover that their predictions are becoming less reliable. If this happens, they will have made an important discovery -- that predicting beyond the range of the data (extrapolation) may be unreliable.

In all discussions of the records of the changes in the height of the plants, emphasize that there is a relation between the number of days since planting and the height of the plant. This relation permits us to (1) make estimations of what the height of the plant may have been between measurements that have already been made, and (2) make estimations of what the height of the plant is likely to be in the future when measurements have not yet been made. Such considerations introduce the idea of a functional relation between two changing quantities. But at this time it is more important for the children to see that there is a relation and to appreciate its usefulness rather than for them to be able to define the concept.

Activity D

This activity shows the children how the use of a standard unit of measurement helps in communicating measurement results. Each child learns this by constructing, from his neighbor's data on Worksheet 2, a new graph with strips of paper scaled in centimeters.

Assign partners and ask them to exchange their copies of Worksheet 2. Say that each child will now use his partner's measurements to make a new graph of the data given him on Worksheet 2. He will do this by looking at each day's measurement, then cutting a strip of that length from Worksheet 4 and pasting it in the correct column of Worksheet 5. Point out that Worksheet 5 is labeled in exactly the same way as Worksheets 1 and 3, so there should be no difficulty in finding the appropriate column for each strip. Remind the children to leave two blanks for the missing measurements -- the Saturday and Sunday data.

When the new graphs are completed, ask the children to connect the tops of the centimeter-scaled strips with a freehand line. Needless to say, these lines will not be too accurate, but they are preferable to lines drawn by a ruler because: (1) graphs of growth can never be exact, as many of the intervening points are unknown, and (2) mechanically, rulers would be difficult and frustrating to use here.

Now have the partners compare the new graphs with the original strip graphs (Worksheet 1). Hopefully, they will

Worksheet 4
Unit 19
Name______________________________

25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

have approximately the same shapes. While there will be some variations because of mistakes in measuring, plotting, pasting, etc., the children should see that the numbers permit them to exchange information easily.

Ask:

> HOW COULD YOU GIVE YOUR PARTNER THE INFORMATION ON WORKSHEET I IN A LETTER? (By sending pictures of the plant, strips of tape, graphs, measurements.)
>
> HOW COULD YOU GIVE THE INFORMATION BY TELEPHONE? (Only by giving the measurements.)
>
> WHY DO THE GRAPHS ON WORKSHEET I AND ON WORKSHEET 5 LOOK ALIKE? (They are both records of the same plant.)

Encourage the children to estimate points in between the data points, such as height at midnight of a certain day, etc.

During the rest of the week the children will continue their daily measurement, extend their graphs, and make predictions. On Friday they will make predictions again and prepare the plants for the weekend as in Lesson 4.

Lesson 6: PREDICTING WITH MORE INFORMATION

This lesson is essentially a repetition of Lesson 4, and should be conducted on Friday, the fifteenth day since the planting of the corn. The children may be more accurate in their predictions for this weekend because of their experience. However, the height increase by Monday may not be as dramatic this time. The rate of growth depends greatly on the temperature of the room, the weather outside, the nutrients in the sand or soil, and the age of the plant.

MATERIALS

- corn plants
- Worksheets 1 and 2
- colored pencils or crayons

PROCEDURE

Activity A

When the children have made their daily plant measurements, ask them to look at the records for the previous weekend to see how accurate their predictions were. Tell them to estimate how tall their plants will be on the coming Saturday, Sunday, and Monday. Have them do this by again making a pencil mark on the paper where they think the top of the paper strip will be for each day.

Activity B

Ask the children to predict in centimeters how tall they think the plants will be. Have them enter these predicted measurements in their record table (Worksheet 2) in some special way -- perhaps by writing the number of centimeters with a colored pencil in the prediction boxes -- so that they will know these are predicted, rather than actual, measurements.

Take the usual precautions in preparing the plants for the weekend, with extra water, and shelter from the cold, if necessary. Remember that too much water may harm the plants.

Lesson 7: CHECKING THE LAST PREDICTIONS

This lesson is like Lesson 5. It should be conducted on the last day that the corn plants are observed and measured. This should be Monday, the eighteenth day since the corn kernels were planted.

After this lesson the plants are discarded or sent home with the children, and you need no longer schedule lessons from other sections to fit in with the plant lessons.

MATERIALS

- corn plants
- Worksheets 1-5
- centimeter rulers

PROCEDURE

Activity A

When the children make their Monday measurements, be sure the paper strips are mounted in the correct columns, leaving two blank columns between the Friday and the Monday measurements. Because the children have done the procedure before, they will know that they can check their Monday predictions by measurement and that by "looking back" and dotting in connecting lines they can estimate what the measurements were on Saturday and Sunday.

Start a discussion of how the growth of the plants over the two weekends compare. Guide the talk so that you can find out how well the children understand the use of the strip records and the connecting lines as a means of predicting and checking predictions. The children should also understand clearly, by now, that the strips and the records in their data tables are ways of recording the past growth of their plants.

It is important to repeat the distinctions between predictions which can be checked by direct measurement and the predictions which can only be checked by estimated measurements derived from the graph -- the Saturday and Sunday ones.

Activity B

Repeat Activity D of Lesson 5, where the children exchanged their copies of Worksheet 2. Have them continue filling in the columns of Worksheet 5 with centimeter strips for the lengths their partners have filled in on Worksheet 2 during the past week.

Activity C

Uproot some of the extra plants so that the children can see root systems and have them discuss the fact that some parts of the plants were growing unseen while the visible parts were being measured.

Now make some final disposition of the plants. Probably most children will want to take their plants and records home. If it is mildly cold, cover the plants with plastic wrap for the trip home; if it is very cold, use several layers of newspaper to protect them. (You may wish to keep a few corn plants in the classroom so that the children can continue to enjoy them. You may also wish to use some of the materials on hand to plant flower seeds. Scarlet runners are highly recommended because they grow very fast and will usually bloom well in the classroom. Plant only one runner seed in each small pot and transplant to a larger pot later, if necessary.)

NOTE: Continue sequentially through the unit from whatever lesson and section you have reached concurrent with the completion of work with the plants.

SECTION 2 TIME -- DURATION AND CLOCK READING

PURPOSE

- To provide background for those relations in this unit that are associated with time.

- To extend work with measurement of durations.

- To review and extend knowledge of clock reading.

COMMENTARY

The lessons in this section continue the association of clock reading with durations from noon (or midnight) that were started in earlier units, particularly Unit 12, Measurement with Reference Units. You can carry this work on through the rest of the year, progressing at any rate and at any level you think appropriate for your class. We indicate that the time line can be extended to include weeks, months and years, but we do not specifically develop this. However, the last worksheets of this section can be adapted for this purpose and you should feel free to change them to suit the needs of your group.

This section begins with an experiment in which the children work with a crude water clock. The clock consists of a paper cup with a small hole in the bottom through which water drips into another container beneath it. The children calibrate this clock -- that is, they establish a numeral scale which shows the water level in the lower container at measured intervals. The duration of the intervals is determined by counting the swings of a pendulum. This experiment implicitly introduces the idea of the functional relation between the depth of the water and the duration of its accumulation.

In Lesson 8 the child should see that the accumulation feature of the water clock has a great advantage over counting. This feature of the water clock is used in Lesson 9 when the children measure durations in establishing another functional relation -- that between the height at which a bubbling dye solution marks a blotter and the duration of the bubbling.

A historical study of clocks is not intended, but discussion of the ancient clocks motivates the study of the familiar twelve-hour clock as a more efficient device for measuring durations and -- when the durations start at twelve -- for indicating the time. If your class is already familiar with some aspects of clock reading, you may wish to modify the presentation. Your modifications, however, should retain our use of the time line and our emphasis on associating the clock reading with the duration of the time interval between twelve o'clock and the moment of reading. Thus, "three o'clock" implies the duration of a three-hour period, the measurement of which began at twelve. Once the idea of telling time in terms of duration since twelve has been developed, you can give the children plenty of practice throughout the year by frequently asking what time it is, what the clock hands show, what the duration has been since noon or since midnight, and so on.

NOTE: If you started the unit with lessons from this section, remember to put corn kernels to soak overnight on the first Wednesday, so that you can conduct Lesson 1 on Thursday. Similarly, soak wax beans overnight Thursday to be ready for Lesson 2 on Friday. Reserve the next Monday for Lesson 3, which will take most of the two MINNEMAST periods for that day because the children will measure and record the heights of their plants for the first time. After that, set aside a regular time (a few minutes each day) for the children to observe changes in all the plants, and to measure and record the height of the corn plants. When you are ready to discard the corn plants, reserve a class period or two for a final discussion. Otherwise, use all remaining time to proceed through this and subsequent sections.

Lesson 8: A SIMPLE WATER CLOCK

This lesson reviews the concept of clocks that was started in earlier units. The idea of duration is needed for the study of many of the changes the children will observe that are associated with time.

First let the children experiment with the equipment in order to become familiar with it and to make their own free observations. Then guide them to calibrate the water clock in terms of the swings of a pendulum. A discussion of water clocks and similar devices will lay a background for work with the familiar twelve-hour clock in later lessons.

MATERIALS

-- for each group of three --

- small tray for the equipment
- label for tray
- tapered paper cup
- 4 straight pins
- 12-ounce tall container with 3 inches of tape on side
- 12-ounce short container half full of water
- sheets of newsprint to protect desks

-- for each group, or for the class --

- pendulum, 12 inches long

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PREPARATION

Before the lesson, prepare a water clock for each group of children. Place four straight pins through the side of the tapered white cup to serve as supports. These pins should be placed around the cup about halfway up the side, and should project far enough to rest on the rim of the tall 12-ounce container. Use a pin to make a hole in the center of the bottom of the white cup. This hole should be large enough to let the water run through in a fine stream rather than in drops. Enlarge it cautiously with a sharp pencil point, testing with water frequently to find the right size. (After the first time you should get it right very quickly.)

Finally, paste a 3-inch length of masking tape down the lower part of the tall 12-ounce container. The tape should touch the bottom.

In addition to this assembly, each group will need another container from which to pour water. This is specified in the materials as the short 12-ounce container.

Activity A

Distribute the equipment to the groups of children, and suggest that the paper cup, the transparent container and the water could be parts of a system that might serve as a clock. Let the groups experiment with the materials, then ask:

WHAT DO YOU NOTICE ABOUT THIS SYSTEM? (Water runs from the cup to the container.)

Watch for the discovery that the amount of water in the lower container increases steadily. Then ask whether anyone can think of a way that the water system could be used for comparing the duration of two activities, such as printing the day of the week (Wednesday) and printing the calendar date (March 12, 1969).

Guide the children to suggest that at the word "start" for each activity they could pour water into the cup and then, when the activity is completed, record the amount of water that has run into the container by marking the tape. For these activities the lower container should be empty at "start." Remind the children that the containers are easily tipped over, and each child doing the marking should use one hand to hold the container firmly in place while marking it with crayon, a very soft pencil, or a marking pen. Two children in each group should attend to the water apparatus while the third writes.

Child 1 says "Start" as he pours water into the top of the water clock. Child 2 immediately begins to write "Wednesday." Child 3 is ready to mark the water level on the tape when Child 2 says he has finished writing. Then both sections of the clock are emptied into the short container, and the procedure is repeated while Child 2 writes "March 12, 1969." The two marks on the tape show how much longer it took to write the date than the day, or vice versa.

Activity B

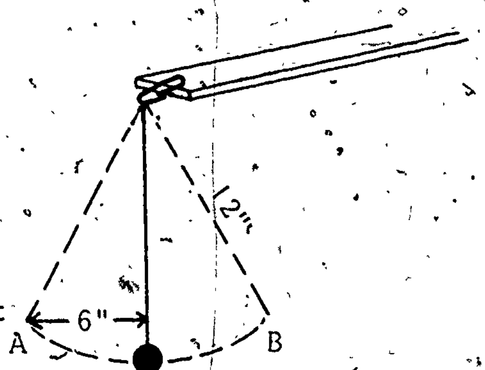
In this activity each group of children will calibrate a water clock by making marks on the lower container according to the number of swings of a pendulum -- one mark for each ten swings. While it is desirable that as many children as possible have experience with the pendulum, use your own judgment about whether to provide one for each group, or for two groups, or for the entire class. Even if only one pendulum is used for all, calibrations will vary from group to group because water will run through at different rates in the different clocks and because of human factors.

Distribute the equipment. The tape used in Activity A should be replaced. Ask the children what might make the water clock more useful for measuring durations. After discussion, if no one has mentioned it, call attention to a pendulum.

> WHAT COULD WE DO TO THE WATER CLOCK SO THAT IT WOULD SHOW THE DURATION OF TEN, TWENTY OR THIRTY SWINGS OF THE PENDULUM?

If they do not think of calibrating the water clock, remind them of how they calibrated a spring scale in Unit 16, using paper cups as weight units. Ask whether something similar could be done to the water clock.

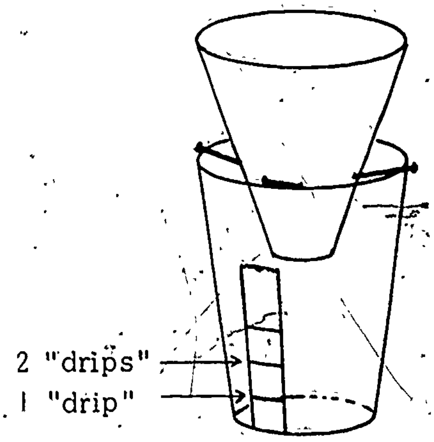
To calibrate the water clock, have each group of children mark the water levels, while one child (for the class or for each group) counts the swings of a twelve-inch pendulum. The counter will hold the pendulum bob about six inches from rest position and say, "Ready, Set, Go." He will release the bob at the word "Go." He will say "One" the first time the bob returns to the starting point, "Two" the second time, and so on. Have the entire class practice counting the pendulum together before beginning to calibrate the water clock.



One full swing of the pendulum means that the bob goes from A to B and back again to A.

After this practice, have the counter for each group start his count. At "Go" one of the group pours the water into the upper cup. At counts 10, 20, 30, etc., another member of the group puts a mark on the container to show the level of the water.

The children should decide what to call each unit of water -- "one drip," "one mark," or whatever they consider appropriate. Let them use their water clocks to measure the durations of various activities that each group chooses. They may wish to compare the duration of different activities or they may wish to compare durations of the same activity done by different children.



Have the children in each group leave the marks on the clocks and label the trays so that they can use the same equipment in Lesson 9.

Activity C

WHY DO WE CALL THIS SYSTEM A WATER CLOCK? (Because we can use it to measure the duration of activities.)

WHAT ARE SOME OTHER THINGS THAT ACT AS "CLOCKS?" (The pendulum, the wall clock, watches, egg timer with sand.)

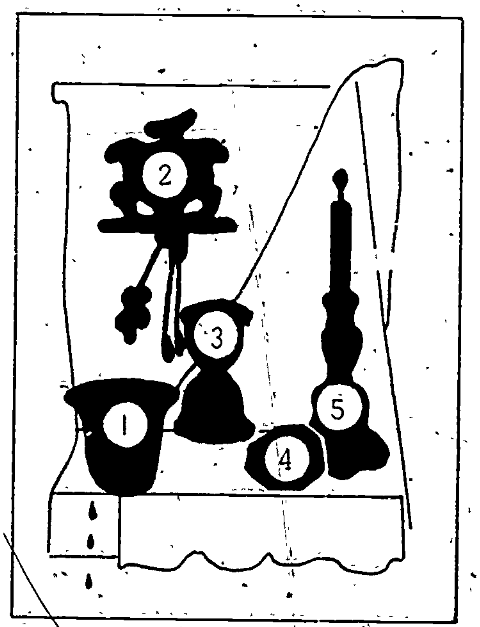
MANY THINGS CAN BE USED AS CLOCKS. HAS ANYONE EVER ~~SEEN A~~ SPECIAL CLOCK THAT WORKS ONLY IN SUNSHINE? (A sundial.) TELL US ABOUT IT.

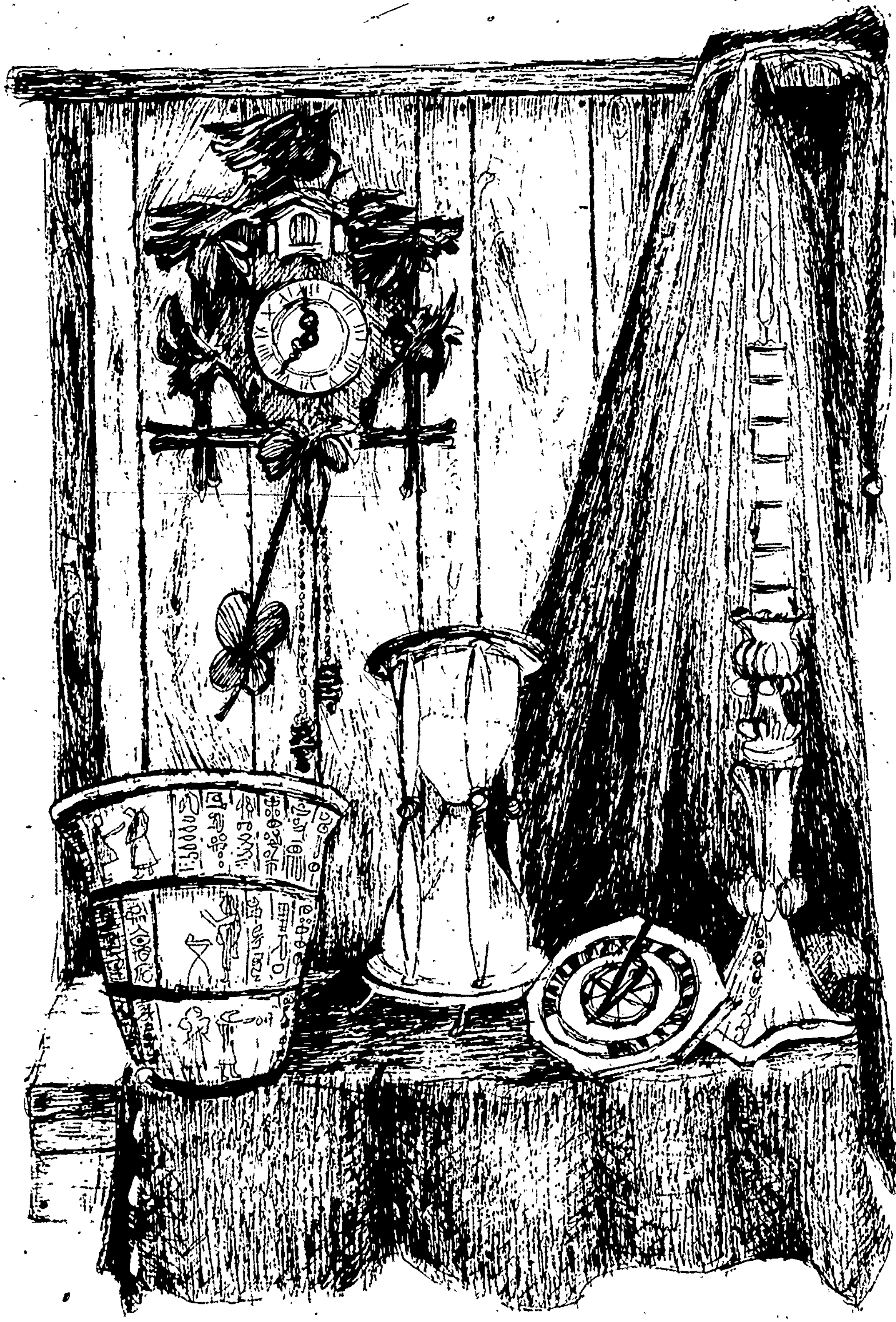
Tell the children that long ago, before there were watches or wall clocks that could be wound up or run by electricity, people had water clocks and used them to tell the time of day. If children had to measure their activities by a water clock today, they would have to start to school, go home to lunch, etc., when the water in the clock was at certain marks.

If you wish, show the children the pictures of the clocks on the opposite page and discuss with them some of these historical ways of measuring duration.

Clocks:

1. Egyptian Clepsydra (Water Clock)
2. Cuckoo Clock
3. Hour Glass
4. Sundial
5. Candle Clock





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Lesson 9: DURATION AND HEIGHT IN A COLOR EXPERIMENT

In this lesson the children use the calibrated water clocks to time an experiment in which three strips of blotting paper are suspended over a bubbling colored solution. The children see a correspondence between the height to which the bubble solution has risen and the length of time the blotter was exposed to it. By arranging the saturated blotter strips in order according to the height of the colored mark on each strip, the children are led to a very elementary plotting of the relation.

MATERIALS

- one-half cup water
- 1 tablespoon food coloring
- Soap Bubbles or other commercial liquid for blowing bubbles -- enough to reach the 1-cm mark in scaled cylinder
- medicine dropper

-- for each group of three --

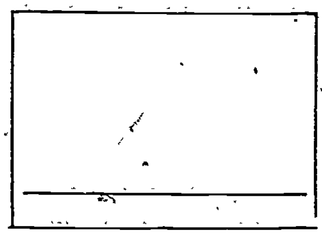
- tray
- water clock and separate container with three-fourths cup of clear water
- 3 strips of blotting paper (1 cm x 10 cm)
- 3 jumbo (2") paper clips
- one-half tablet of Alka-Seltzer of the type sold in aluminum foil packet, soufflé cup
- sheet of paper, pencil, ruler
- cylinder with centimeter tape attached
- paper towel

PREPARATION

Mix the food coloring and Soap Bubble liquid with one-half cup of water, and set this solution aside for later distribution. Cut strips of blotting paper. Place each half-tablet of Alka-Seltzer in a soufflé cup. On the water clock trays from the previous lesson assemble all the items specified above for each group.

PROCEDURE

Have the children in each group of three take the same tray they used in Lesson 8. Explain that the water clocks are going to be used to time an experiment where strips of blotting paper are suspended over a bubbling solution for different durations, but that first you want them to practice the procedure without the solution. Then ask one member of each group to draw a straight line across, and near the bottom of, the plain piece of paper you have provided. Tell the children that in the real run each blotter will be placed with the wet end on this line for comparison.

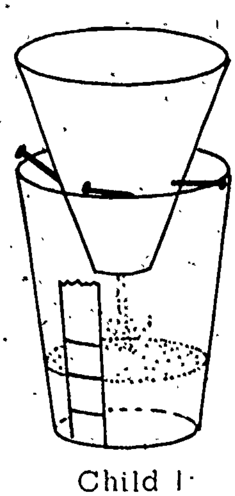


Before starting the trial run, let the children speculate a little about what they think will happen to the blotters if each remains suspended for a different duration.

Give instructions for the trial run, as follows:

<u>Child 1</u>

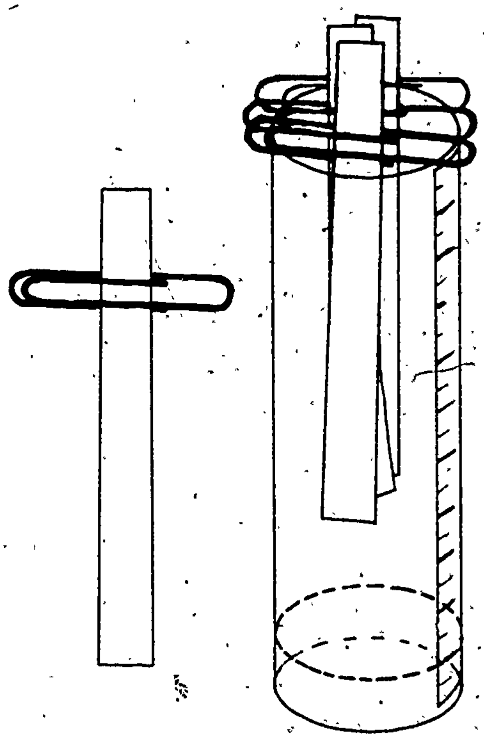
Child 1 of each group runs the water clock. He says "Go" when he starts pouring the water into the empty water clock. He says "Now" each time the water reaches a drip mark.



Child 1

Child 2

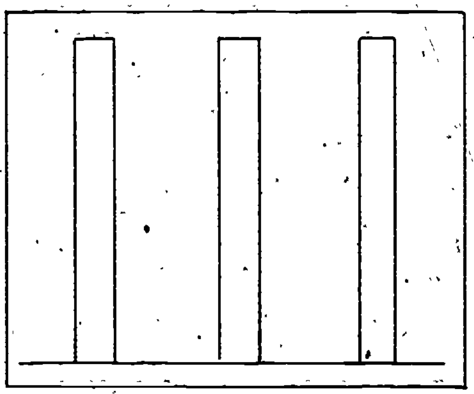
Child 2 prepares blotting strips by putting a jumbo clip on each strip (see diagram). He measures to see that all the clips are placed uniformly, one half-inch from the end of the strip. He places the three strips in the cylinder in such a way that the clips rest on the rim. (Explain that in the real run the bottoms of the strips should not touch the colored water that will fill the cylinder to the 1-cm mark.)



Child 2

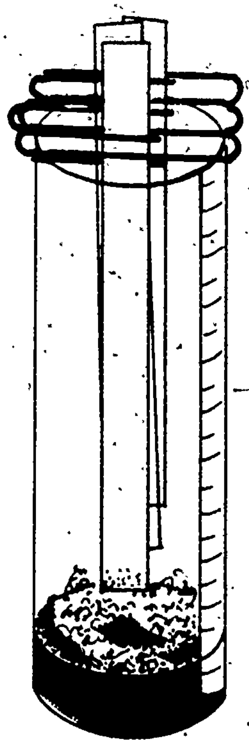
Child 3

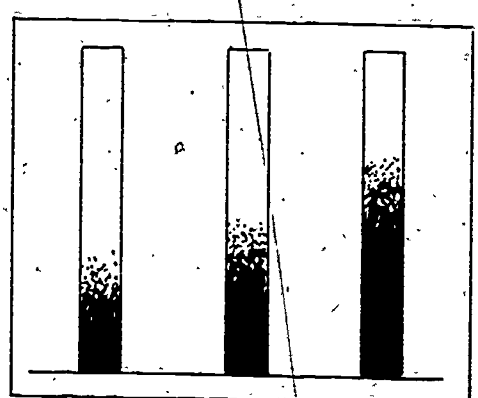
Child 3 prepares the half-tablet of Alka-Seltzer by breaking it into small bits in the soufflé cup. He may have to use the flat end of a ball point pen or unsharpened pencil to do this. He must be sure to keep the substance dry until it is used. When Child 1 says "Go," Child 3 pretends to empty the bits from the soufflé cup into the cylinder. Warn him not to do so until the real run. (If a Child 3 actually empties the bits into the cylinder, be sure all of it is returned to the soufflé cup and the cylinder is wiped clean, so that the reaction will not begin when the liquid is added.) At each "Now" he removes one of the strips of blotting paper and hands it to Child 2, who places it on the sheet of paper with one end on the line. Child 2 puts the first strip at the left, the second to the right of the first, and the third to the right of the second. Explain that in the real run, each strip will be partly wet and that it is the wet end which will be placed on the line.



Child 3

When the technique is familiar, put enough of the dye solution into each group's cylinder to come up to about the 1-cm mark, and have the groups each make a real run. The procedure is exactly the same as for the trial run, except that now there will be dye and Alka-Seltzer used, and Child 2





Real Run

must remember to put the wet end of each strip at the line on the sheet of paper.

Let the children discuss anything they observe, but if any notice that there is a relation between the number of "drips" of the water clock and the height of the color on the strips, have them tell the class about it. If necessary, call attention to the relation with a question:

WHY WAS THE COLOR ON SOME STRIPS HIGHER THAN ON OTHER STRIPS? (The longer the strip was in the cylinder, the higher the bubbles rose.)

Activity E

Hold a discussion about the water clocks:

WHY DOESN'T EVERYONE USE WATER CLOCKS? (They have to be refilled regularly; they are messy; they don't tell time very accurately.)

COULD I CARRY A WATER CLOCK ON MY WRIST?

COULD WE EASILY MEASURE THE LENGTH OF A SCHOOL DAY WITH A WATER CLOCK?

IF YOU TOLD YOUR MOTHER THAT WE STARTED OUR ART WORK AT THIRTY-FIVE "DRIPS" TODAY, WOULD SHE KNOW WHAT YOU MEANT?

IF YOU SAID THAT IT STARTED AT TEN O'CLOCK WOULD SHE UNDERSTAND?

Does a water clock make a good wristwatch?

Lesson 10: TWELVE-HOUR CLOCKS -- SECONDS, MINUTES

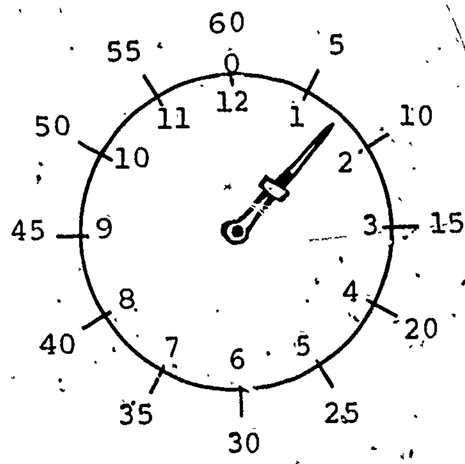
This lesson and Lesson 11 review and extend earlier work with the familiar twelve-hour clock. The treatment is similar to that begun in Lessons 29, 30, and 31 of Unit 12, Measurement with Reference Units. Many of your students may be able to tell time, and the rest should begin to develop this skill. We also want the children to develop an understanding that each clock reading indicates a duration since twelve (noon or midnight). The children will be given practice in measuring and recording these durations.

MATERIALS

- wall or kitchen clock with second hand
- demonstration clock face (to be borrowed from first grade kit)
- tape
- white tagboard clock faces provided with the printed materials for this unit, 1 per child
- scissors
- 1 brass fastener per child
- paper clips
- time lines, provided with printed materials
- newsprint

PREPARATION

Before you teach this lesson, tape your demonstration clock face to the chalkboard where all the children can see it, and tape the hands together. Put numerals around it showing seconds and minutes, as in this diagram.



(Note that there are both a zero and a sixty above the twelve.) Paste a zero above the twelve of the wall clock also.

PROCEDURE

Activity A

Give the children each a tagboard clock face to cut out and assemble. Show them how to put the brass fastener through the dot at the end of the long hand, then through the dot on the short hand, and finally through the dot at the center of the clock face. Check to see that the children spread the brass fasteners apart at the back of the clock face to secure the hands. Next ask each child to cover the short hand with the long hand and fasten the two together with a paper clip. Explain that you want this done so that the children can study one hand of the clock at a time.

Now call attention to the wall clock, and ask the children to watch the movement of the hand that is traveling around the clock most rapidly.

DOES THE HAND THAT MOVES MOST QUICKLY TRAVEL CONTINUOUSLY OR IN JERKS? (It moves continuously.)

DOES ANYONE KNOW THE NAME OF THIS FAST-MOVING HAND? (It is called the second hand.) WHY IS IT CALLED THAT? (Because it measures the number of seconds.)

WHAT DOES THE POSITION OF THE SECOND HAND TELL US? (It tells us the duration in seconds since it pointed straight up to twelve.)

THE HAND POINTS TO TWELVE, BUT WE ALWAYS START COUNTING AT ZERO. THAT IS WHY I HAVE PUT A ZERO ABOVE THE TWELVE OF THE DEMONSTRATION CLOCK AND OF THE WALL CLOCK. LET US AGREE TO TALK ABOUT ALL DURATIONS EXTENDING FROM ZERO.

Tell the children to consider the clipped-together hands on their clock faces as one hand, the second hand. Have them take turns setting the hand on the demonstration clock face at different positions, while the rest of the children each set the hands of their small clock faces in the appropriate positions and tell how many seconds passed since the hand pointed to zero.

The children will need considerable practice with the demonstration clock, on which you have marked the numerals 0-60 to show seconds, before they are able to make second hand readings on their own clock faces, which show only the hours.

Help the children see that the marks on their small clock faces show the seconds in fives. Remind them to check with the numerals (5, 10...60) you have drawn around the demonstration clock for each setting of their clock faces.

Working in pairs, have one child set his clock to indicate certain durations since zero, and the other tell the duration (25 seconds, etc.), then change about.

Return to this activity occasionally as seems advisable to you.

Activity B

Direct the children's attention to the minute hand of the wall clock.

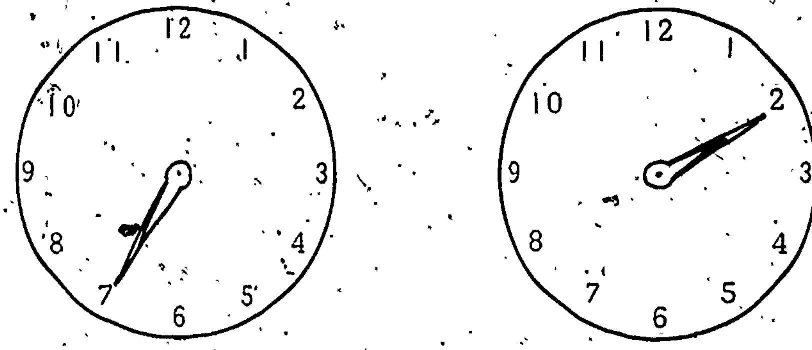
WHAT DO THE POSITIONS OF THE BIG HAND TELL US? (They tell us the duration in minutes.)

WHEN THE SECOND HAND GOES AROUND ONCE, HOW MUCH DOES THE MINUTE HAND MOVE? LET'S WATCH IT: (It moves one space -- one minute.)

HOW FAR DOES THE SECOND HAND MOVE IN ONE MINUTE? (It moves all the way around -- 60 seconds.)

Have a volunteer set the hand of the demonstration clock to show the same minutes as the wall clock while the rest of the class does the same with the hands of the small clock faces.

WHAT HAS THE DURATION IN MINUTES BEEN SINCE THE MINUTE HAND WAS AT ZERO? (Thirty-five minutes, etc)

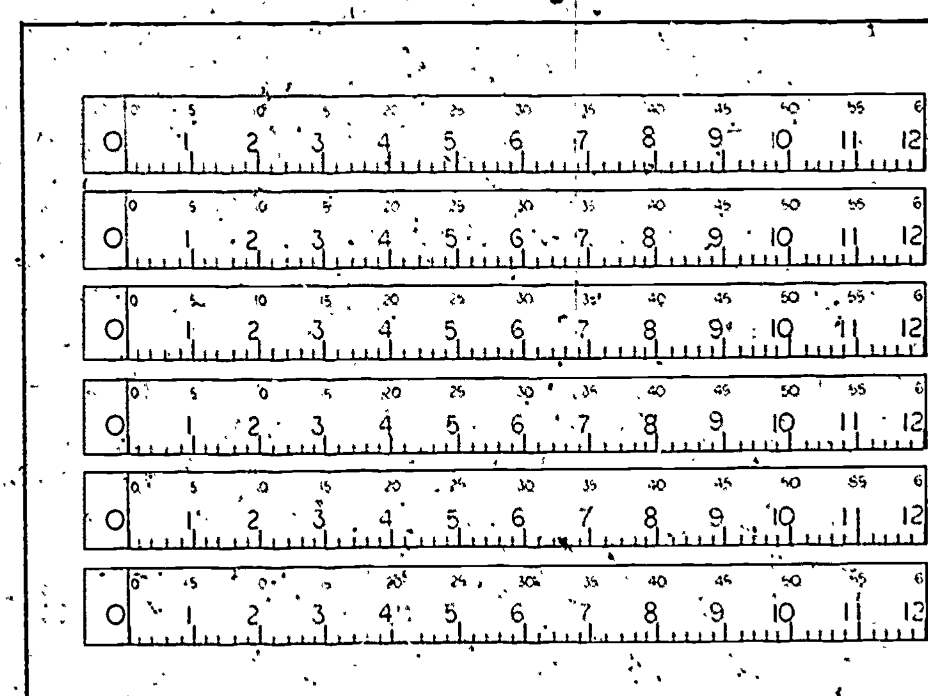


Have the children set the clock face to other durations since zero. Compare these with the setting of the demonstration clock face. Have the children hold up their clock faces so that you can check them quickly. Occasionally, from day to day, ask the class to tell you the duration since twelve in minutes -- the time in minutes.

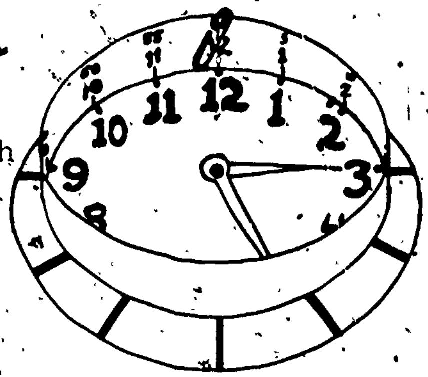
Activity C

Have the children carefully cut out the time lines provided with the unit.

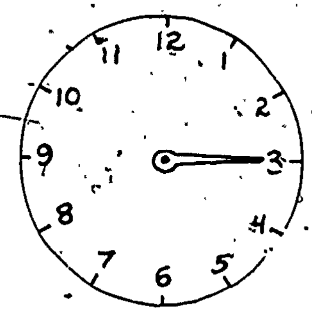
Time Lines



Have each child make a loop of one time line with the numbers on the inside, by bringing the right end just to the zero-mark and fastening it with a paper clip. Have each child set the loop on his small clock face and arrange it so that the twelve-mark is above that line on the clock face. Call the children's attention to the other numerals. Ask the children what they notice about the numerals and lines. They should see that the heavy marks and numerals on the clock face are just below the same markings on the time line.



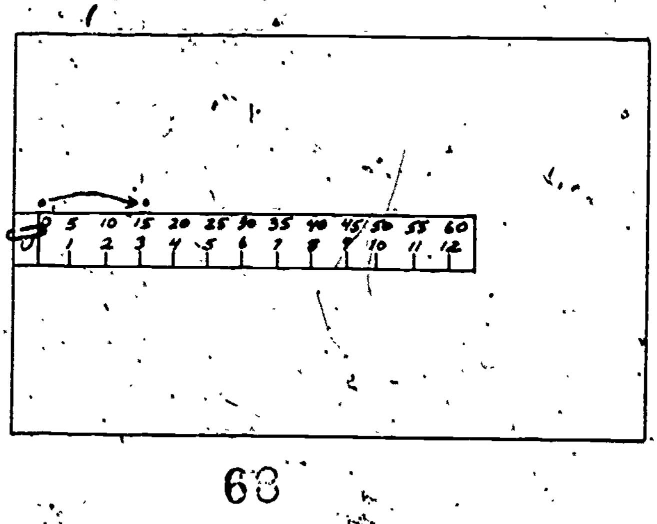
Now ask each child to unfasten his time line and clip the zero end to the left side of a sheet of newsprint. Set the demonstration clock (single hand) to fifteen minutes since zero. Ask the children to set their clock faces to the same position.



WHAT DURATION DOES THIS CLOCK SHOW SINCE ZERO MINUTES -- SINCE TWELVE? (Fifteen minutes.)

HOW CAN WE SHOW THE DURATION OF FIFTEEN MINUTES ON THE NEWSPRINT ABOVE THE TIME LINE?

Have the children put a mark at zero and at fifteen on the newsprint above the time line. Then ask them to draw an arrow from zero to fifteen.



Continue this exercise by having the children transfer various readings, in minutes, from the wall clock to the time lines with arrows.

Save the time lines for Activity B of the next lesson in which the children will clip them to fresh sheets of newsprint.

Lesson 11: TWELVE-HOUR CLOCK -- MINUTES, HOURS

This lesson extends the association of time duration since twelve (noon or midnight) to telling time in hours and minutes. As seems appropriate to you later in the year, you can have the children extend the time line to include weeks, months and years with worksheets similar to Worksheets 11 and 12, which are modeled on Worksheet 36 of Unit 12.

MATERIALS

- wall or kitchen clock with second hand
- demonstration clock face
- student clock faces
- time lines provided with unit, newsprint
- Worksheets 6-12

Activity A

Separate the hands of the clock faces and have the minute hands remain at twelve (zero minutes) throughout this activity.

Call the children's attention to the short hand of the wall clock. Probably many in the class will already be familiar with its indication of the hours.

WHAT DOES THE POSITION OF THE SHORT HAND ON THE WALL CLOCK TELL US? (The duration in hours since twelve -- since noon or midnight.)

HOW FAR DOES THE HOUR HAND MOVE WHILE THE MINUTE HAND GOES AROUND ONCE? (One large space -- from one to two, etc.)

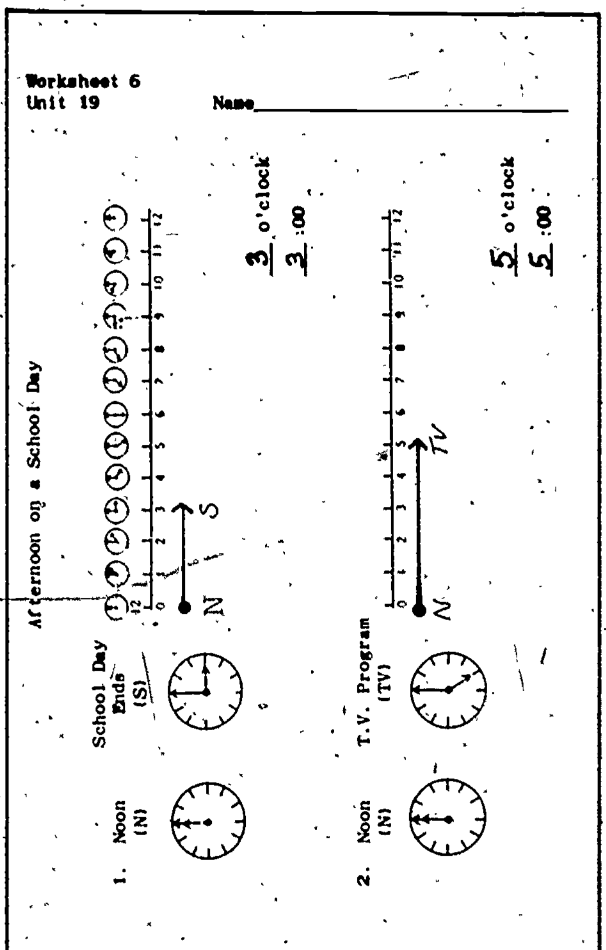
HOW FAR DOES THE MINUTE HAND MOVE IN ONE HOUR? (It moves all the way around -- sixty minutes.)

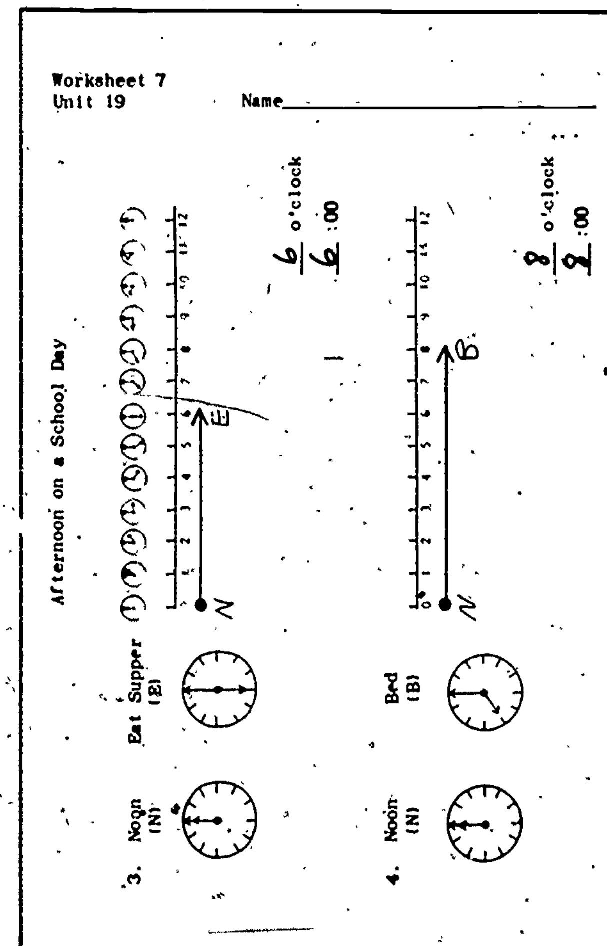
Develop the use of the time line and clock faces for representing durations in hours since twelve (noon or midnight) as you did for minutes in Lesson 10, but now have the hour duration line drawn below the time lines. Point out that a duration of four hours since noon means 4 o'clock (4:00) in the afternoon; ten hours since midnight is 10 o'clock (10:00) in the morning.

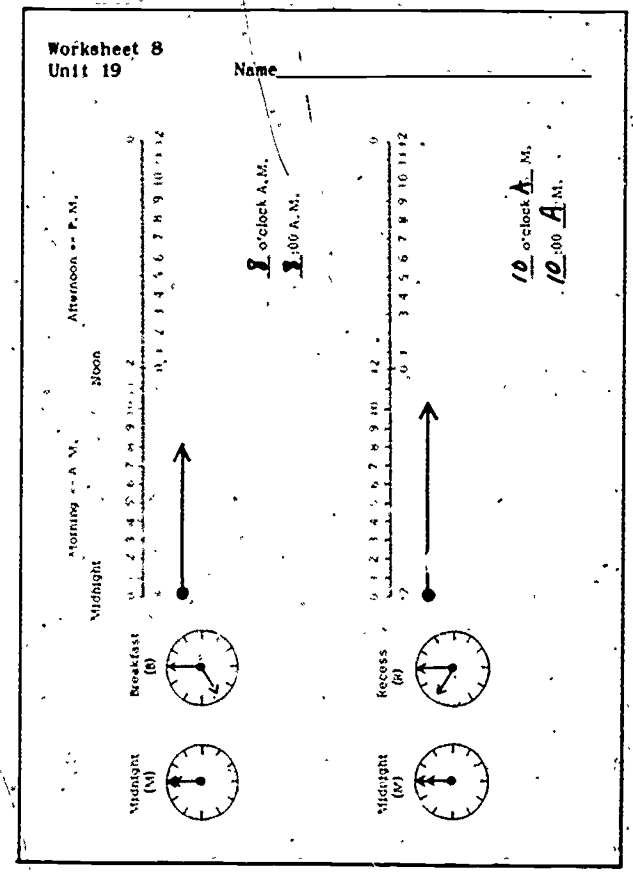
Morning hours are A.M. (ante meridiem -- before noon)

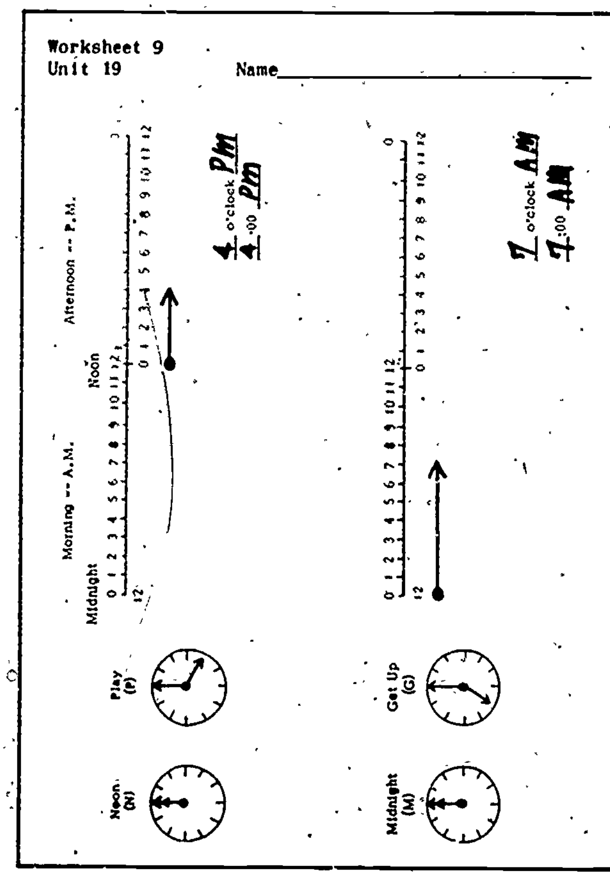
Afternoon hours are P.M. (post meridiem -- after noon)

Worksheets 6 through 9 are appropriate here.



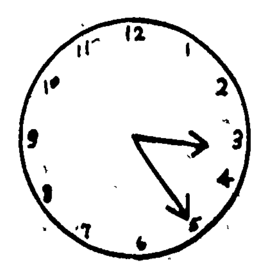




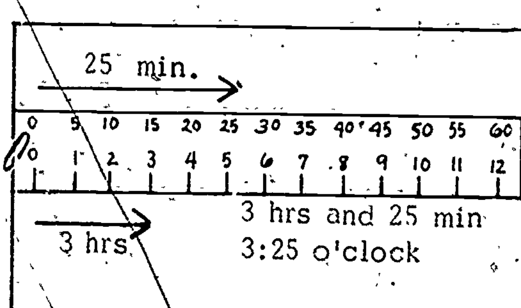


Activity B

For this activity see that each child has a student clock face and a time line clipped on a new sheet of newsprint. Ask the children to show each duration, as you give it, on the clock faces and then on the time lines. The durations you name should include both hours and minutes. For example:



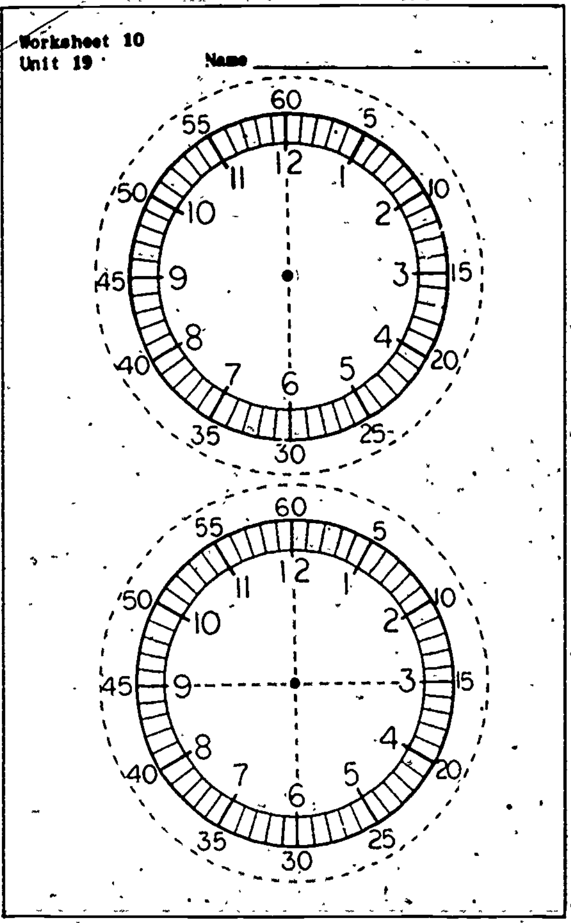
SET YOUR CLOCK FACES AT 3:25. NOW, WITH AN ARROW BELOW THE TIME LINE, SHOW THE DURATION IN HOURS SINCE TWELVE. NEXT, WITH AN ARROW ABOVE THE TIME LINE SHOW THE DURATION IN MINUTES.



Have the children hold up the clock faces after they set them for each duration, so that you can check before they draw the arrows. Give as much practice as you think necessary.

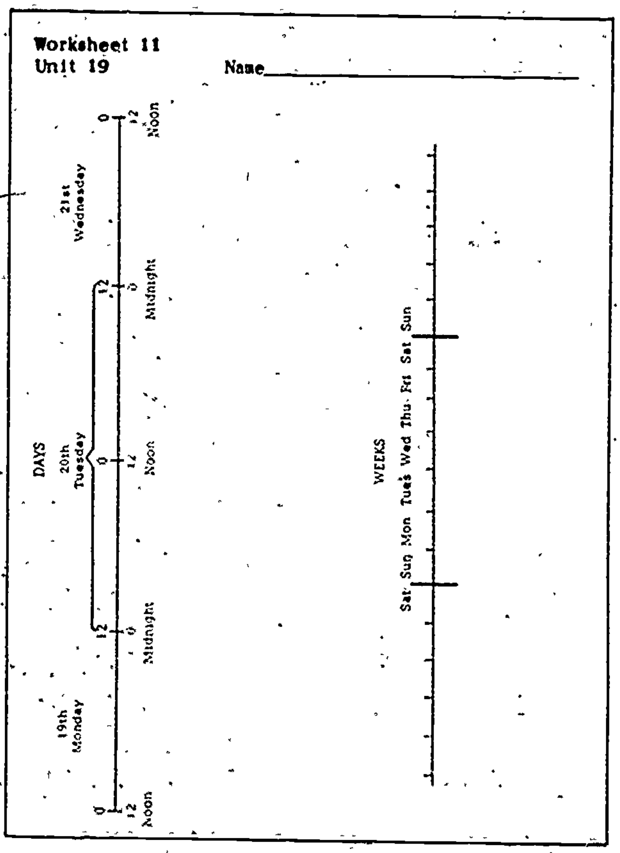
Activity C

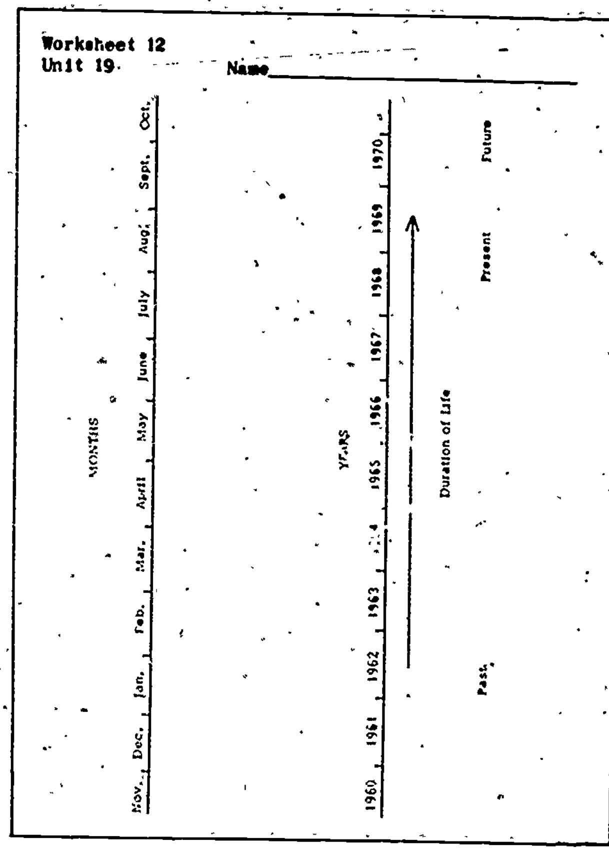
Have each child turn to Worksheet 10 with two clock faces on it. Have the children cut out the clock faces along the dotted circles. Ask them to fold one clock face into two equal parts by folding along the dotted line through the twelve and the six. Then ask them to open the folded clock face and color each half of it. Have the children fold the second clock face in the same way, and then in half again, this time along the dotted line joining the three and the nine. Ask them to make each quarter of the clock a different color. Discuss half and quarter hours in relation to the colored halves and quarters.



The children should also mark off their time lines in half and quarter hours. For instance, they could draw a line of the appropriate color for the first quarter hour between zero and fifteen above the number line and color a line from zero to thirty below the line to indicate the first half hour, etc.

Follow the procedure where the class uses the demonstration clock and their individual clocks, but this time have them set the hands to correspond to half and quarter hours. Direct the children to look at a real clock when the hands show a quarter after and a quarter before an hour. In particular, have them notice the hour hand and ask them to observe its position when the time is a quarter after or half past an hour, etc.





Worksheets 11 and 12 can be used to extend the idea of the time line to days, weeks, months and years. You may prefer to save them for use later in the year.

SECTION 3 OTHER FUNCTIONAL RELATIONS

PURPOSE

- To lead the children to observe some simple functional relations and to record them in various ways.
- To have the children discover that there is a relation between the changes in one property and the changes in another.
- To have the children learn to record data in simple graphs.

COMMENTARY

Equal emphasis should be given to the points listed above. The development of skills in observing and recording functional relations will be continued and extended in Sections 4 and 5. The children will usually require experience with a variety of changing conditions and the graphs that record them before they learn to recognize simple functional relations. Therefore, do not feel that the children must have mastery of the skills and problems presented in this section before they can go on to work in Sections 4 and 5 fruitfully.

Lesson 12: PREDICTING CANDLE LENGTH

In this lesson the children will observe five candles that have all been lit at the same time and then extinguished at ten-minute intervals, so that one candle will have burned for ten minutes, one for twenty minutes, one for thirty minutes, etc. One of the candles will be hidden from view, and the children will be asked to predict its length. The prediction will be based on the observations of the lengths of the other candles.

Start this lesson at a time when your class will be able to return to it intermittently during a full hour.

MATERIALS

— 6 candles (thin tapers), cut off at the bottom so that each is 10" tall

— Plasticene or clay

— cardboard, 17" x 24"

— matches

— wall clock

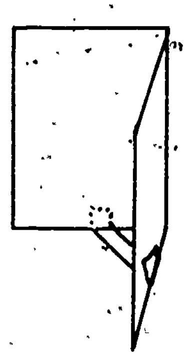
— kitchen timer

— 5 student clock faces

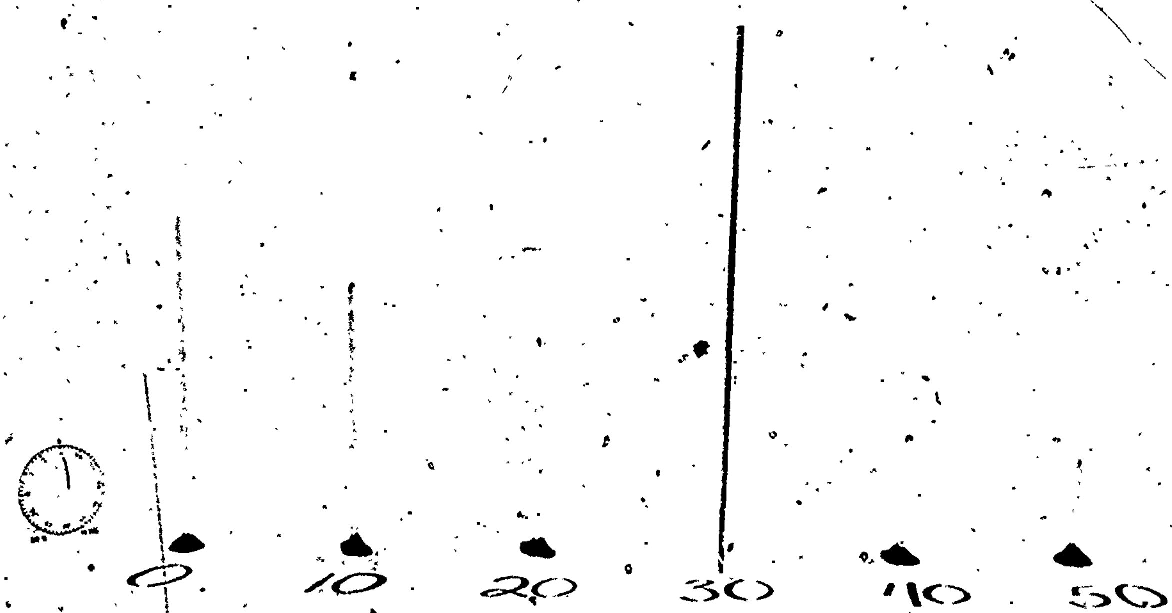
— ½" x 10" paper strips, 6 per child (5 strips of white and 1 of another color)

PREPARATION

Set each candle firmly in a lump of clay or Plasticene. Prepare a shield behind which one candle can be hidden. Use a piece of stiff cardboard about 17" x 24". Fold it in half and brace it with a piece of tape.



Place six candles in a row, about one foot apart, so that when you blow one out the candle next to it will not be affected. Set the candles up where there is no draft so that they will burn uniformly. If possible, set them in front of a chalkboard.



PROCEDURE

Explain the purpose of the lesson. Tell the children that you are going to light five candles and then blow one out after it has burned for a duration of ten minutes, one after twenty minutes, one after thirty minutes, one after forty minutes and one after fifty minutes. One candle will not have been burned at all. The children will be able to see all the candles except one mystery candle that will be hidden behind the shield. After looking at all the other burned candles, they are to predict how high the mystery candle is.

Label each candle to show how long it will burn. You may write on the chalkboard above each candle, or place a card at the base of each.

Now assign five children to watch the clock. Tell them at what time you will light the candles, and make sure the children know how to tell when ten, twenty, thirty, forty and fifty minutes will have elapsed. Give each a clock face on which he can set his assigned time. Then they can watch to see when the wall clock reading matches their clock settings. (Set your kitchen timer for about nine minutes each time, to serve as a reminder to the clock-watchers.)

Light all the candles but the one at the extreme left. Work as quickly as you can so that the first candles do not burn down too much before the last ones have been lit. Place the shield so that it hides the thirty-minute candle. (Make sure this candle is at least four inches away from the cardboard.) Now set your timer for nine minutes, and turn to other work during the intervals for the next hour. Blow a candle out every ten minutes. Be sure to keep the thirty-minute candle hidden at all times. When all the candles have been extinguished, their heights should range from the ten-inch height of the unlit candle at the left down to about a three-inch height for the candle at the extreme right. If the candles have all burned at a steady rate, there should be about the same decrease in height between them. Even if they have not burned at the same rate, there should be an obvious decrease in height between each two candles.

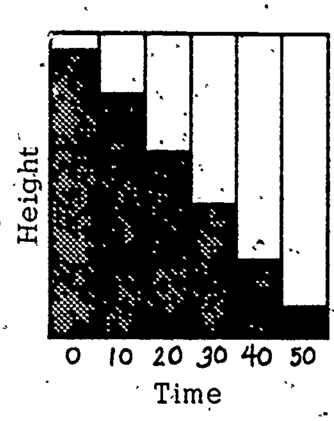
Now remind the children that they are to try to estimate how tall the hidden candle is. Ask for suggestions about how this should be done. Then tell the children they are going to use paper strips to make their predictions:

> THERE ARE NOT ENOUGH CANDLES FOR EVERYONE TO HAVE A SET, SO I AM GOING TO MAKE PAPER CANDLES FOR YOU TO WORK WITH. EACH OF YOU WILL GET FIVE STRIPS OF WHITE PAPER CUT TO THE HEIGHTS OF THE FIVE CANDLES YOU CAN SEE, AND ONE STRIP OF COLORED PAPER THAT YOU CAN MARK OR CUT TO SHOW HOW TALL YOU THINK THE MYSTERY CANDLE IS.

Cut and distribute the strips, and have the children arrange them in order with the tallest at the left and the shortest at the right. Ask them to use the colored strip to estimate the height of the mystery candle by marking or cutting it. If this seems difficult, suggest to the children that they put numerals on each of the five strips to show how long the candle each represents has burned (10, 20, 40, and 50). After that, the children should be able to see that if they put the colored strip between the strips that are marked 20 and 40, it would be helpful in judging about how tall the thirty-minute candle is, but do not tell them to do this.

After all the estimates have been made, remove the shield from the mystery candle and let the children make a direct comparison between it and their estimates. If some children made very close predictions, ask them to explain to the rest of the class how they did it.

Using chalk, or a paper strip cut to the length of each burned candle, make a bar graph on the board.



Lesson 13: TREE RINGS

In this lesson the children use Worksheet 13, which depicts the cross section of a tree, to compare former widths of the tree with the age of the tree at different times. They measure the radii at various ages and show the relation between the age of the tree and the radius on a grid (Worksheet 14).

MATERIALS

- Worksheets 13, 14, and 15
- ticker tape
- scissors
- cellophane tape or paste
- centimeter rulers

PROCEDURE

Have the children turn to Worksheet 13. ~~Explain that this is~~ the picture of a cross section of a tree -- what you would see if a tree were cut across its width. Ask the children if any know, or can guess, what the tree rings indicate. If necessary, explain that each wide ring represents the growth of the tree during the spring and that the narrow (darker) rings show the growth in the summer. Have the children speculate about which rings grew first and give their reasons for thinking so.

Now ask the children to find the fifth dark ring from the center of the picture.

HOW OLD WAS THE TREE WHEN THAT RING WAS FORMED? (It was five years old.)

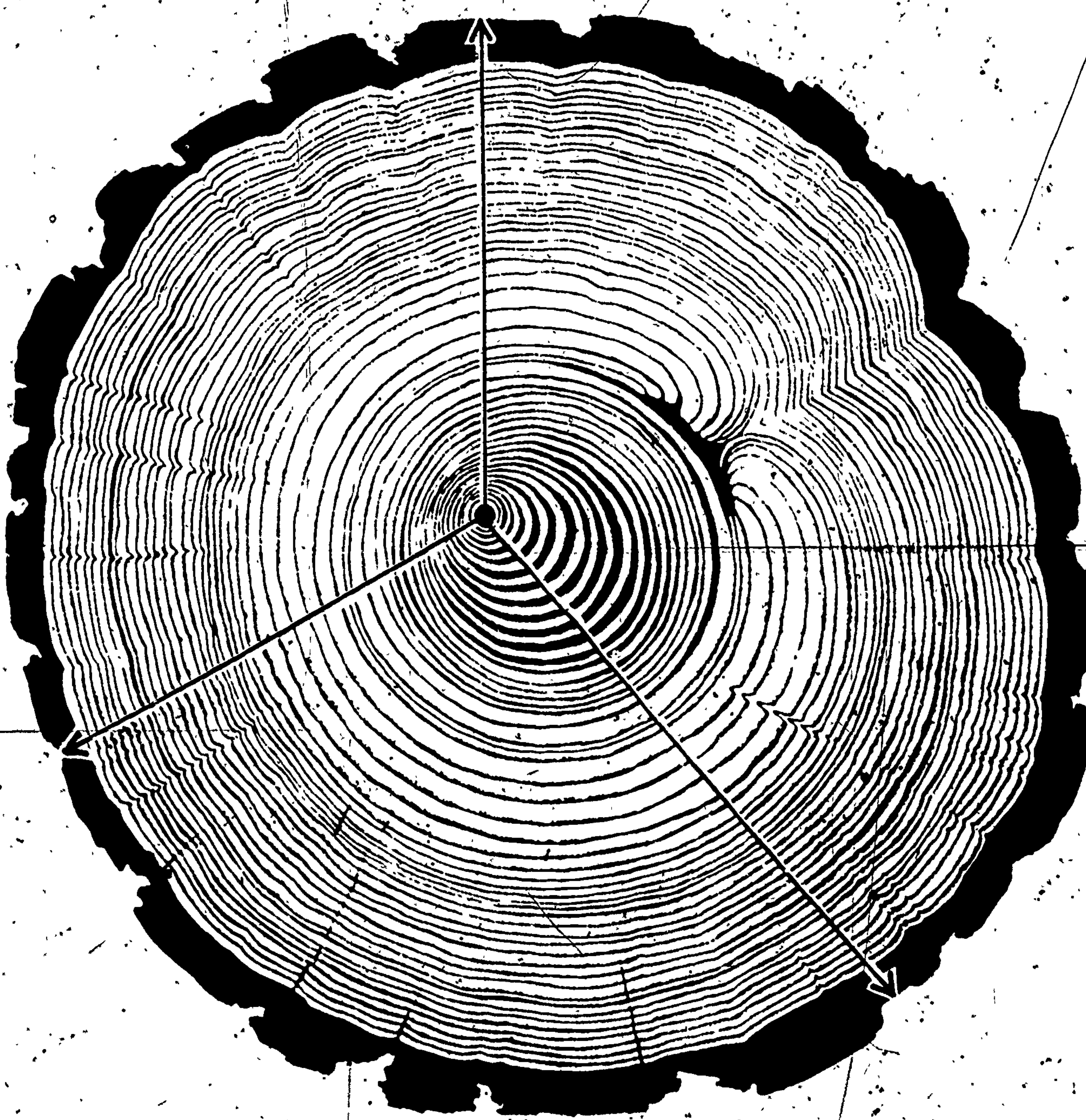
HOW LARGE WAS THE TRUNK OF THE TREE THEN? (It was the size of that ring.)

HOW CAN WE MEASURE THAT SIZE? (By measuring across the ring.)

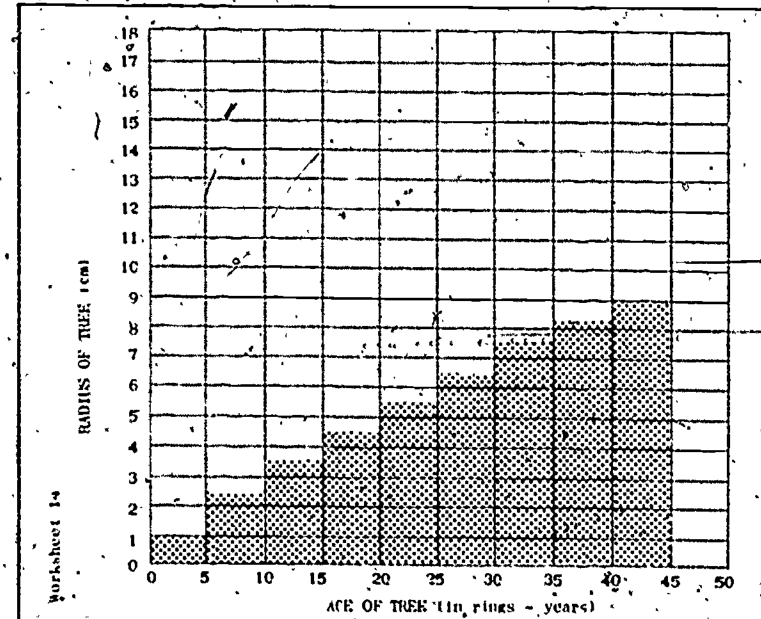
THAT WOULD BE THE DIAMETER OF THE RING, BUT IT WILL BE EASIER IF WE MEASURE FROM THE CENTER. WE CALL THAT DISTANCE THE RADIUS OF THE RING.

Worksheet 13
Unit 19

Name ______________________



Each arrow indicates a radial line of the cross section of the tree from first growth until it was cut down. The children will be measuring the length of rays for lesser durations also. Each child will draw his own ray from the center of the cross section to the outer edge, and will make all his measurements along the same radial line.



Ask the children to look at Worksheet 14. Explain to them that they are to measure in centimeters the radius for each five years' growth on Worksheet 13, then cut ticker tape to each length and paste it on Worksheet 14. Have them start by drawing a radial line where the tree rings are farthest apart. Remind them that they have to count the dark rings along this line to find the correct number of years. Give them a little practice in recording the first few measurements by writing them on the chalkboard, e.g.,

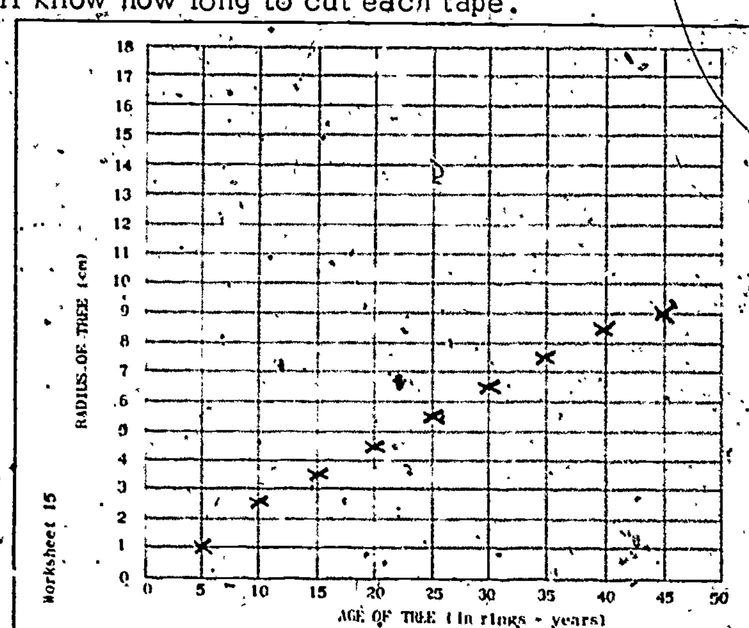
Radius of tree at 5 years ≐ 1 cm

Radius of tree at 10 years ≐ 2 ½ cm

Radius of tree at 15 years ≐ 3 ½ cm

After this practice, ask the children to complete the worksheet. Remind them to write down each measurement in centimeters so they will know how long to cut each tape.

When the ticker tape graphs are finished, you may wish to have the children try to plot the data on Worksheet 15 (Stage 4 in the development of graphing as described on page 2 of this manual), or you may make this a class activity, using one child's data.



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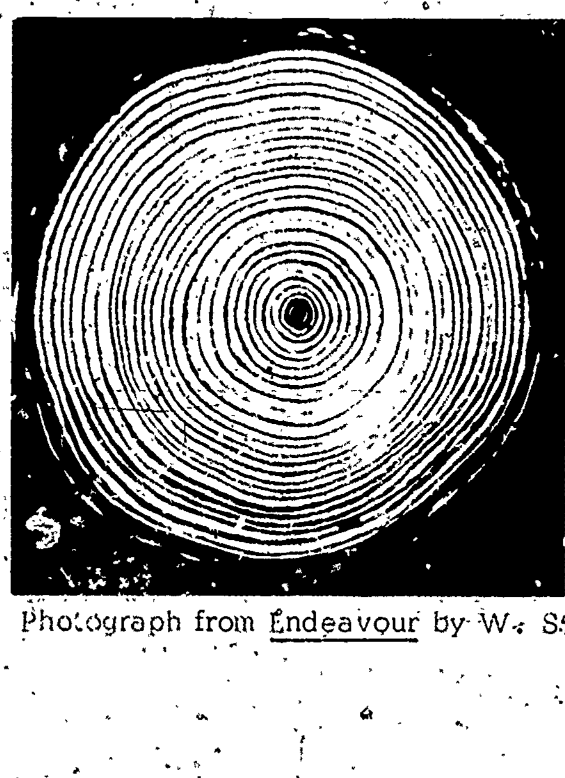
NOTE: Tree rings are very useful research tools for scientists. Their shape, size and pattern reflect past conditions in the life of the tree which may cover hundreds or even thousands of years. Geologists and anthropologists examine and compare the cross sections of many trees and timbers in an area to discover the history of the climate, the age of buildings and dates of forest fires or droughts.

If possible get a small log or branch, or even wood blocks or pieces of two-by-fours for the children to examine. Their understanding of tree rings will be increased when they see that they are three-dimensional. (They extend for long distances and are added to form a layer near the bark so that older parts of a tree have more rings than younger parts.) You can demonstrate this by putting a large cylinder around one of slightly smaller circumference, and surrounding both with another slightly larger, etc.)

Some children may want to know about the distortions in the tree rings shown on their worksheets. Encourage the children to find their own answers first. Then, if you wish, provide this explanation concerning the cross section on the worksheet. The drawing represents a cross section of a loblolly pine about fifty years old. This tree has survived several disasters. Something pushed against it in its early years. The tree responded by growing denser (heavier) wood on the pushed side. This resulted in the formation of rings that are more oval than round during that period. Later, whatever was leaning on the tree (perhaps another tree) was removed but then there was a forest fire. The fire scarred the tree but did not kill it. It continued to grow for a number of years after the fire.

For an explanation of such distortions send to the Public Relations Department of St. Regis Paper Company, 150 East 42nd Street, New York, New York 10017 for the free booklet, The Trees and the Forest. In this booklet you will find colored illustrations and the history of a tree very similar to that on the worksheet.



Photograph from Endeavour by W. S. Glock and S. R. Agerter

Have the children discuss why the tree grew more during some years than during others. How old was the tree when the fire happened? How many years did it grow after that? Show them this picture of the cross section of another loblolly pine that grew under nearly ideal circumstances. It apparently had the advantages of appropriate climate and soil, normal rainfall and sunshine and no injuries from fire, termites, etc.

Lesson 14: RELATION BETWEEN DIAMETER AND CIRCUMFERENCE

In Lesson 4 of Unit 16, the children had the opportunity to discover that the length of the circumference of a circle is about three times the length of its diameter. In this lesson the concept is reviewed, reinforced and extended. The children measure and graph the circumferences and diameters of several cylindrical objects of different sizes. The objective is to give the children experience in plotting data in which both variables (from object to object) are distances, and to lead them to see that the relation between circumference and diameter is shown quite simply when the data is graphed -- all the data points fall on a nearly straight line. This extension of stage one in the development of graphing emphasizes the fact that a data point is determined by measuring the appropriate distances along the two axes. It also introduces the idea that a time duration need not be one of the variable. In a relation such as this, time is not of any importance -- the relation between the length of the circumference and the length of the diameter remains constant, whether they are measured today or next year.

By having the children work in small groups, you can reduce the amount of equipment and have children available to help others who are having trouble cutting the paper strips.

In addition to the graph made by each child, you may wish to have the class make a large graph on the flannel board or bulletin board. The children may be astonished to find that the relation between circumference and diameter is the same for large objects as for small ones.

MATERIALS

— 1 can, waste basket, or other large cylindrical object

— 1 ruler or yardstick

-- for each child --

— Worksheet 16

-- for each group of four --

— ticker tape (one-half inch wide)

— paste

- scissors
- variety of cylindrical objects -- large and small cylindrical property blocks, plastic containers of various sizes, etc.

PROCEDURE

Show the class a large cylindrical object such as a large can or waste basket.

WHAT SHAPE IS THIS? (Round, circular, cylindrical.)

WHAT IS THE SHAPE OF THIS OPEN END? (Round, circular.)

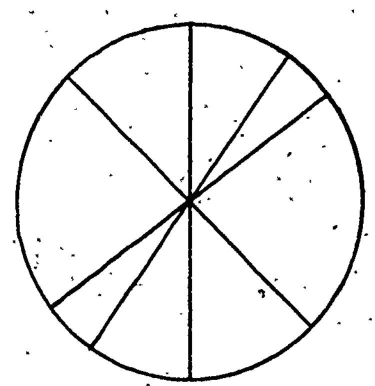
Stretch a length of ticker tape across the diameter of the object.

DOES ANYONE REMEMBER WHAT WE CALL THE LONGEST DISTANCE ACROSS A CIRCLE? (A diameter.)

Use one end of your large container to draw a circle on the chalkboard. With a ruler or yardstick, draw a diameter and label it.

CAN ANYONE DRAW ANOTHER DIAMETER OF THIS CIRCLE?

Have several children add diameters.



WHO REMEMBERS THE NAME FOR THE DISTANCE AROUND THE CIRCLE? (Circumference.)

Tell the children that there are many interesting things about circles and that you are going to let them try to discover one of them. You are going to show them how to start.

Take a piece of paper tape and cut it to equal the diameter of the large circular object you first used.

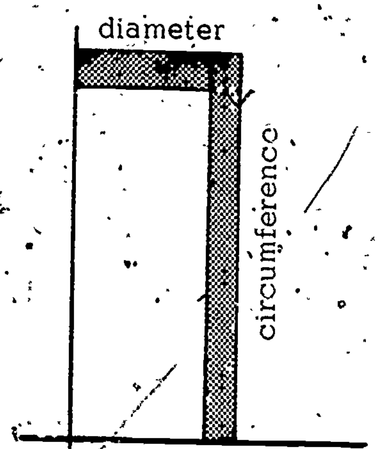
WHAT DOES THIS LENGTH REPRESENT? (The length of the diameter of the can.) I'LL MARK IT "DIAMETER."

By wrapping tape around the can, measure and cut another piece to represent the circumference.

WHAT DOES THIS LENGTH REPRESENT? (The length of the circumference of the circle.) I'LL MARK IT "CIRCUMFERENCE."

On the chalkboard draw carefully a vertical and a horizontal axis.

I AM GOING TO PUT THE DIAMETER STRIP ACROSS HERE, OUT FROM THE "UP" AXIS. AND I WILL PUT THE CIRCUMFERENCE STRIP HERE, UP FROM THE "OVER" AXIS, AND MOVE THEM UNTIL THEIR ENDS JUST OVERLAP LIKE THIS.



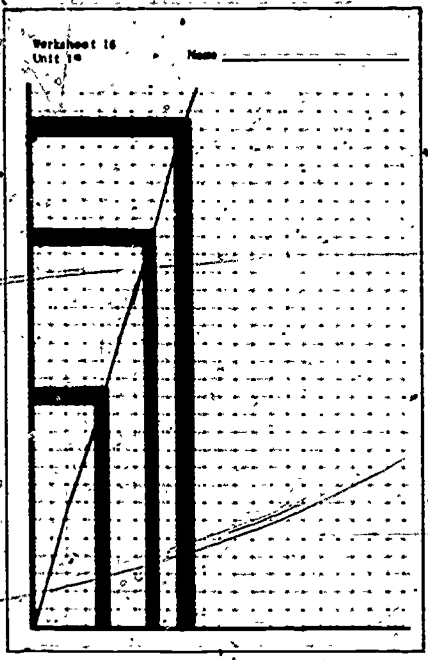
Have one or two children hold the tapes in place while you attach them with bits of masking tape.

HOW DOES THE DIAMETER STRIP GO? (Straight across from the "up" axis.)

HOW DOES THE CIRCUMFERENCE STRIP GO? (Straight up from the "over" axis.)

HOW DO THE ENDS OF THE STRIPS MEET? (The end of one just covers the end of the other.)

Tell the children that they are going to measure the diameters and circumferences of some cylinders and cut and paste strips of corresponding lengths on Worksheet 16.



(After putting several sets of strips on Worksheet 16, the children should discover that the circumference of any cylinder is about three times greater than its diameter.)

Distribute the objects to each group. To make sure that each circumference is put with the diameter from the same object, suggest that they first number the objects and then the tapes that represent their measurements.

WHEN YOU HAVE SEVERAL SETS OF STRIPS IN PLACE, WHAT DO YOU NOTICE? WHAT INTERESTING FACT DO YOU DISCOVER? WHEN YOU KNOW THE INTERESTING FACT, COME AND TELL ME QUIETLY. DON'T TELL OTHERS.

CAN YOU FIND OTHER CIRCULAR OBJECTS IN THE ROOM THAT YOU CAN MEASURE AND RECORD ON YOUR WORKSHEET TO CHECK YOUR IDEA? (If you wish, give the children some practice in predicting a circumference when you provide the diameter of an object, or vice versa. Some of the more able children may make use of the fact that the intersections of the pairs of strips fall on a straight line.)

Lesson 15: CHANGING WATER LEVEL WITH MARBLES

This lesson leads the child to see that the water level in a container is directly related to the number of marbles put into it. The lesson is also intended to improve predicting and graphing skills.

The children add four marbles, one at a time, to a cylinder of water. They predict the new water height before adding each marble. After adding a marble, they note the new water height, record it on Worksheet 17, and compare the result with the prediction.

In Activity A you demonstrate the procedure, starting with water up to the fifty-millimeter mark in a cylinder. In Activity B, the children work in small groups to carry out the same experiment, but they fill their cylinders with water up to the sixty-millimeter mark.

The children may notice that water distorts the shape and size of the marbles. Some may even notice that the water level is higher around the side of the cylinder than it is at the center. All of these observations are worth the time it takes to speculate about them, if the children bring them up.

MATERIALS

- roll of adhesive centimeter tape with millimeter divisions
- water

-- for your demonstration --

- your copy of Worksheet 17, provided with the lesson
- 1 tray of equipment prepared for a group (see below)
- water

-- for each child --

- Worksheet 17
- 1 red and 1 blue crayon

-- for each group --

- tray
- plastic cylinder with scaled tape attached, as shown in the photograph on page 79.
- water
- medicine dropper
- craft stick or tongue depressor
- paper towel

PREPARATION

Put a millimeter scale on each plastic cylinder. Do this by cutting a length of ten centimeters from your roll of scaled adhesive tape and pasting it to the side of the cylinder, with the zero at the bottom. Put all the items specified for each group on a tray, except the water. (One member from each group can come to a table and measure sixty millimeters of the water into the group's cylinder at the start of Activity B.)

PROCEDURE

Activity A

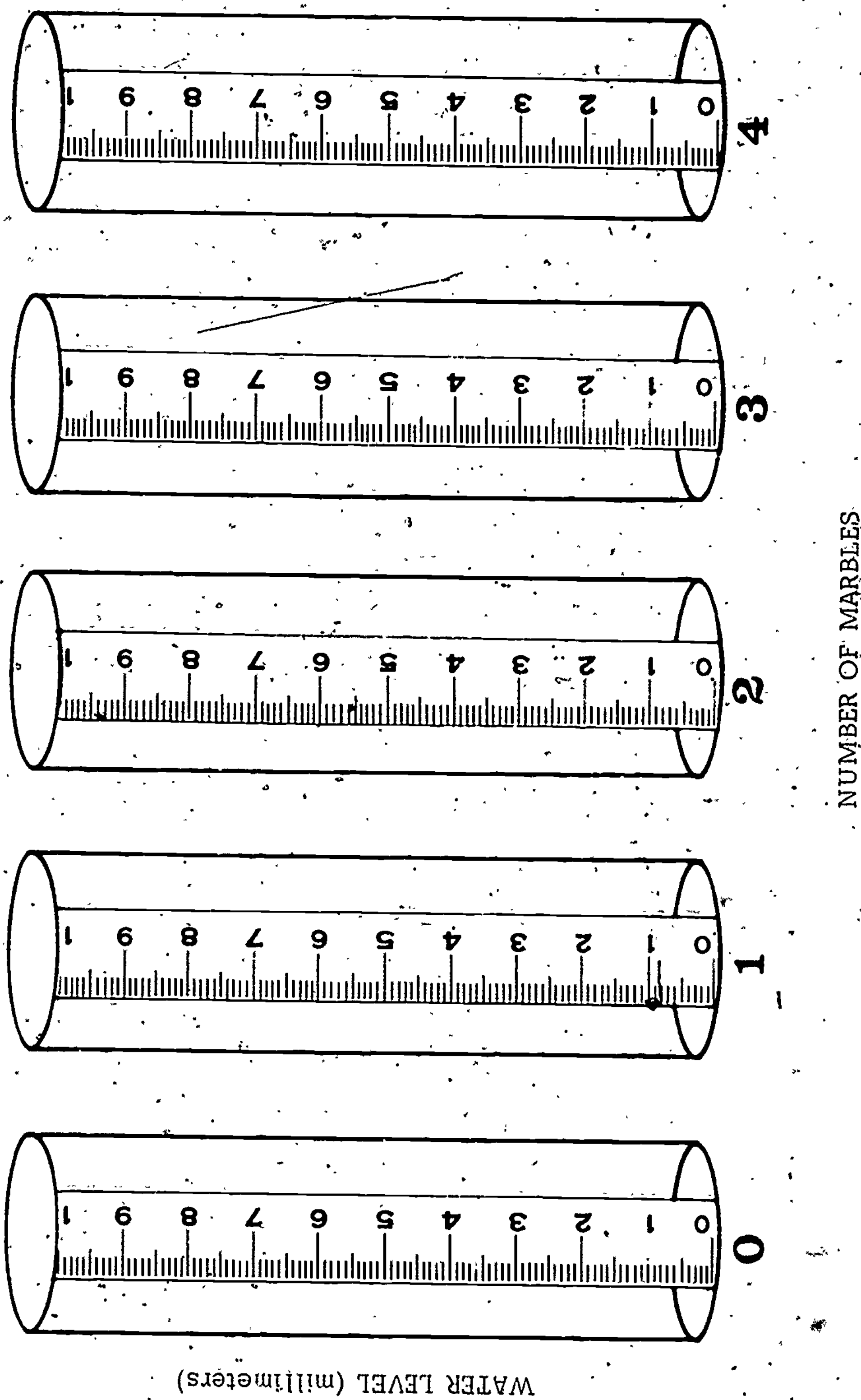
For this demonstration activity, mount a copy of Worksheet 17 on the chalkboard. Place it rather low on the board so the children can see and mark it easily. Use the equipment on one of the trays you have prepared for the children.

Have the children gather around closely, so that all can see. Begin by showing an empty cylinder with the scale on it. Explain that each centimeter is divided into ten smaller parts called millimeters. Remind the children that since they are used to counting by tens, all they need to do to count the millimeters is to count by tens at every centimeter mark. For example, at the one-centimeter mark, they would say "ten millimeters," at the two-centimeter mark, "twenty millimeters," and so on. Throughout the lesson, express every measurement in millimeters yourself, but accept the word "marks" from the children.

Worksheet 17
Unit 19

Name ______________________

NUMBER OF MARBLES	WATER LEVEL (millimeters)



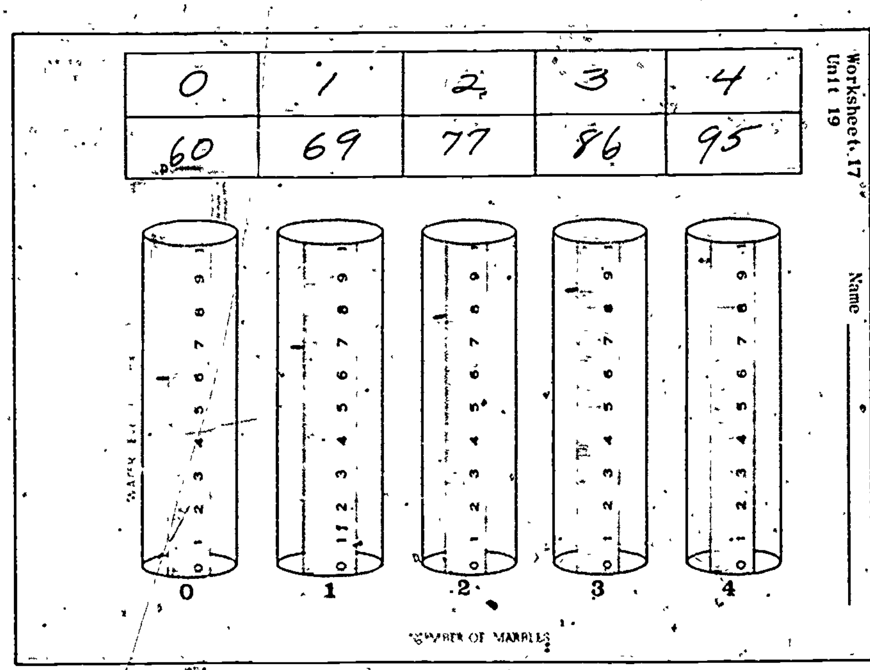
Now fill your cylinder with water to the 50-millimeter level. Stop pouring a little short of the mark and use the medicine dropper to get the water to just the right level. Explain that you are going to place four marbles, one at a time, into the water in the cylinder. Let the children look at the marbles and guess what will happen to the water level when you add the marbles.

Ask a child to read the starting level of the water in your cylinder and to put a red crayon mark on your copy of Worksheet 17 where he thinks it should be. Guide him, if necessary, to put the red mark beside the 50-millimeter mark in column 0.

Next, use a craft stick placed in the cylinder to let the first marble roll gently into the water. Tell the children that this is the careful way each marble should be added, so that the liquid will not splash out. Have another child give you the reading for the new water level. Ask the class to help the child decide where the new mark should go. The children should decide to put the new mark on the cylinder marked "1" (number of marbles) at whatever reading was taken. This should be at or very near the sixty-millimeter mark.

Before sliding another marble into the water, ask the children to make some predictions about how high the level will be when this second marble is added. Make a brief record of the predictions on the chalkboard (the child's initials and the numeral).

Put the second marble in the cylinder and have the reading and recording done. Then let the children check their predictions and make new ones for the third marble. Continue this process of predicting, adding a marble, recording, and checking with the predictions until all four marbles have been added to your cylinder.



Before going on to the next activity, give the children some practice in reading the millimeter scale, if you think it necessary. Use an empty cylinder for this, having different children show you where the marks are that show (e.g.) 61 mm, 77 mm, and so on.

Activity B

Distribute the trays of equipment to the groups of children. Check to see that each plastic cylinder has water in it to the sixty-millimeter level. Tell the children that they are going to do the same experiment they helped you do, but that there is something slightly different about it. See if they can tell you that they have more water than you had, "ten millimeters more."

Ask the children to mark the water level at the start on Worksheet 17 with red crayon at the left of the column labeled "0 marbles", and then to mark with blue crayon a prediction for each of the other columns, putting the blue marks to the right. Then have them complete the worksheet using red crayon for actual readings.

A discussion of the results will show that slight variations exist from group to group. You might ask the children why this is so. They should be able to suggest that the marbles may vary slightly in size, that measurements are never exact, that water may have splashed from some cylinders, etc.

Some children may have made excellent predictions, because they noticed that each marble made the water rise about nine or ten millimeters. Ask a child who has had unusually accurate predictions to tell the class how he made them.

Lesson 16: SWELLING AND SHRINKING SEEDS

Although this lesson extends over four days, it requires very little time each day. Plan to teach the lessons in Section 4 during the remainder of the two MINNEMAST periods each day.

When seeds are left overnight in a cylinder of water, the seeds swell and the height of the column of seeds in the cylinder increases.

Column of seeds at start

Day 0

Column of seeds after 24 hours

Day 1

After observing the increase in height of the seed column, the children spread the seeds on paper towels to dry. The next day the children put the seeds into an empty cylinder and measure the height of the seed column again. Then they spread the beans out once more and measure them after a second day of drying to see whether they have shrunk still more. The children record each day's data on Worksheet 18.

This activity gives the children an opportunity to observe and record a change in size that can be made to go in two directions, rather than just increasing or decreasing.

The absorption of water (imbibition) by various materials such as peas, beans, rice and wood has practical applications that the children might enjoy thinking about. For example, their mothers have to know how much water a cup of rice will absorb to know how much to add for cooking, how large a pan to use to cook it in, and how many people it will serve.

In some instances the power of swelling objects has been used to great advantage. Before explosives were discovered, stone was quarried by pouring water on pieces of dry wood that had been wedged into holes in the rock. Even now this method is used in quarrying marble and granite for special purposes. There is some historical evidence that swelling seeds were also used to split rocks. You can demonstrate the power of swelling seeds with a simple experiment. Fill a small plastic bottle with beans and pour as much water into it as possible. Screw the cover on very tightly, or use strong surgical tape to keep the cover securely in place. The next day the plastic bottle will be broken.

NOTE: The height of the water level in the cylinders on Day 0 and Day 1 is not a consideration in this lesson, beyond the fact that a certain level was specified to insure that the beans have enough water to absorb. There should be very little change in the water level, if the tops of the cylinders have been tightly covered with plastic wrap and if there has been no spillage.

MATERIALS

-- for each child --

- tray
- plastic cylinder with centimeter tape attached
- tape or label for child's name
- soufflé cup filled with Michigan navy beans
- container of water

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- medicine dropper
- piece of plastic wrap to cover top of cylinder
- paper towel
- Worksheet 18

-- for the class --

- box or pan in which to store all the cylinders from day to day
- 1 beam balance (from Unit 16)
- box of paper clips (#1)
- extra plastic cylinder with screw top, or plastic pill bottle with cap and strong adhesive tape (optional)
- enough beans to fill a cylinder or plastic pill bottle (optional)

PREPARATION

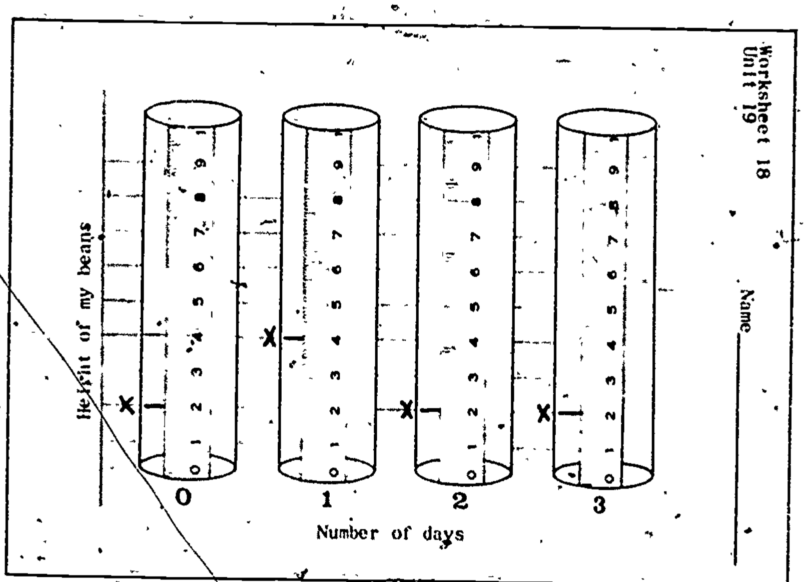
Attach centimeter tape to enough cylinders so that each child can have one. Fill soufflé cups with Michigan navy beans. Assemble all the materials specified for each child on trays, or arrange them on a table where the children can come and get them.

PROCEDURE

Day 0

Give a tray to each child, or ask the children to come and get the materials and have them work on paper towels. Ask each child to label his cylinder with his name or initials. Next have each child fill his cylinder to the 2-cm mark with beans from the soufflé cup. Suggest that the children take out or put in beans, and jiggle them around a little in the cylinder to get the beans as nearly level with the 2-cm mark as possible. Next ask the children to pour enough water in each cylinder so that beans and water combined reach the 7-cm mark. Remind them that they can adjust the water level with a medicine dropper. After that, each child should cover the top of his cylinder tightly with plastic wrap and stand it in the box or pan you have provided for that purpose. Next, ask each child to look at Worksheet 18.

WE HAVE JUST STARTED AN EXPERIMENT WITH BEANS -- ON WHICH CYLINDER SHALL WE MARK THE HEIGHT OF THE BEANS TODAY? (On the cylinder above the column marked "Day 0.")

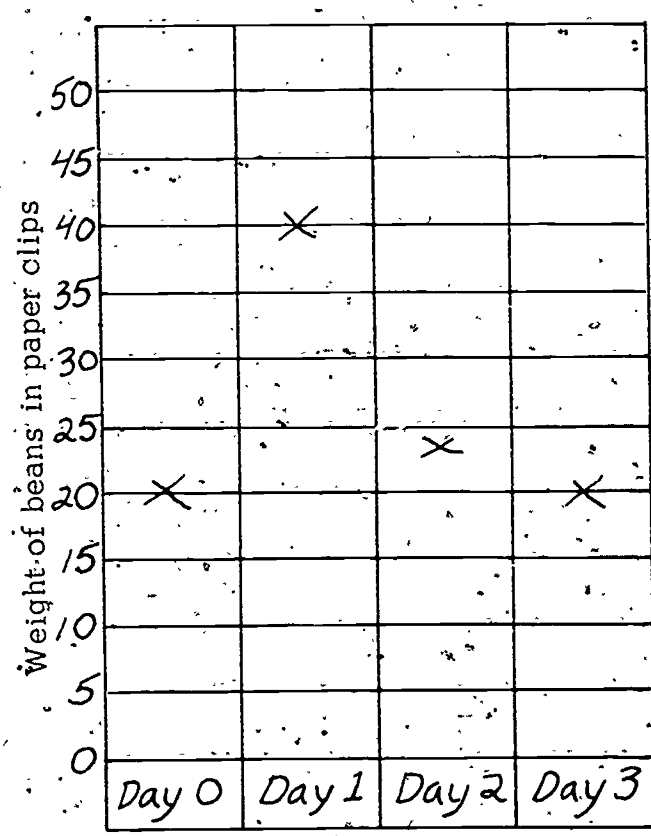


Have the children put a mark at the left of the cylinder to show the height of their bean columns on Day 0.

TOMORROW AT ABOUT THIS SAME TIME WE WILL LOOK AT OUR CYLINDERS AGAIN AND FIND OUT WHETHER ANYTHING HAS CHANGED. WHAT DO YOU THINK WILL CHANGE?

Let the children speculate freely about what will happen, but do not reveal whether they are right or wrong.

Now ask one child (George) to fill a cylinder with beans to the 2-cm mark and then to weigh the beans with the beam balance, using paper clips as weight units. Make a record of the weight of the dry beans on Day 0 on a chalkboard chart that will eventually look like this:



George's weight experiment

Next have George put the beans back in the cylinder and add water up to the 7-cm mark. When he has done that, have him pour the water into another container and weigh it. Make a simple record for the weight of the water in paper clip units on the chalkboard. (If George has used #1 paper clips, the record should look like this: On Day 0, the weight of the water in George's cylinder ≐ 40 paper clip units.)

Have George label his cylinder "Weight Experiment," restore the water to it, cap it with plastic wrap and set it aside until the next day.

Day 1

Have each child observe the new bean level in his cylinder and fill in the new reading in the appropriate column of Worksheet 18. Then have each child drain the water out of his cylinder and spread his beans out on a paper towel. (Some of the inverted cylinders may have to be tapped sharply on the desk to dislodge all the beans.) Have each child mark his towel with his name or initials and put it in a place where it can be left overnight for the beans to dry out.

Now have George drain the water from his cylinder into the same container he used the day before for weighing the water, and weigh his beans before he spreads them out on a paper towel. Make a record of the weight of the beans above Day 1 on his chalkboard chart. Have the children compare the increase in weight of the beans with the increase in the height of the beans in the cylinder. (Both measurements for Day 1 are about twice those for Day 0.)

Before George weighs the water from his beans, ask the children to speculate about whether there will be more water, less water, or about the same amount of water as on Day 0, and give their reasons. Then have George weigh the water and record the new weight on the chalkboard. (It should be about half that of Day 0.) Ask the children what became of the rest of the water. (It went into the beans; the beans absorbed it.)

If you wish to do it, this is a good time to start the experiment with a cylinder crowded full of beans, and then water, and ask the children what they think will happen. Be sure the cap to this cylinder is so tightly screwed or taped in place that the cover will not come off and spoil the experiment.

Day 2

The children take the dry beans from their paper towels, put them in their empty cylinders, make a reading of the new bean height, and record it on the worksheet. Then they spread the beans out on the towel again. Depending on the conditions in the classroom, the shrinkage by the next day may not be measurable, but the possibility is worth speculation and investigation by the children.

Ask the children to predict the weight of George's beans. Then have George weigh his beans and record the new weight. Have the children compare the loss of weight with the loss of size. (The losses will be about the same. George's beans will weigh about half of yesterday's weight, and the height of the dry beans in the cylinders will be about half of yesterday's height.)

WHY DID GEORGE'S BEANS WEIGH SO MUCH LESS TODAY? (Because they shrank like ours; because the water evaporated from them; they dried out, etc.)

The children should be able to see that there is a relation between the loss in size and the loss in weight, both caused by loss of water from the beans.

IF GEORGE PUTS HIS BEANS IN WATER AGAIN, WILL THE BEANS CHANGE AGAIN? HOW WILL THEY CHANGE IN SIZE? HOW WILL THEY CHANGE IN WEIGHT?

After the children predict, have George put his dried-up beans in the cylinder and add water to the 7-cm mark, as before.

Day 3

On this day, the children make the last measurement and recording of the bean heights. Then George weighs several batches of beans that other children have been drying for two days, in order to get an approximate reading for Day 3 on his weight chart. The children compare George's weight record with their own height data. They discover there is a correspondence between the two.

Next George shows the class his cylinder of re-soaked beans, and the class observes that the beans have again increased in size. Then he weighs the wet beans so that the class can see the beans have also again increased in weight.

If you have done the broken-bottle experiment, let the children examine the broken cylinder and speculate about the cause. Then, if you like, tell the class how this swelling through absorption of water has been used to split rock.

Whether you have done the bottle experiment or not, lead the children to a discussion of whether the swelling of seeds is of any practical use by telling anything they have noticed about the cooking of rice, barley, oatmeal, etc. at home.

WHEN YOUR MOTHER COOKS OATMEAL, DOES SHE ADD A LOT OF WATER TO A SMALL AMOUNT OF OATMEAL, OR DOES SHE FILL THE POT MOSTLY WITH OATMEAL AND ADD A LITTLE WATER? WHY?

If you wish, let the children bring small amounts of dry barley, rice, wheat, etc. to test with water in their cylinders. Wood chips or sawdust could also be soaked in water and the results noted.

You can call the children's attention to the fact that wood absorbs water by asking them why bureau drawers and house doors stick at times.

SOMETIMES IT IS DIFFICULT TO OPEN THE DRAWERS OF WOODEN FURNITURE. CAN ANY OF YOU TELL US WHY THIS HAPPENS? DOES THIS OCCUR IN ANY PARTICULAR KIND OF WEATHER?

SECTION 4 PLOTTING ORDERED PAIRS

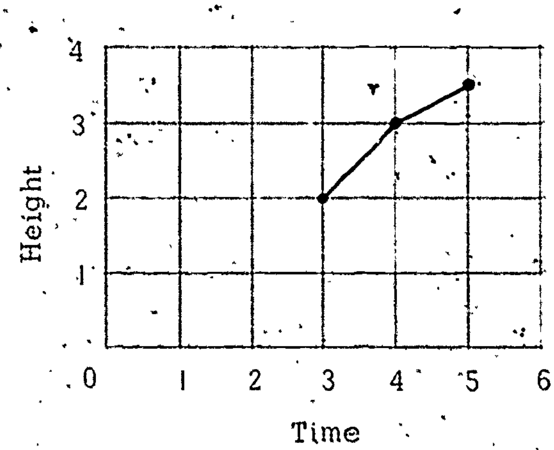
PURPOSE

— To give practice in plotting data on a grid.

— To give practice in interpreting graphical data.

COMMENTARY

This unit is devoted to the observation of different kinds of changes, and the recording of those changes in a number of different ways. One of these recording methods is to graph the data by plotting points on a grid on which the horizontal or x-axis shows one change and the vertical or y-axis shows another change. For example, to show growth over a period of time, we use the x-axis to represent regular units of time, and the y-axis to represent units of height measurement. The graph showing that a plant grew from 2 inches tall on the third day, to 3 inches tall on the fourth day and then to 3½ inches tall on the fifth day would look like this:



The location of the point recording plant size on the third day can be described by a pair of numerals (3,2) that locates the point in reference to the two intersecting axes, time (x) and height (y). The pair of numbers (the coordinates) is called an ordered pair, because it is always given in the same order -- that is, the horizontal or x-axis location is always stated first, and the vertical or y-axis location is always stated second.

The lessons in this section are designed to prepare the children for graphing data in this way and for interpreting such graphs.

We begin with columns and rows of desks and show the children how these can be recorded on a room map. The children learn to locate each child's desk by an "address" which is an ordered pair of numerals naming the column and the row in which the desk is located. Lines drawn through the columns and rows on the map become the children's first experience with numbered grid lines.

The children continue locating points on a grid by "name and address." That is, point A is at (3, 2). They learn to find 3 on the horizontal axis (called the "over" axis) by starting at 0 and moving over to 3; they find 2 on the "up" or vertical axis by moving up from 0. Then they trace the grid lines from each of the axes to the point at which they intersect.

Ordered pairs are provided in tables, and the children transfer them to grids. (The bonus for this task is to draw a "follow the dot" picture on the grid.) They also work with the inverse operation -- that is, they read the plotted points on the grid and transfer their addresses (the ordered pairs) to tables.

It is expected that many children will be able to handle this work easily, after their work with graphs in preceding activities. Others will need extensive practice. Therefore, the lessons of this section may be used formally or as free-time activities, as best fits the need of your class. It is hoped that they will appeal to the children so that they will continue to play the games and thus review the processes even after the unit is completed. You can consider the section successfully completed when the majority of children are able to locate a point on a grid when given its coordinates as an ordered pair. You may then proceed to the next section, in which these skills are applied to specific problems.

Lesson 17: PLOTTING ADDRESSES

In this lesson the children learn to describe locations of their desks in terms of ordered pairs of numerals referring to the column and row they are in. They locate the corresponding intersections on a grid superimposed on a map of the room.

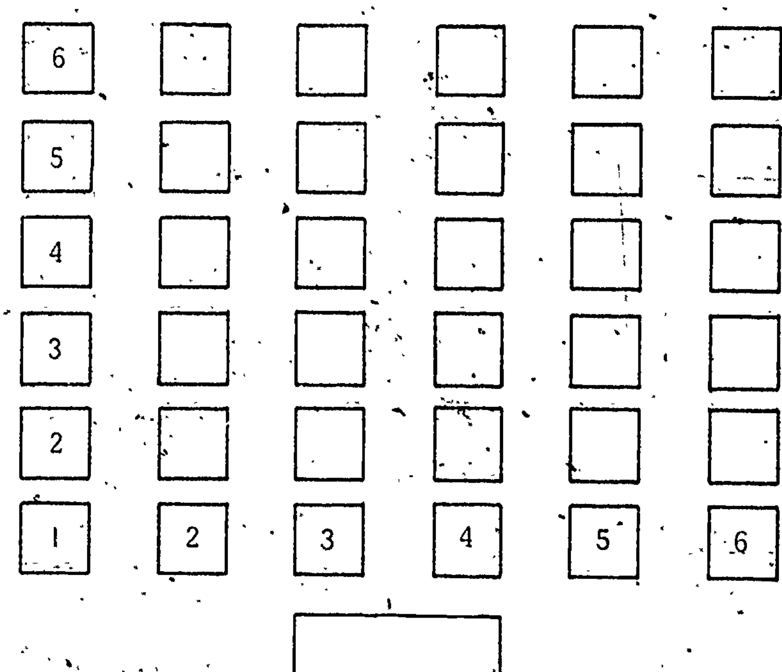
MATERIALS

- tagboard
- cards with numbers for labeling rows and columns of desks
- red marking pen

PREPARATION

Before teaching this lesson, arrange the desks in an array as shown in the diagram below, and draw a map of the arrangement on a large piece of tagboard. (If you normally have the desks in an array, draw the map of your regular arrangement. It is not essential to have six columns or six rows.)

Put numeral cards on the first desk of each column and row. As you face the class, Column 1 will be on your left, and Row 1 will be closest to you. Show your own desk in its proper location.



PROCEDURE

Activity A

Remind the children that in an array, such as that formed by their desks, columns go up and down and rows go across. Distribute the cards assigning numbers across the first row and down the first column of desks. Have the children seated at their desks. Tell them that when you shut your eyes, they are to move quietly to other desks. Keep your eyes closed throughout the first part of the activity.

When the children are settled, ask:

MARY BROWN, WHERE ARE YOU SITTING?

If she answers "At John's desk," say:

I'VE FORGOTTEN WHICH DESK THAT IS; CAN YOU TELL ME IN ANOTHER WAY? (Third column, second seat.)

If necessary, help out by asking:

WHICH COLUMN ARE YOU IN? (Third.) WHICH ROW? (Second.) YOU ARE IN COLUMN THREE, ROW TWO -- OR YOU ARE AT THREE, TWO.

NOW TELL ME WHO IS SITTING AT FOUR, THREE -- IN COLUMN FOUR, ROW THREE?

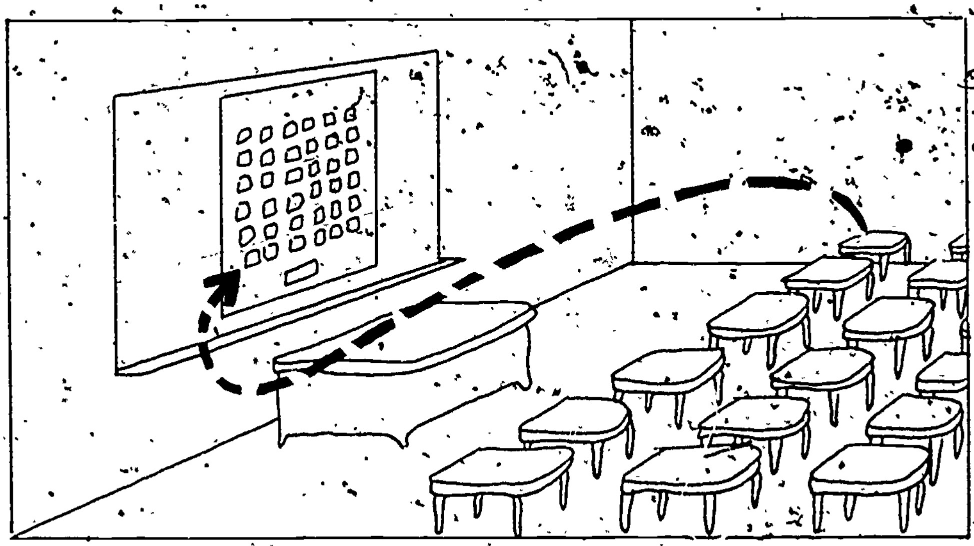
Repeat this with several children.

Then open your eyes and call on several children to give you their addresses --- that is, to name the column and row of the desk they are sitting at. Emphasize that the column address is always given first, and since we know that, it is not necessary to use the words "column" or "row" before the numerals.

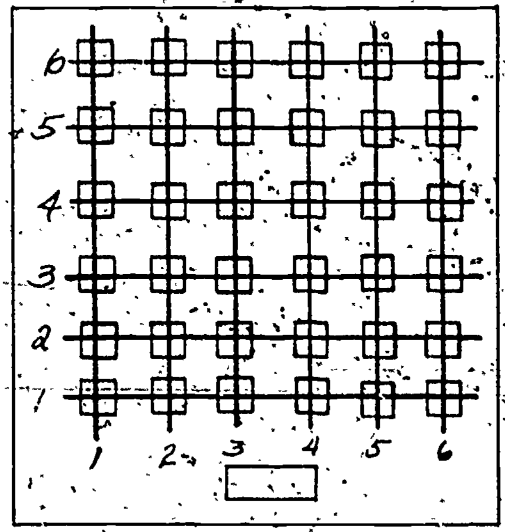
Vary this by calling out addresses e.g., (2,6), (1,4) and having the children seated at those desks stand.

Activity B

If you normally have the desks arranged in an array, have the children return to their own seats. Show the class the tagboard map of the desk arrangement. Tell them that it shows the desks as you see them from the front of the room. Take the map to the back of the room so that the children have to turn around in their seats to see it. This will make it easier for them to relate their physical positions to the visual impression given by the map. It will help them see why the desk that seems to be in the front right hand corner of the room is shown at the lower left hand corner of the map.



With a red marking pen draw vertical lines through each column of desks and across each row. These lines will form a grid with a desk at each intersection.



Continue to ask children to give their addresses, or to respond to addresses you call out, but now have each also go to the map and put his initials on the desk at the proper intersection. Occasionally point to a desk on the map -- one that does not have initials on it -- and ask the class for its address. Then the child at that desk should go to the map to initial the appropriate desk.

When the children are able to do this activity with facility, carry the map to the front of the room and continue as before. If they have too much trouble with the change in orientation, continue working from the back of the room, since the main purpose of the lesson is to teach the reading of coordinates on the grid. Keep the whole class involved in checking addresses. You may prefer to let each child call out a child's name or address after he has initialed or given his own address.

Lesson 18: PLOTTING PICTURES

In this lesson the children use ordered pairs to locate points on a grid. Then they connect the points to draw pictures. This gives them a great deal of practice with naming points on the grid.

We supply more of these worksheets than you may want to use in class time. Optional worksheets can be done during free time.

MATERIALS

-- for each child --

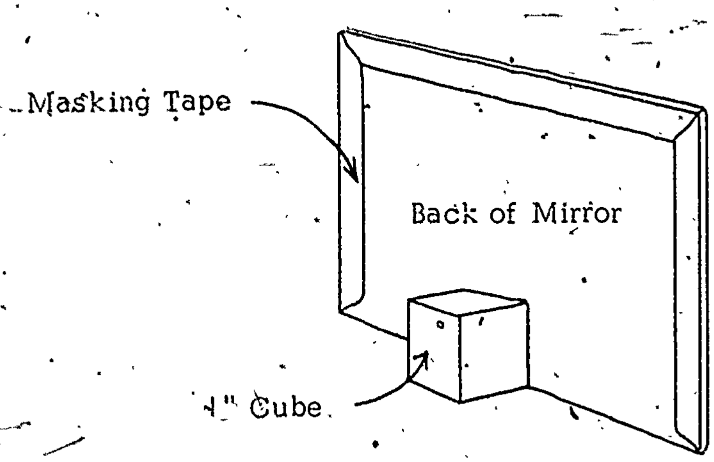
— mirrors, 1" cube, masking tape ($\frac{1}{2}$" wide), glue

— Worksheets 19 - 26

PREPARATION

Before distributing the mirrors provided in your kit, follow these steps. (Tape, wooden cubes, etc., are included in the kit.)

1. Glue 1" cube to the back of the mirror at the center of the lower edge. The block should be even with the edge of the mirror.



2. Use the $\frac{1}{2}$" masking tape to cover the two side edges and top edge of the mirror, as shown above.

PROCEDURE

Activity A

On the chalkboard draw a 10 by 10 grid, and number the axes. Have the children turn to Worksheet 19. As you read off the data, one point at a time, the children are to plot each point on their worksheets. Tell the children that we call the address of a point "an ordered pair" because we always give and plot the numerals in the same order.

Plot the first few points at the board while the children follow on their worksheets.

> WHAT IS THE ADDRESS FOR POINT A? (1, 1).
>
> FIND INTERSECTION (1, 1). THERE IS A DOT AT THIS INTERSECTION ON THE WORKSHEET. IT IS LABELED POINT A.

Use a finger of your right hand to trace from 0 to 1 on the horizontal or x-axis. Tell the children that to find the first number of the pair we go over from 0 along the "over" axis. Use a finger of your left hand to trace up from 0 along the vertical or y-axis. Tell the children that to find the second number of the pair we go up from 0 along the "up" axis. Then trace along the grid lines with both fingers until they meet at the intersection. Mark it with the ordered pair (1, 1) and label it "A."

> THE ADDRESS OF POINT A IS (1, 1). WHAT IS THE ADDRESS FOR POINT B? (1, 7).
>
> FIND INTERSECTION (1, 7). PUT A DOT THERE. LABEL IT "B."

Repeat the detailed procedure for point B while the children work at their seats. Then have a child come to work at the board as you continue reading the addresses, one by one.

A	(1, 1)	C	(2, 8)
B	(1, 7)	D	(2, 10)

E	(3, 10)	J	(6, 1)
F	(3, 9)	K	(6, 3)
G	(4, 10)	L	(5, 3)
H	(8, 7)	M	(5, 1)
I	(8, 1)	N	(1, 1)

After all the points are plotted, the children will connect them in alphabetical order, using straight line segments between points. Have them use a straightedge to draw the line segments. (They need practice in this skill to prepare them for work in Unit 21.)

Now have the children do Worksheet 20 independently. (Provide help only when it is needed.) Worksheets 21 and 22 are optional free-time activities.

All the children should do Worksheet 23. This provides one-half of a symmetrical figure. Have the children stand their mirrors up along line DH, the line of symmetry, to see what the complete figure should look like. Then, by counting grid lines, they should complete the figure, label the points with letters and ordered pairs, and write the addresses for the points in the table. Worksheet 24 is another optional activity involving symmetry.

Activity B

Have the children work in pairs. On Worksheet 25 each child is to draw a four-sided figure using straight line segments that begin and end at grid intersections. (Each new line segment is to begin at the same point that the last one ended on.) The children write down and then read to their partners the addresses of their points. Each reproduces the other's figure, and then they compare the reproductions with the originals.

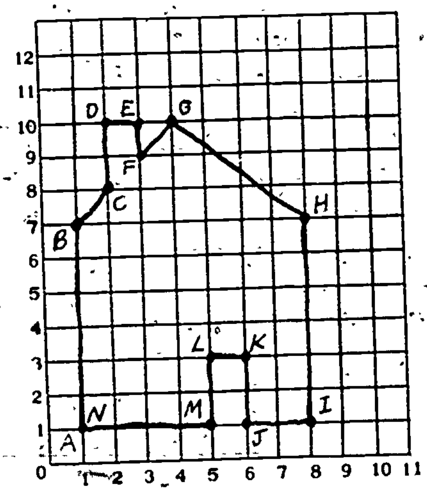
Worksheet 26 provides for a similar activity in which the children draw simple pictures, again using straight line segments.

Worksheet 19
Unit 19

Name ____________

Plot and label these points.
Then connect them in alphabetical order.

A (1,1)
B (1,7)
C (2,8)
D (2,10)
E (3,10)
F (3,9)
G (4,10)
H (8,7)
I (8,1)
J (6,1)
K (6,3)
L (5,3)
M (5,1)
N (1,1)

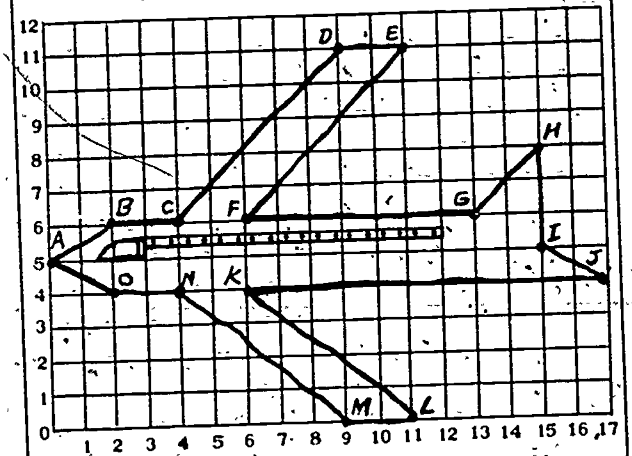


Worksheet 20
Unit 19

Name ____________

Plot and label these points.
Then connect them in alphabetical order.

A (0,5)
B (2,6)
C (4,6)
D (9,11)
E (11,11)
F (6,6)
G (13,6)
H (15,8)
I (15,5)
J (17,4)
K (6,4)
L (11,0)
M (9,0)
N (4,4)
O (2,4)

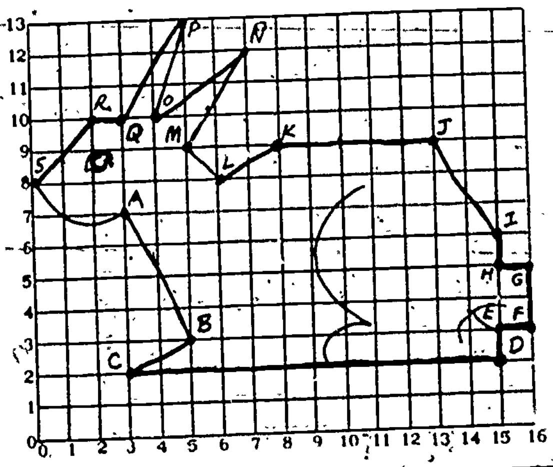


Worksheet 21
Unit 19

Name ____________

Now solve this puzzle.

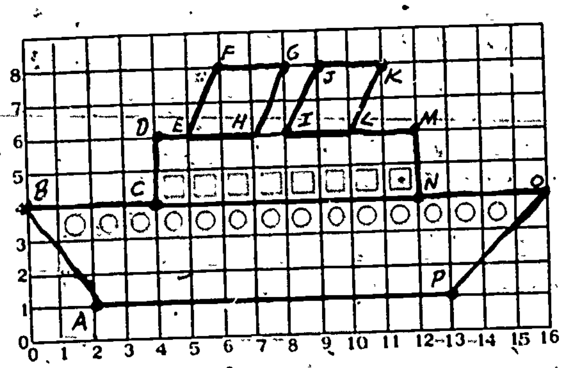
A (3,7)
B (5,3)
C (3,2)
D (15,2)
E (15,3)
F (16,3)
G (16,5)
H (15,5)
I (15,6)
J (13,9)
K (8,9)
L (6,8)
M (5,9)
N (7,12)
O (4,10)
P (5,13)
Q (3,10)
R (2,10)
S (0,8)



Worksheet 22
Unit 19

Name ____________

A (2,1)
B (0,4)
C (4,4)
D (4,6)
E (5,6)
F (6,8)
G (8,8)
H (7,6)
I (8,6)
J (9,8)
K (11,8)
L (10,6)
M (12,6)
N (12,4)
O (16,4)
P (13,1)



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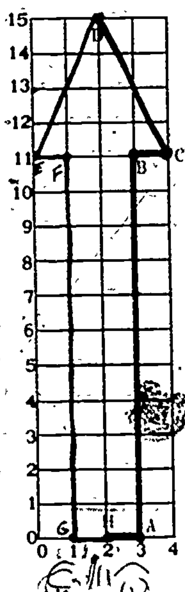
Worksheet 23
Unit 19 Name ____________

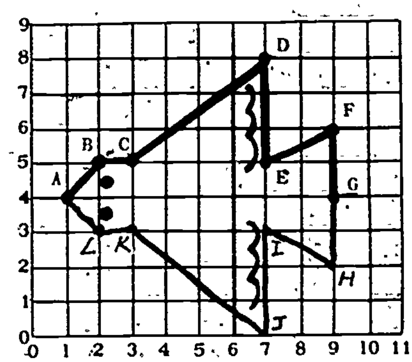
Here is half a picture.
Use your mirror to see it all.
The line of symmetry is DH.
Count the grid lines to complete the picture.
Now name the points and fill in the chart.



A (3 , 0)
B (3 , 11)
C (4 , 11)
D (2 , 15)
E (0 , 11)
F (1 , 11)
G (1 , 0)
H (2 , 0)

Worksheet 24
Unit 19 Name ____________

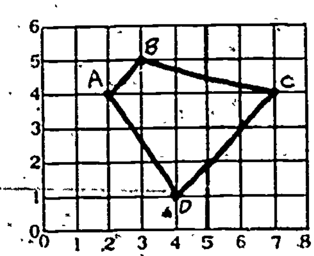
Here is another symmetrical picture.
Use your mirror on line AG.
Complete the picture and fill in the chart.



A (1 , 4)	E (7 , 5)	I (7 , 3)
B (2 , 5)	F (9 , 6)	J (7 , 0)
C (3 , 5)	G (9 , 4)	K (3 , 3)
D (7 , 8)	H (9 , 2)	L (2 , 3)

Worksheet 25
Unit 19 Name ____________

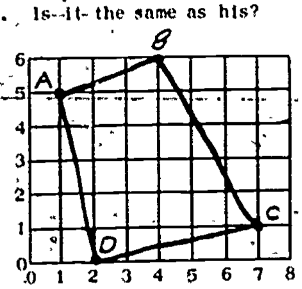
Draw a 4-sided shape on the grid.
Name the points and fill in the chart.
Then tell the addresses to your friend.
Did your friend draw the same shape?



A (2 , 4)
B (3 , 5)
C (7 , 4)
D (4 , 1)

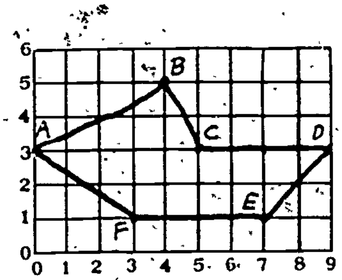
Write the addresses for your friend's shape.
Now draw the shape. Is it the same as his?

A (1 , 5)
B (4 , 6)
C (7 , 1)
D (2 , 0)



Worksheet 26
Unit 19 Name ____________

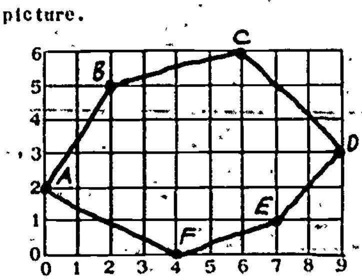
Draw a picture. Use only straight lines.
Tell your friend the addresses.



A (0 , 3)
B (4 , 5)
C (5 , 3)
D (9 , 3)
E (7 , 1)
F (3 , 1)

Write your friend's addresses.
Then draw his picture.

A (0 , 2)
B (2 , 5)
C (6 , 6)
D (9 , 3)
E (7 , 1)
F (4 , 0)



Lesson 19: "GO MOKO"

This game provides further practice in naming and locating points on a grid. It is similar to tic-tac-toe, and can be played either as a class activity or by pairs or small groups of children. Some extra grid sheets are provided at the back of the student manuals so that children can play during their free time.

PROCEDURE

Draw a 10 by 10 grid on the chalkboard and number the axes.

Divide the class into two teams, the O's and the X's.

The teams take turns calling out the addresses of grid intersections by giving the ordered pairs. As each intersection is called it is marked with an X or an O, according to the team that called it. No intersection may be called twice.

The objective of the game is for one team to capture any four adjacent points that lie in a straight line, either horizontally, vertically, or diagonally. The teams should choose intersections with two considerations in mind -- to gain control of a line of points, and to block the other team.

Fill in a demonstration game as you explain the game to the class. Allow the teams to consult for each turn until they are familiar with the rules. Then you can make the game more challenging by making the rules stricter. For example, consultation or calling an address out of turn might lose the team its turn.

Be sure that the child who marks the grid uses the first number in the address to go along the "over" axis and the second number to go along the "up" axis. The children will quickly learn that a turn is wasted if the address is called out in the wrong order, because the wrong point is captured.

SECTION 5 VOLUME AND WEIGHT

PURPOSE

- To review and extend the concepts of weight and volume and the measurement of these two properties.
- To reinforce the concept of conservation of weight and volume despite change in shape of an object.
- To help children develop an intuitive idea of the relation between weight and volume.
- To have the children gather data and record it by means of graphs, and to have them interpret graphs.
- To give practice in extending a table of measurements from data already known.

COMMENTARY

This section is intended to review and enlarge the children's understanding of weight, volume, function and measurement. Graphs are used by the students as tools for analyzing the relations between two kinds of measurements. Thus function is the major subject of the section, with the weight-volume relation as the vehicle.

In Lesson 20 the children compare the capacities of containers of different sizes. To do this they have to make some simple computations, using repeated addition or multiplication. (A few children may also use subtraction.)

In Lesson 21 the children reinforce or rediscover a concept that was introduced in earlier units -- that changing the shape of an object does not change its volume or weight. The procedure is to have the children change balls of clay into various shapes (without adding or removing any clay) and then drop them, one at a time, into a container of water. The children arrive at the conclusion that no matter how they change the shape of the clay its volume remains the same, because they note that each time the water in the container rises to the same level. That change of shape does not affect weight is checked by weighing each changed shape of the clay.

Lessons 22 and 23 give the children the opportunity to gather volume and weight data about some lead sinkers and to plot this data in Lesson 24. In Lesson 25 the children find the weight and volume of clay objects of different sizes. In Lesson 26 the children use their water displacement and weighing techniques to find out whether an "unknown" object contains more lead or more clay.

Lesson 27, though primarily a review and evaluation lesson, does give an early introduction to, and practice in, the kinds of graphing lessons the children will have in later units. In this lesson the children are required to interpret graphs, and from the ease or difficulty they have in trying to do this, you can estimate how much understanding of graphs they have acquired by that time. Because the children will be given much more work with making and interpreting graphs in the future, do not be discouraged if only a few students seem to have mastered the ideas.

Lesson 20: MEASURING THE VOLUME OF FIVE BOXES

The children construct paper boxes of assorted sizes and shapes, and find the volume of each as measured in Minnebar units. They may use any method they choose for finding the volume -- counting, matching, adding, multiplying, or any combination of these methods. The children will see that there are many ways to find the answer to a problem.

Problems involving numbers larger than those with which the children have previously worked are introduced, but it is not expected that they complete all the computations independently. Rather, they should see that they can describe procedures even when they cannot carry them out.

MATERIALS

- Worksheets 27, 28, 29 and 30
- cellophane tape
- 1 red and 1 yellow crayon for each child
- set of Minnebars for each child
- addition slide rules

PREPARATION

Cut out and assemble the wheel base and two wagon bodies from your copy of Worksheet 27, using as aids the diagrams on Worksheet 28. This will enable you to anticipate any difficulties the children may have when they assemble theirs.

PROCEDURE

Activity A

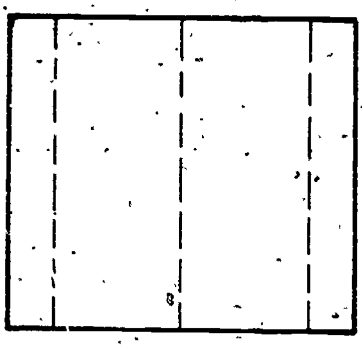
Use the story situation that begins on page 109 to introduce the problems of this lesson.

110

Worksheet 27
Unit 19

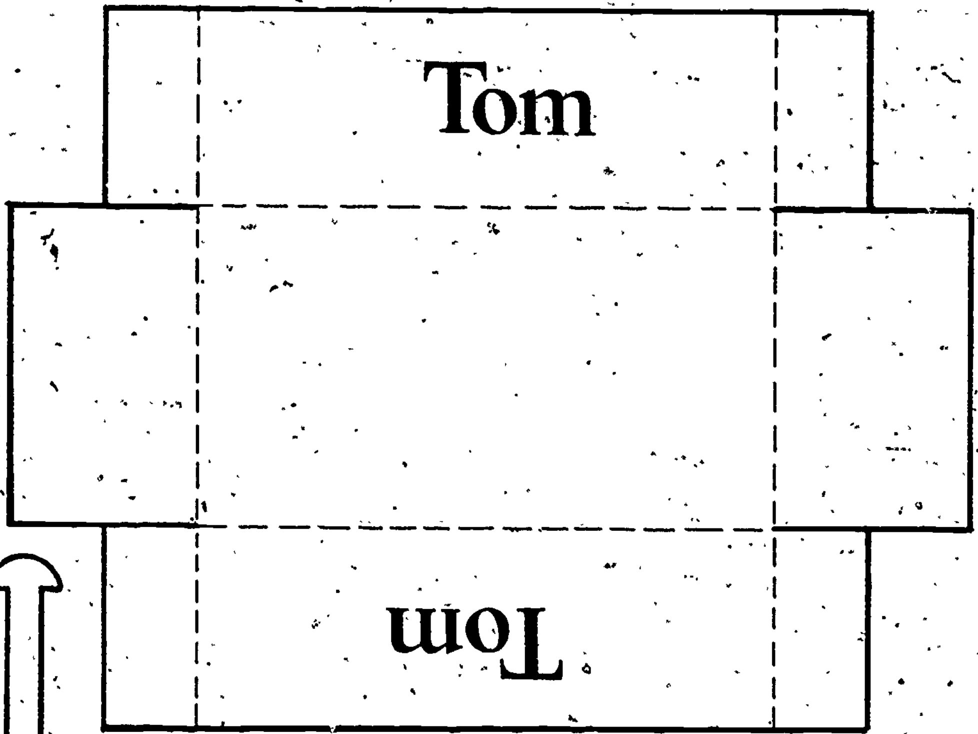
Name ____________________

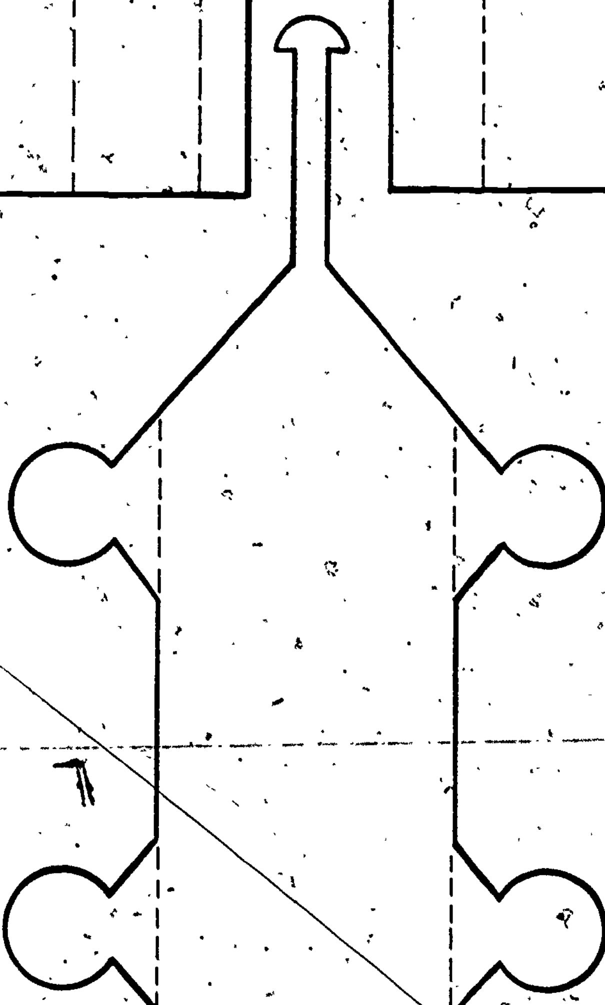
Wheel support



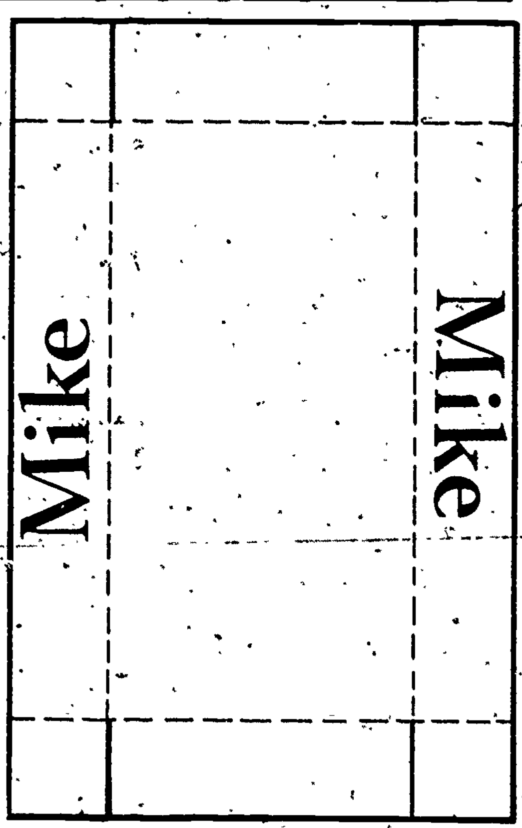
Wheel support

Tom's wagon body



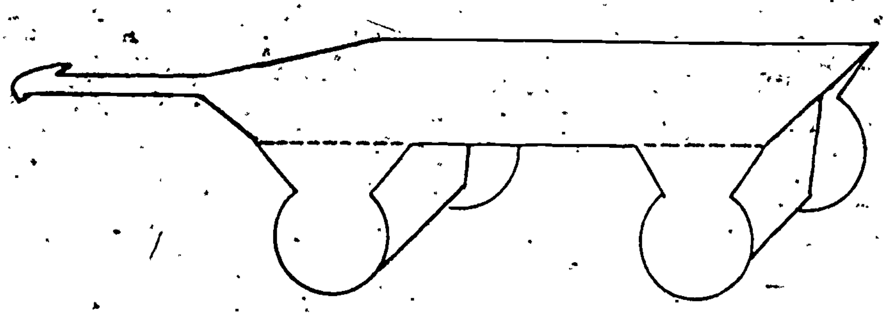


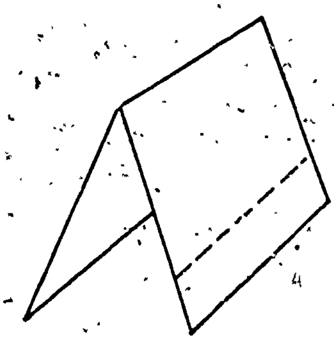
Wheel base

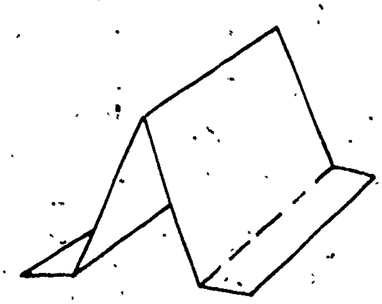


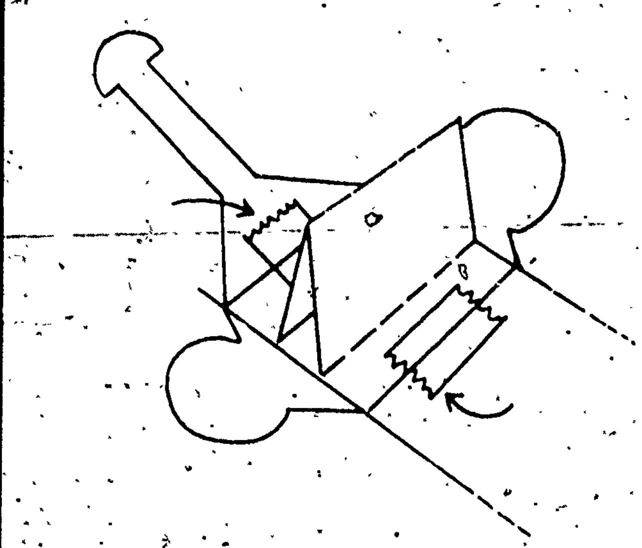
Mike's wagon body

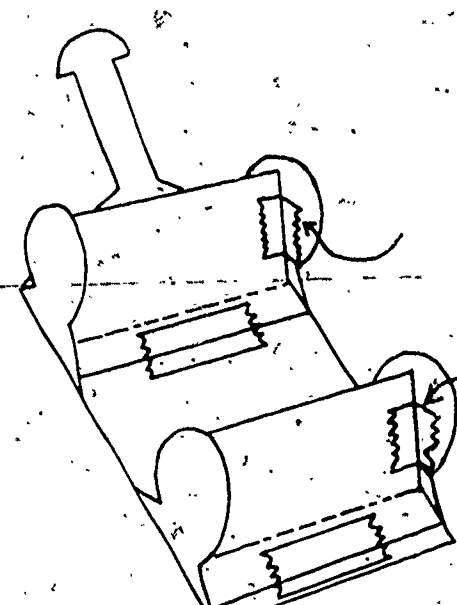
Worksheet 28
Unit 19 Name ____________________











Mike was all excited because he had been given a bright red wagon for his birthday. It was not so big as his friend Tom's yellow wagon, but it was much shinier, and its wheels didn't squeak. On Saturday morning Mike could hardly wait to finish eating his breakfast so that he could go out and use his wagon.

Tell the children they are now going to build small paper representations of Mike's and Tom's wagons from Worksheet 27. The children can use Worksheet 28 for reference, but give the following oral instructions also:

1. Cut out wagon bodies, wheel base and wheel supports. Cut along heavy black lines only -- dotted lines are for folds.
2. Color Mike's wagon red and Tom's yellow.
3. Assemble bodies by folding along dotted lines and pasting flaps at each corner.
4. Fold wheel supports on dotted lines.
5. Fold wheels down along the dotted lines.
6. Attach wheel supports between the wheels, using tape.
7. Attach wheels to supports, using tape.

Activity B

Mike's father said to him, "Mike, I have a job for you to do, and I think you will enjoy it. But if I had asked you to do it last week I don't think you would have liked it at all. Can you guess what it is?"

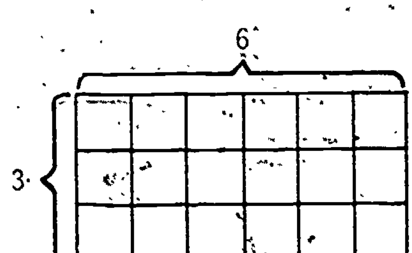
Mike couldn't guess. His mind was really on his red wagon, not on Dad's riddles. So he looked at his father's face for a hint, and he saw that his father was looking out of the kitchen window. He looked too, and he saw the big pile of wooden blocks that was in the back yard. "I know!" he said. "It's the blocks! Do you want me to move them in my red wagon?"

"You guessed it," Dad said. "Mr. Johnson is going to use them to build a playhouse for his grandson. Would you cart them over to his yard this morning?"

"I sure will!" Mike said. "I wonder how many trips I will have to make."

Mike and his father went out into the yard to figure it out. Mike filled his wagon with blocks. He put one layer into the wagon, and then he piled a second layer on top of it. But when he started to pull the wagon, he found that the second layer slid off because it was above the sides of the wagon. So he knew that he could carry just one layer of blocks at a time.

Remind the class that their red wagons and their Minnebars are scaled-down representations of Mike's wagon and blocks. Have them load each red wagon with a layer of Minnebars. Ask a child how many units of Minnebars there are (18), and have him tell the class how he found out. (He may have counted all the bars; he may have counted the rows and columns and computed by repeated addition or by multiplication.) Ask other children to tell how else one could find out how many units the wagon holds, until all the above possibilities are mentioned. As the answers are provided, write them on the board.



$$\begin{array}{r} 6 \\ 6 \\ +\ 6 \\ \hline 18 \end{array} \quad \text{or} \quad 3 \times 6 = 18$$

DO YOU REMEMBER WHAT VOLUME IS? (The number of units a container can hold.)

THEN WHAT IS THE VOLUME OF THE RED WAGON? (18 Minnebar units.)

Mike knew how many blocks his wagon would hold, but he still didn't know how many trips he would have to make. The blocks in the back yard were not in a neat array so he could not count the number of rows and columns and layers. He decided that he would just keep making one trip after another until he finished. It did look as if he would make a great number of trips. And he began to think how he would like to coast down the hill in his red wagon. So he was very happy when his friend Tom came along with his yellow wagon.

"Let me help you," Tom said. "My wagon holds a lot more than yours, and we will get done faster. Then we can go coasting together."

"How much does your wagon hold?" Mike asked.

Have the children fill their yellow wagons with Minnebars and find the volume. They may count, add or multiply. As each method is described, write it on the board.

$3 \times 6 = 18$

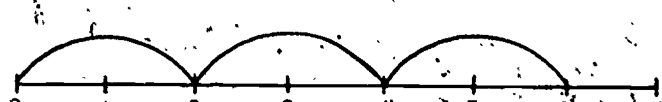
$3 \times 6 = 18$

$$\begin{array}{r} 18 \\ +18 \\ \hline 36 \end{array}$$

or $2 \times 18 = 36$

or $2 \times 3 \times 6 = 36$

Remind the children that they learned how to multiply by taking repeated jumps on the number line. Review a simple problem, such as 3 x 2.



Have them turn to Worksheet 29. Along the edge they will find a number line showing 18 units of the same size as their addition slide rule units. They can cut this strip off the worksheet and use it for doing repeated addition or multiplication of 18 on their addition slide rules, since the slide rules provide only for adding 10 or less and it would be very tedious to count 18 units over and over again. Encourage the children to use the addition slide rule whenever they think it will help them in the following activities.

HOW MANY BLOCKS MORE DOES TOM'S WAGON HOLD THAN MIKE'S? (18.)

HOW DID YOU FIND OUT?

There are a number of observations that may be made about the difference in volume of the two wagons. Some children may simply suggest that the volume of one be subtracted from the volume of the other. You may write 36 − 18 = 18 on the board, but do not expect the children to be able to do the computation independently.

Some may observe that one wagon holds twice as much as the other, and that therefore if one holds 18, the other will hold 18 more.

Some may suggest matching a Minnebar unit from Tom's wagon with each unit from Mike's wagon, and then counting the units that are still left in Tom's wagon.

The next problem the boys thought about was how many blocks they had hauled altogether. They had tumbled each wagonload out, so instead of neat stacks that would be easy to count, they had a big heap. They decided to figure out how many blocks there were in Mr. Johnson's yard by the number of trips that had been made. Mike had made three trips by himself, and then he and Tom had made one trip together. How many blocks had they carried?

First lead the class to add up the total number of trips each made. (4 for Mike, 1 for Tom.) Encourage computation by way of layers -- that is, 4 layers for Mike, 2 for Tom. Write on the board all the equations the children suggest that might describe the total number of blocks. Encourage them to devise a variety of equations, including those they are unable to solve. Some are listed below:

18 + 18 + 18 + 18 + 18 + 18 = 108

6 x 18 = 108

4 x 18 = 72, 2 x 18 = 36, 72 + 36 = 108

The boys made one more trip and discovered that the rest of the blocks just filled the two wagons. WHAT WAS THE COMBINED VOLUME OF THE WAGONS? (18 + 36 = 54, or 3 x 18 = 54, or 18 + 18 + 18 = 54.)

The boys calculated that they had hauled 108 blocks before, and then 54 on the last trip, or a total of 162 blocks. This sounded like a great deal to them, because they knew how big the blocks were, and how hard they had worked. They were all set to brag about their work to the other boys they would meet when they went coasting on the hill. "But wait a minute," Mike said, "If we tell them we hauled 162 blocks, they might think we mean those little blocks we used to play with in kindergarten. We have to remember to tell our friends that the blocks we hauled were great, big, heavy hunks of wood."

"Right!" Tom agreed, and the two boys were just leaving the Johnsons' yard, when Mrs. Johnson came out to thank them.

"You must be pretty hungry after hauling all those big blocks," she said. "I'd better give you some cookies." So she did, and the boys ate them, and then they spent the rest of the morning coasting down the hill in their wagons and telling the other boys about the work they had done.

Activity C

Worksheet 29 gives some additional work with volume. In preparation for this, have the children assemble the boxes on Worksheet 30. These represent other children's wagons. They are called boxes C, D and E. Mike's wagon body is called box A and Tom's is box B, for the purposes of Worksheet 29.

At the bottom of the worksheet is a number line marked off by 18's -- an 18 scale. This is to be used in class discussion. Ask the children to study it and answer your questions.

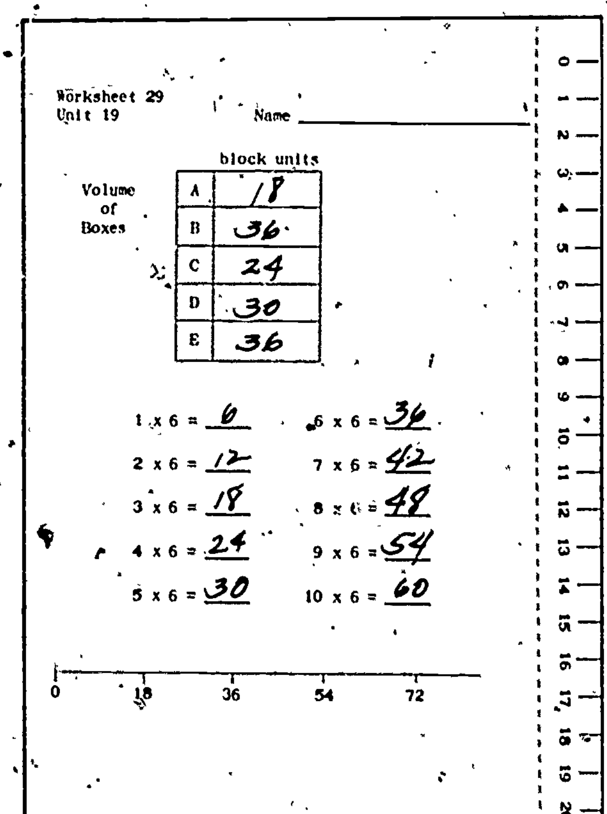
LOOK FROM 0 TO THE FIRST NUMBER ON THE NUMBER LINE. YOU CAN TELL FROM THIS THAT EACH UNIT REPRESENTS 18.

WHAT DOES THE INTERVAL FROM 0 TO 36 SHOW? (18 + 18.)

HOW MANY 18'S ARE SHOWN IN THE INTERVAL FROM 0 TO 36? (2.)

HOW MUCH IS 36 + 18? (54.)

Have the children find the combined volume of boxes A and B, B and E, and A and E, using the 18-scale.


Worksheet 29
Unit 19

Name ______

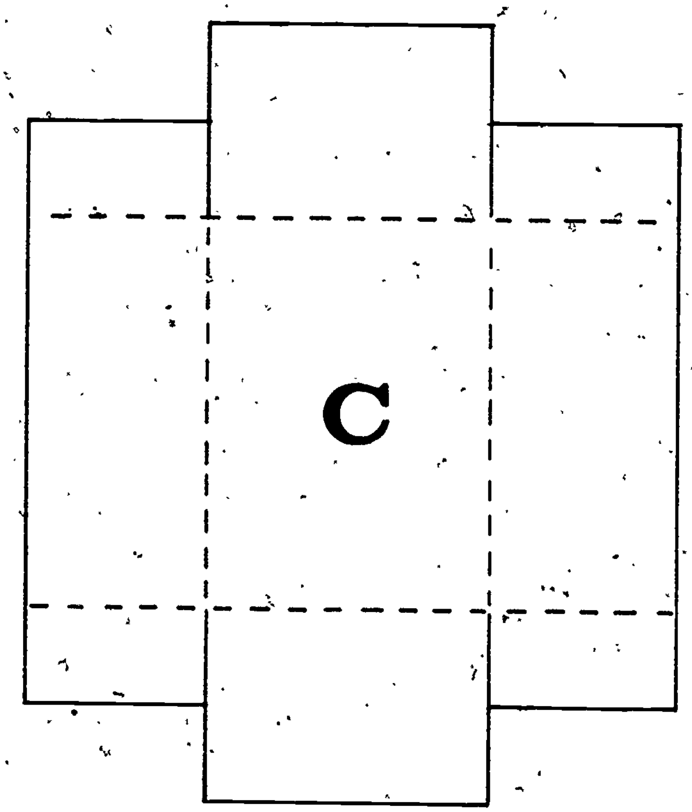
Volume of Boxes

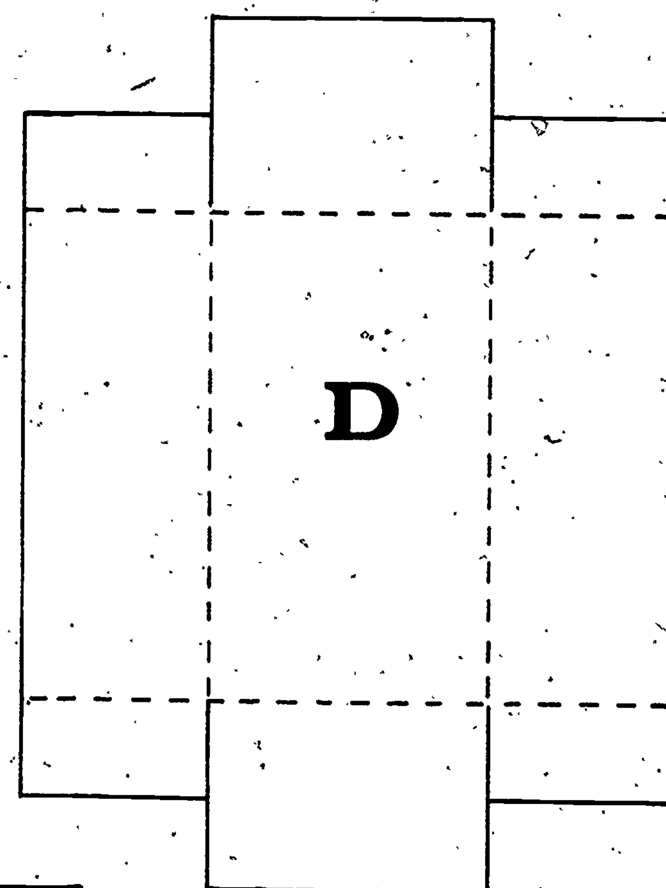
	block units
A	18
B	36
C	24
D	30
E	36

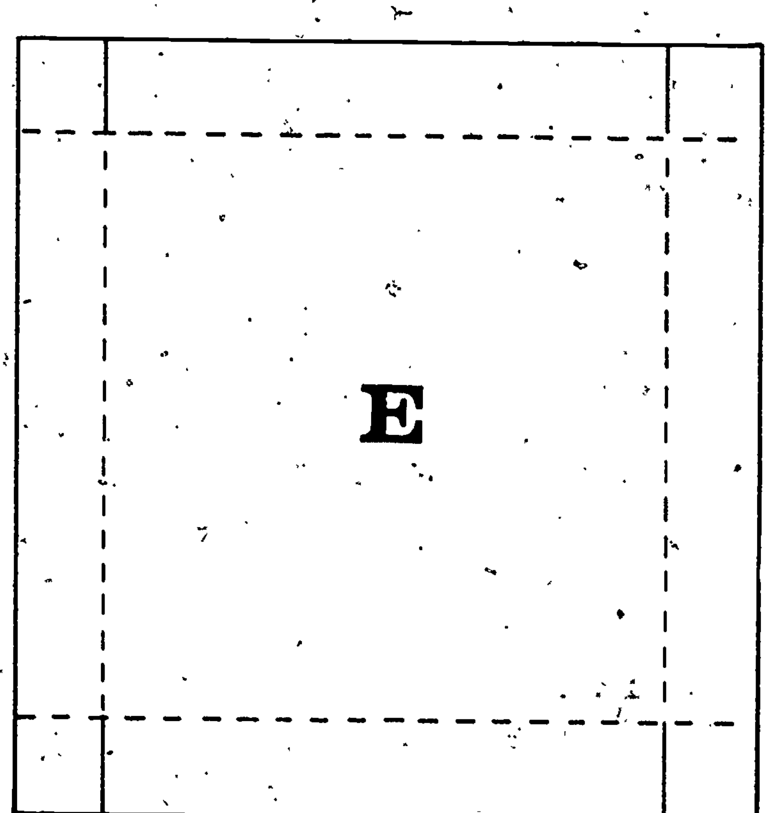
1 x 6 = 6 6 x 6 = 36
2 x 6 = 12 7 x 6 = 42
3 x 6 = 18 8 x 6 = 48
4 x 6 = 24 9 x 6 = 54
5 x 6 = 30 10 x 6 = 60

Worksheet 30
Unit 19

Name ______________________________







Cut along heavy black lines.

Fold along dotted lines.

Lesson 21: CONSERVING WEIGHT AND VOLUME

In this lesson, the children experiment with balls of clay to find whether changing their shape will affect their weight or volume. This is an example of the use of measurement to verify and make reasonable a general principle, that of conservation of weight and volume. The displacement of water by an object will be one of the methods used to study volume. In both activities, the children will use the balances they constructed in Unit 16.

MATERIALS

- beam balance or rubber band scale from Unit 16
- paper cups
- #1 paper clips
- oil-base modeling clay

-- for each pair of children --

- 2 plastic containers (8 oz. size)
- water
- a matched pair of clay balls, about the size of walnuts
- 2 strings about 8" long
- 2 rubber bands

PREPARATION

Before the lesson, prepare a small ball of soft modeling clay for each child. The balls should be divided into matched pairs in which the two balls are of equal volume. Use a plastic container of water to make the pairs. Insert a string into each ball. Submerge the first ball, mark the water level in the container with a rubber band, and then put enough clay in the second ball to make the water rise to the same level.

PROCEDURE

Activity A

Hold up a ball of clay about the size of a walnut and ask the children:

DOES THE WEIGHT OF THIS BALL OF CLAY CHANGE WHEN

IT IS MOLDED INTO A DIFFERENT SHAPE?

As you ask the question, change the shape of the clay ball a number of times, ending up with a doughnut shape. Then ask the class to suggest and discuss experiments that could be performed to test whether the clay ball changes its weight when the shape is changed. (Two weighings will be necessary to illustrate that the weight is the same before and after the shape is changed.)

Have several groups of children weigh a clay ball on the beam balance and record the weight on the chalkboard. Then have them change the shape of the ball, weigh the new shape, and record the results beside the previous weight.

WHAT SYMBOL SHOULD GO BETWEEN THE TWO WEIGHTS, ≐, <, or >? (≐).

Discuss these results with the class and help the children generalize an answer to the original question. (Changing the shape of the ball does not change the weight.)

Activity B

In this activity the children again experiment with clay balls, this time to determine how the volume is affected when the shape of the clay is changed. Start the activity with some questions about volume.

WHAT IS VOLUME? (The space something occupies.)

If the children are thinking about the wagons in the last lesson and offer a definition involving how much an object contains, ask about the volume of a solid object.

IF WE CHANGE THE SHAPE OF AN OBJECT, DOES ITS VOLUME CHANGE?

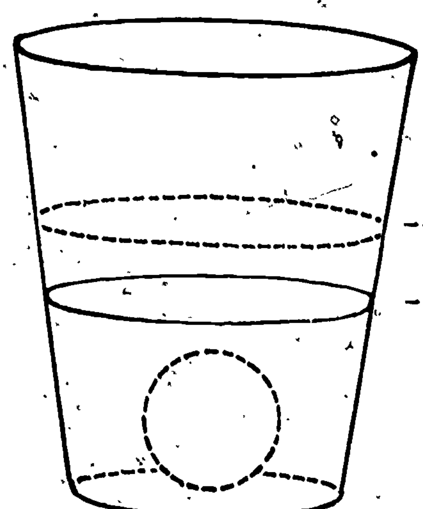
HOW CAN WE FIND OUT?

DO YOU REMEMBER HOW WE CAN DECIDE IF TWO OBJECTS HAVE THE SAME VOLUME?

Discuss the problem with the children. They may remember the procedure they used in Unit 5, Introducing Measurement, or Unit 12, Measurement With Reference Units, that is, measuring and comparing the displacement by two objects. The test might be made in water, sand, cork stoppers or popcorn. If the children do not remember these procedures, explain them and review the meaning of displacement.

Divide the class into pairs. Give each pair two plastic cups, four rubber bands, and two balls of clay of about the same volume. One child in each group should fill the cups approximately two-thirds full with water, and place them side by side to be sure that the water levels are the same. The children can put a rubber band around each cup to mark the water level. Then each child should insert a string in his ball of clay, lower it into one of the containers, and mark the new water level with a second rubber band. The two containers can be compared again to see if the new levels are the same -- if the displacements are the same.

Now each child should remove the clay from the water, alter its shape and return it to the water. He should notice whether the water returns to the same level, indicating that the water displacement is the same as before. This can be repeated for several shapes of the clay. Each time the two children can also compare their resulting water levels.



Have the class discuss their findings and develop a general statement about volume.

WHAT HAPPENED TO THE WATER LEVEL WHEN ONE PARTNER CHANGED THE SHAPE OF HIS CLAY? (The water level was still the same as his partner's.)

WHAT HAPPENED WHEN THE OTHER PARTNER CHANGED THE SHAPE OF HIS CLAY? (The water level did not change.)

WHAT DOES THIS SHOW US ABOUT THE SHAPE OF A SOLID OBJECT AND ITS VOLUME? (Changing the shape does not change the volume.)

Lesson 22: MEASURING THE VOLUME OF LEAD SINKERS

In Lesson 15 the children had practice in measuring water displaced by marbles, and they did some simple recording of the results. In this lesson they measure the water displaced by one lead sinker and from this they compute how much water would be displaced by any number (up to ten) of such sinkers. Since the water level rises about three millimeters for one sinker, the children are guided to count by threes to develop a repeated addition or multiplication chart in the lefthand column of Table 2 of Worksheet 31. To this volume data, the children will add weight data concerning the lead sinkers in the next lesson, filling in at that time the righthand column of Table 2 of Worksheet 31. Data from these two lessons will result in a set of ordered pairs that the children will plot in Lesson 24.

Activity A is a review of centimeter and millimeter reading, and your class may not need it.

MATERIALS

-- for each child --

- Worksheet 31
- 1 lead sinker
- piece of string about 10" long
- cylinder with centimeter tape attached to side (used in Lessons 15 and 16)

-- for each group of four --

- container of water
- medicine dropper
- paper towels

PROCEDURE

Activity A

Distribute a scaled plastic cylinder to each child. Ask the children to study the scale. Discuss their observations. Then ask them to hold the cylinder on its side so that the tape looks like a number line. Discuss the numbered marks and ask the children how many marks there are between one and two, between five and six, etc.

Now have the children turn their cylinders to a vertical position. Ask if the number line is different now. When they agree that only the position has changed, have them count the unmarked lines up to one. By the time they reach one on the tape, they will have counted to ten. Remind them that the one stands for one centimeter, and that each unnumbered mark is a millimeter.

THE MARK LABELED 1 IS EQUAL TO 10 MILLIMETERS. HOW MANY MILLIMETERS IS THE 2 MARK EQUAL TO? (20.)

You may wish to continue the counting to reinforce this idea. If so, draw a large millimeter scale on the chalkboard and have the children practice reading such points as 44 mm, 32 mm, etc. Tell the children that "millimeter" is often written "mm."

Activity B

See that each child has a lead sinker, a piece of string, and a scaled cylinder. Provide each group of four children with a container of water, a medicine dropper and paper towels. Let the children examine the lead sinkers, then hold one up.

CAN ANYONE TELL ME WHAT THIS IS? WHAT KIND OF METAL IS IT? WHAT IS IT USED FOR?

Explain, if necessary, that the object is made of lead, that fishermen use lead weights such as this to make their lines sink into the water, and that therefore they are called "sinkers." (Sinkers provided by MINNEMAST are large -- they weigh one ounce each. Such sinkers are used only on lines intended to catch very big fish, so the children may never have seen any of this size.)

Ask the children to tie a string to each of the sinkers. Then have them fill their cylinders to the 40-millimeter mark with water and gently lower their sinkers into the water. Then ask the class:

HOW CAN WE FIGURE OUT HOW MUCH WATER WAS DISPLACED BY EACH OF YOUR SINKERS? (By counting up from the 40-millimeter mark.)

HOW MANY MILLIMETERS DID THE WATER LEVEL RISE? (It rose about 3 millimeters.)

Refer to the clay ball activity in Lesson 21 and ask:

WHAT PROPERTY OF THE SINKER ARE WE MEASURING WHEN WE FIND THE WATER DISPLACEMENT? (The volume of the sinker.)

Have the children turn to Worksheet 31 and look at the first row of boxes in Table 1. Explain that each child is to measure the volume of his sinker four times and enter each measurement in the boxes below "Trial 1, Trial 2," etc.

Discuss the results. All should be similar -- "about 3 mm." If some children do not get results that can be described as "about 3 mm.," ask them to discard their weights and borrow others. (You want the class to agree on this non-fractional measurement for the computations they will now be making.)

Call attention to the first column of Table 2 of Worksheet 31.

IN THIS LESSON WE ARE GOING TO FILL IN ALL THE BLANKS FOR VOLUME SHOWING HOW MANY MILLIMETERS ONE SINKER MADE THE WATER RISE, HOW MANY WE THINK TWO SINKERS WILL MAKE IT RISE, AND SO ON. HOW CAN WE DO THAT WITHOUT DOING ANY MORE EXPERIMENTING

Worksheet 31
Unit 19

Name ____________

Table 1

	Trial 1	Trial 2	Trial 3	Trial 4
Water displaced by sinker	3 mm	3 mm	3 mm	3 mm
Weight of sinker	___ paper cups	___ paper cups	___ paper cups	___ paper cups

Table 2

Number of Sinkers	Volume measured in mm rise of water level	Weight measured in paper cup units
1	3	
2	6	
3	9	
4	12	
5	15	
6	18	
7	21	
8	24	
9	27	
10	30	

WITH THE SINKERS AND THE WATER?

Children may use any method of calculating they wish. They may count, add by threes, or multiply by threes. The result should be a worksheet like that shown on page 123.

When the volume table is finished, have a few children check some of their answers with actual experiments -- by adding two sinkers, three sinkers, etc. to their scaled cylinders of water.

Save these worksheets for use in Lessons 23, 24 and 25.

Lesson 23: MEASURING THE WEIGHT OF LEAD SINKERS

In this lesson the children use the beam balance to find the weight of a lead sinker in paper cup units. After several trials, they find that the weight of each sinker is about the same as the weight of five paper cups. They then calculate by fives to figure out how much two to ten sinkers would weigh in paper cup units, and enter these figures in Table 2 of Worksheet 31.

MATERIALS

-- for each child --

— Worksheet 31 from Lesson 22

— 1 lead sinker

-- for each group of four --

— beam balance from Unit 16

— 20 paper cups

PROCEDURE

- Give each child a lead sinker and each group a beam balance and twenty paper cups. Explain to the children that each one is to weigh his lead sinker four times, using the beam balance with paper cups as units of weight, and then enter the results for each trial in the second row of boxes in Table 1 of Worksheet 31.

Have a class discussion of the results. The children should observe that each sinker weighs about the same as five paper cups.

Using five paper cups as the accepted weight for one

Worksheet 31 Name __________
Unit 19

Table 1.

	Trial 1	Trial 2	Trial 3	Trial 4
Water displaced by sinker	3 mm	3 mm	3 mm	3 mm
Weight of sinker	5 paper cups	5 paper cups	5 paper cups	5 paper cups

Table 2

Number of Sinkers	Volume measured in mm rise of water level	Weight measured in paper cup units
1	3	5
2	6	10
3	9	15
4	12	20
5	15	25
6	18	30
7	21	35
8	24	40
9	27	45
10	30	50

sinker, have the children compute in any way they wish the weights of two to ten sinkers, and fill in these weights in the appropriate places in Table 2 on Worksheet 31.

Lesson 24: PLOTTING VOLUME AND WEIGHT DATA

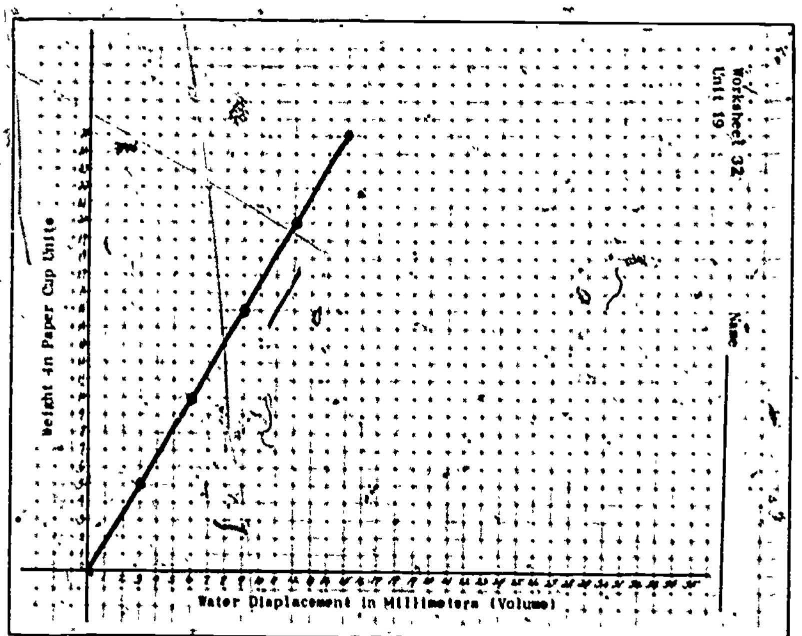
The children plot data from Worksheet 31 on Worksheet 32. When they have done this, they have straight line graphs showing the relation between the volume and weight of the lead sinkers used in the previous lessons.

MATERIALS

— Worksheets 31 and 32

PROCEDURE

Have the children turn to Worksheet 32. Point to the numerals on the left side of the graph paper and explain that these numerals on the "up" axis represent the weight of the sinkers in paper cup units. Then explain the numerals across the bottom of the graph -- on the "over" axis. These numerals represent water displacement in terms of water level rise shown in millimeter units, and therefore indicate volume of the sinkers.



Tell the children to turn to Worksheet 31 and look at the numerals in Table 2. Point out that there are two numerals that go together for each number of sinkers. The displacement numeral in the first column and the weight numeral in the second column are an ordered pair. For one sinker, the ordered pair is (3,5). The 3 means the sinker made the water level rise 3 mm units; the 5 means the sinker weighed 5 paper cup units.

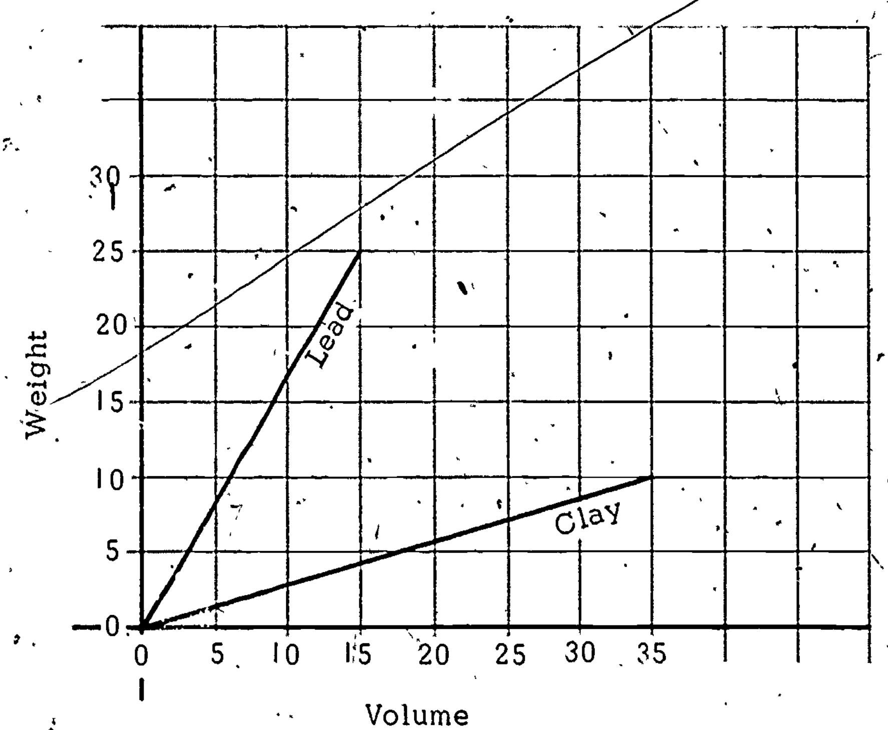
Show the children how to plot an ordered pair. For a displacement of 3 mm (the first numeral of the ordered pair) the children move on the "over" axis to the numeral 3. For the weight of 5 units (the second numeral of the ordered pair) they move up to 5 on the "up" axis. Then they trace along both grid lines to find the intersection, and mark that point.

Have the children plot five of the ordered pairs from Table 2 of Worksheet 31. Then ask them to draw line segments from one mark to the next. If there were no errors, the children should each have a straight-line graph.

Lesson 25: VOLUME AND WEIGHT MEASUREMENTS -- CLAY VS. LEAD

In this lesson the children measure and graph the weight and volume of clay objects of different sizes. Then they receive some practice in interpreting the graph, so that they can begin to understand that it shows the relation between the volume and the weight of any piece of clay within the range of the graph. They also learn that if they know the volume of a piece of clay, they can find out the weight from the graph, and vice versa.

In the last activity of the lesson, the children add to the same grid a graph of the volume and weight of various numbers of lead sinkers. The result is that the completed worksheet shows two graphs with very different slopes. Because the "up" axis shows weight measurements and because lead is much heavier (volume for volume) than clay, the slope for the lead sinkers is very steep. It rises sharply from 0 to 25 on the "up" axis, while extending only from 0 to 15 along the "over" axis. The graph for the clay shows a much more gradual slope, extending only from 0 to 10 on the "up" axis, but spreading from 0 to 35 along the "over" axis.



By having the children practice selecting a volume measurement along the "over" axis and then comparing the weights of both the clay and the lead sinkers for that volume, we hope the children will understand what a comparison of the two graphs shows: that for a given volume, lead is much heavier than clay. However, do not worry if your class is not particularly adept at interpreting the graphs, as later units will give much more practice in graph interpretation. In any case, the concept that a specified volume of lead is much heavier than the same volume of clay should be verified at the conclusion of the lesson in a less abstract way -- by filling one container with clay and another of the same size with lead sinkers and letting the children compare the two by hefting.

MATERIALS

-- for each child --

— Worksheet 31 (saved from Lesson 23) and new Worksheets 33 and 34

-- for each group of five --

— tray
— 1 stick of oil base clay
— 1 craft stick for cutting clay
— 5 pieces of string about 10" long
— 5 pieces of masking tape for labeling strings
— 5 cylinders with millimeter tape attached
— container of water
— medicine dropper
— paper towels
— 2 beam balances
— 20 paper cups

-- for the class --

— 1 soufflé cup filled with clay (Activity D)
— 1 soufflé cup filled with lead sinkers (Activity D)

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PREPARATION

Assemble the materials specified above for each group. Draw a large 40 x 40 grid on the chalkboard. Mark the "over" axis "Volume" and the "up" axis "Weight."

PROCEDURE

Activity A

Divide the class into groups of five and have each group pick up a tray of materials, two beam balances and twenty paper cups. Have the children turn to Worksheet 33 and ask the members of each group to list there the five names in the group. Then explain that the first child listed in each group will use the beam balance to make a ball of clay as close to the weight of 2 paper cups as he can. The next child on the list will make a ball of clay equal in weight to 4 paper cups; the third a ball equal to the weight of 6 paper cups; the next a ball equal to 8 paper cups; and the fifth child a ball equal in weight to 10 paper cups. Ask all the children to write these weight units in order in the third column of the worksheet. Then explain that when a child makes a clay ball of the correct weight, he is to put a string in it and measure its volume in a scaled cylinder filled to the 40-millimeter mark with water.

Give the children a demonstration of what they are to do. Put two paper cups in one of the containers of a beam balance, then keep adding bits of clay to the other container until you have achieved as fine a balance as possible. Next make a cylindrical shape of all the bits of clay in the balance, inserting a string at the same time. Label the string with masking tape marked "2" to show the weight. Next fill a scaled cylinder to the 40-millimeter mark with water, lower the clay cylinder into it, and have a child count the number of millimeters it rose. Mention that when the children reach this point, they will enter this measurement in column 2 of the worksheet.

Now ask the children in each group to make their measurements of the volume of clay cylinders equal in weight to 2, 4, 6, 8 and 10 paper cup units and to record the measurements. Go about the room helping the various groups. Tell the children that when they measure one of the larger pieces of clay for volume, the water should rise all around it -- if it protrudes above the water they will not have an accurate measurement of the water rise. It may be helpful for the children to recall here that in Lesson 21 they learned that changing the shape of the clay does not change either its volume or its weight, providing no clay has been removed. Before the children put away their equipment to graph their data, make a quick check of their worksheets to see whether the volume measurement for each item is represented by a numeral at least three times greater than the numeral representing its weight. Below is a table of measurements (ordered pairs), representing a very precise set of measurements.

Worksheet 33
Unit 19

Name ____________

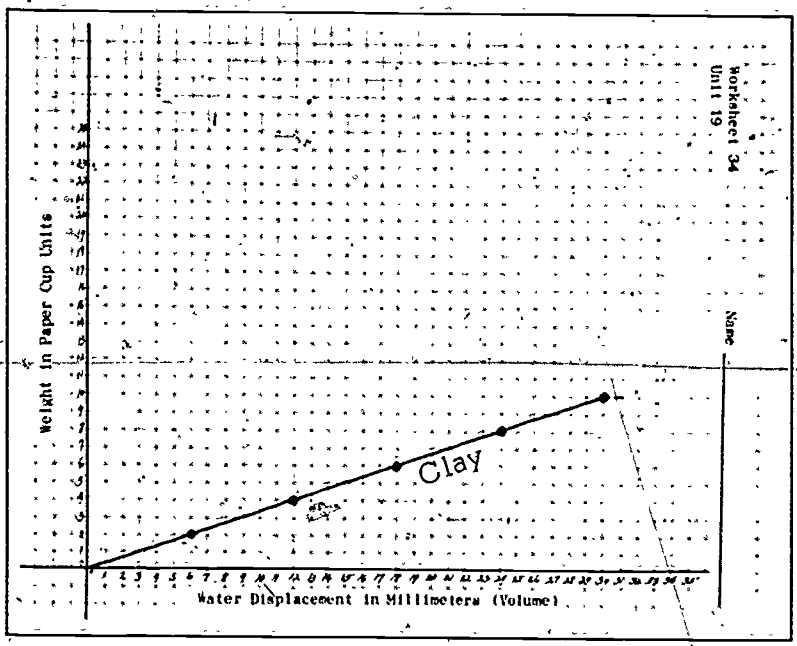
[illegible] ject	[illegible] water level	[illegible]
MARY	6	2
TOM	12	4
JOHN	18	6
JANE	24	8
BILL	30	10

If a child's volume measurements are <u>less</u> than three times those for the weights, ask him to make new measurements -- perhaps with the help of his group -- and to revise his data.

Activity B

Have the children turn to Worksheet 34. Point out the numerals across the bottom of the grid paper -- on the "over" axis. Remind them that these represent the volume in millimeters of water displacement. Explain that the numerals on the "up" axis represent weight in paper cup units.

Have the children plot the ordered pairs from Worksheet 33 onto Worksheet 34. When all points have been plotted by each child, ask each to draw a straight line segment from (0,0) to the first point and then to connect all the other points with similar straight line segments. The result in each case should be a slope that extends more than three times as far on the "over" axis as it does on the "up" axis.



Check the worksheets and accept as valid any that show a line sloping gradually from the point (0,0) to such points as (35,9), (35,10), or (35,11) at the right edge of the paper. Have worksheets that seem very doubtful revised, suggesting that children remember that in plotting an ordered pair they must apply the first numeral to the "over" axis and the second numeral to the "up" axis.

Now select one child's clay data to be plotted on the chalkboard grid. Have this child call out one ordered pair at a time and have other children plot each point. When all five points are plotted, connect them with line segments starting at (0,0) and extending to the right edge of the grid. Mark the completed line "Clay."

WHAT DOES THIS LINE SHOW US? (The relation between the volume of clay and its weight.)

HOW CAN WE MAKE USE OF THIS LINE? IF WE KNOW THE VOLUME OF A PIECE OF CLAY, CAN WE FIND OUT FROM THIS LINE HOW MUCH THAT PIECE OF CLAY WEIGHS? LET'S TRY IT AND SEE.

Select a numeral on the volume line. Have a child come up and find the weight for that volume by tracing with a finger of his right hand straight up until it meets the sloping line, and with a finger of his left hand tracing the line from the "up" axis that meets the sloping line at the same point. Have a number of children call out volume measurements for which other children find the weight measurements. After this practice, ask:

CAN ANYONE SHOW ME ANOTHER WAY TO USE THIS LINE TO FIND THE WEIGHT OF AN OBJECT WHEN I KNOW ITS VOLUME?

Some child may be able to demonstrate that if he selects a certain numeral on the volume axis, all he has to do is count the squares above that numeral to give the weight in paper cup units. If no child volunteers, show the children how it is done, and give them some practice by having the class call out volume measurements for which various children should find the weight measurements. Emphasize the usefulness of the clay graph in this way:

HOW MANY CLAY OBJECTS DID I HAVE TO MEASURE TO PLOT THIS GRAPH? (Five.)

COULD I USE THIS GRAPH TO FIND THE WEIGHTS OF OTHER CLAY OBJECTS THAT I DID NOT MEASURE? HOW MANY? (From this graph you could find the weight of any clay object that would displace up to 35 millimeters of water in our scaled cylinders.)

Ask one child from each group to call out the volume of an object his group measured and ask other children to see if the graph shows the weight for that object.

WE HAVE SEEN HOW USEFUL THIS GRAPH IS IN FINDING THE WEIGHT OF AN OBJECT WHOSE VOLUME WE KNOW. COULD WE ALSO USE THE GRAPH TO FIND THE VOLUME OF AN OBJECT IF WE KNEW ONLY ITS WEIGHT?

The children should be able to see that they can find the volume for any object (within the range of the graph) whose weight they know. Have them show how they would locate the weight on the "up" axis, then count the squares "over" to the graph. The number of squares counted on the "over" axis would be the weight. Let some children name weight measurements and other children find the corresponding volume measurements, until most of the class seems to know how to do it.

Activity C

WE HAVE MADE GRAPHS SHOWING THE RELATION BETWEEN TWO PROPERTIES OF SOME CLAY OBJECTS -- NAMELY, THEIR VOLUME AND WEIGHT. DO YOU SUPPOSE WE COULD GRAPH THE SAME PROPERTIES OF LEAD SINKERS ON THE SAME GRID?

Suggest that the children have the data for the volume and weight of the lead sinkers all ready to plot. Where? In Table 2 of Worksheet 31.

ON THE CHALKBOARD AND ON WORKSHEET 34 WE HAVE GRIDS THAT ARE ALREADY LABELED FOR GRAPHING VOLUME AND WEIGHT MEASUREMENTS. CAN ANYONE SHOW US HOW WE CAN USE THE SAME GRID TO GRAPH OUR SINKER MEASUREMENTS?

If no child wishes to demonstrate on the chalkboard grid, help by having one child call out the first ordered pair (3, 5) and marking the point yourself. Then call on another child to mark the next point as it is called out. After that, ask the children to plot as much of the volume and weight data from Table 2 of Worksheet 31 as will fit on Worksheet 34. When they have finished plotting, have them draw a line from (0,0) through all their points. Then complete your chalkboard graph of the lead sinker data and mark the new line "Lead." Ask the children to mark their worksheet graphs in the same way.

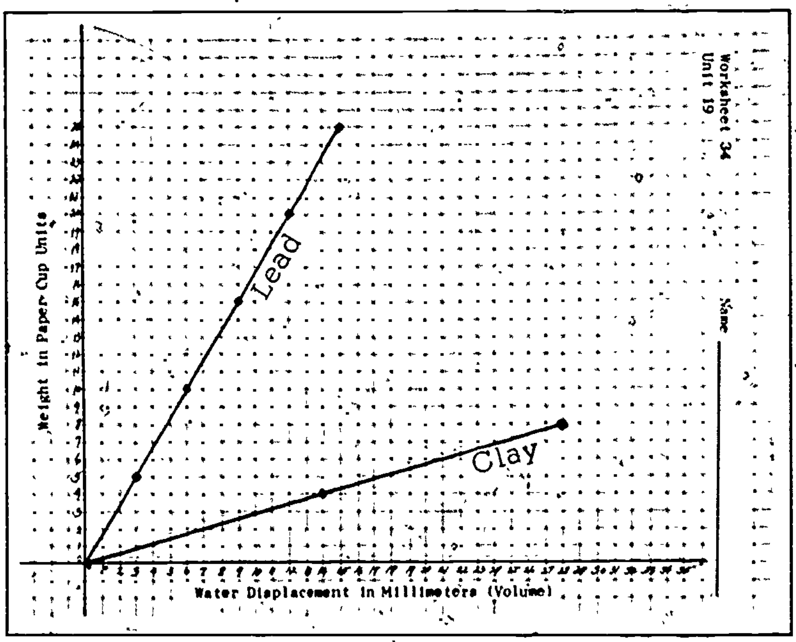
Hold a discussion about the two different graphs:

WHAT DID OUR FIRST GRAPH SHOW US? (The relation between the volume and the weight of clay objects.)

WHAT DOES OUR NEW GRAPH SHOW US? (The relation between the volume and the weight of lead objects.)

WHICH GRAPH HAS THE STEEPER SLOPE -- THE LEAD GRAPH OR THE CLAY? (The lead.)

CAN ANYONE TELL US WHAT A COMPARISON OF THESE TWO GRAPHS SHOWS? LET'S SEE IF WE CAN FIGURE IT OUT.



Have a child come to the chalkboard and put his finger on the "over" axis at the numeral 7, and ask the class what the 7 means. (It describes the volume of an object that would make water rise 7 millimeters in our scaled cylinders.) Have the child move a finger up the 7-line, stop at the first graph, and say how much a clay object of that volume weighs. (About the same as 2 paper cups.) Now have the child continue moving the finger up the 7-line, stop at the second graph, and tell how much a lead object of that same volume weighs. (About the same as 11 paper cups.)

WHAT A COMPARISON OF THE GRAPHS SEEMS TO SHOW US, THEN, IS THAT A LEAD OBJECT THAT HAS A VOLUME OF SEVEN UNITS WEIGHS MORE THAN A CLAY OBJECT OF THE SAME SIZE. HOW MUCH MORE?

Children may say, "The lead weighs a lot more," or "Many times more," or even, "The lead is five times as heavy for its size as the clay." Any of these answers is acceptable.

LET'S INVESTIGATE SOME OBJECTS OF OTHER SIZES AND SEE HOW THEY COMPARE IN WEIGHT.

Have the children practice comparing the weights of lead and clay objects of various volumes shown on the grid. When most of the children seem to understand how the comparisons are made, ask:

CAN ANYONE THINK OF A WAY WE COULD CHECK TO SEE WHETHER A LEAD OBJECT IS REALLY HEAVIER THAN A CLAY OBJECT OF THE SAME SIZE?

Help the children with any simple experiment they suggest. For example, they may wish to make a clay object that is about the same size as a lead sinker and compare the weights on a beam balance. (They will discover, if they do this, that they will have to make more clay objects to achieve a balance with the sinker.)

For the next lesson the children need to understand that similar volumes of different materials can vary greatly in weight. To drive home this point, fill one soufflé cup with clay and another with lead sinkers, and ask each child to hold one cup in each hand and tell which is the heavier. Emphasize that the volume in each cup is about the same.

Ask the children if they can think of any reasons why it might be important to know whether a volume of one kind of material weighs much more than the same volume of another kind of material. You may receive all sorts of answers: "A present in a large box that doesn't weigh very much probably contains clothing or a stuffed toy." "A present in a big box that is heavy probably contains a steel truck or tractor." "A box that is very small and very heavy is probably full of books or tools." "A big bag that is not hard to carry may be full of packages of corn flakes or rolls of toilet paper." Whatever the replies, tell the children that in their next MINNEMAST lesson, their knowledge will be put to good use because they will have to decide whether three "mystery" objects -- all of the same size and appearance -- are all clay, mostly clay, or a combination of clay and some other material.

Save the chalkboard graph of the clay and lead and all copies of Worksheet 34 for use in the next lesson.

Lesson 26: UNKNOWN OBJECTS

A story, "The Golden Bracelet," is used to motivate the experimental activities in this lesson. The children are shown three mystery objects and asked to determine which is made of clay, which is clay with some lead, and which is mostly lead. They are to weigh and measure the volume of the objects, and then make their determination by using the graphs they completed in Lesson 25.

The final activity of the lesson can serve as an evaluation of how well the concepts in this particular section have been understood. The children are given irregulary shaped pieces of lead and are asked to find their volume without using the displacement technique. If they have understood the previous activities, they should be able to think of weighing the objects and using the graph to find the volume.

MATERIALS

- Worksheet 35
- 3 objects conatining various amounts of clay and lead

  -- for each group of five --
- the same equipment used in Lesson 25
- 5 pieces of lead of irregular size made by breaking printers slugs (Activity C)

PREPARATION

Make three "unknown" objects -- all of the same size -- to display on your desk during the reading of the story and for the children to use in an experiment. The composition of each object is as follows:

Object A — a lump of clay rolled into a form which can be measured in the scaled cylinder for volume. A size that displaces about 35 millimeters of water is suggested.

Object B — a lump of clay of the same size as Object A, but with 1 lead sinker hidden inside.

Object C — a lump of clay of the same size as Objects A and B, but with 2 lead sinkers hidden inside.

Insert a string into each object and attach the appropriate label to identify the object as A., B., or C to the other end of the string.

Prepare 5 pieces of lead of different sizes for each group by breaking the printers slugs. If the slugs do not break easily by hand, use a hammer and chisel to break them.

PROCEDURE

Activity A

Place the three mystery objects on your desk. Then read the story, "The Golden Bracelet," as an introduction to this lesson. Use the questions that follow the story to start a discussion about determining the content of the mystery objects.

THE GOLDEN BRACELET

Story by Elaine Vogt

Illustrations by Sonia Forseth

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Once upon a time there was a young man named Alberto who was engaged to be married to Dorinda, the most beautiful girl in all the countryside. Alberto owned a small farm. He worked very hard from sun-up to sundown, day after day and month after month. He cleared forest land to make room for planting crops, and he sold the wood that he chopped. He watched over his animals carefully, and he never let a weed grow. The spring he was to be married was especially lucky for him. The rain and the sun were just right for his crops. Every sheep had twin lambs. And the town cabinet-maker paid him a high price for an unusual kind of wood he found in his forest.

All his hard work and good fortune brought him four units of gold. This gold he took to Mario, the goldsmith.

"Mario," he said, "I have here in my measure exactly four units of pure gold. I want you to use it all to make a bracelet for my true love, Dorinda, whom I shall soon marry."

"Ah, you want to give her a fine bracelet for a wedding present!" the goldsmith said. "Well, let me put your gold into my measuring pot to see whether you have brought as much as you say."

Alberto watched as Mario measured the gold. Alberto thought that Mario had a very greedy and scheming look on his face as he measured, but he had seen an expression something like this before—when some other men admired his gold—so he thought little of it. "Exactly four units, just as you said," Mario announced. "I shall bring the bracelet to you when it is ready. And for making it, you shall pay me ten ducats." Alberto agreed to pay what was asked.

On the very day of the wedding, the goldsmith brought the bracelet he had made. He presented it to Alberto in a white box lined with red velvet. Alberto was very pleased. It was more beautiful than any bracelet he could ever imagine!

Dorinda was even more pleased than Alberto. "How hard you must have worked, and how long you must have saved, dear husband, so that I could have this beautiful gift!" she exclaimed. Then, turning to the goldsmith, she said sweetly, "Much thanks to you, too, Mario. Never before have I seen a bracelet so beautifully designed!"

Then, because Alberto was a generous man and because the bracelet had so delighted his bride, he paid the goldsmith twice as much for his work as was agreed upon. The goldsmith said not one word of thanks, but quickly pocketed all the money. Then he said, "I really deserve this extra money, you know, because I worked hard and long to make this wonderful bracelet. There is not another like it in the whole wide world!" Then he hurried away, lest anyone should decide he was overpaid.

From the very start, Dorinda was exceedingly proud of the bracelet. Everywhere she went she showed it and boasted about it. "Isn't it beautiful?" she would ask. "My husband Alberto had Mario, the goldsmith, make this bracelet for me from four units of pure gold. There is not another like it in the whole wide world!"

Now many of Dorinda's good friends shared in her joy, but some who were not such good friends, were quite grudging and envious. One jealous woman said, "Let me hold your bracelet, Dorinda, so that I may admire it more closely." Dorinda slipped the bracelet from her wrist, but when the woman had it in her hand, she said, "Humph, for such a large bracelet, this one doesn't seem heavy enough to be made of solid gold. I think it's made of silver inside, with some gold covering it up.."

Though Dorinda laughed, she really felt quite hurt. It seemed that she had been hearing this jealous remark quite often lately. It made her think. But, finally, she told herself, "It doesn't matter what people say; my bracelet is made of solid gold. Otherwise Mario would be a thief, and I can't believe that." And, in her secret heart, she treasured, too, the idea that there was not another bracelet like hers in the whole wide world.

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But one day as she was telling some townspeople about the bracelet, a traveler from a distant land stopped to listen. Then he interrupted, saying, "You are mistaken, young woman, if you think there is not another bracelet like yours in the whole wide world. Mario, your town goldsmith, has one exactly like it tucked away in his safe. He just tried to sell it to me to take home to my wife, but the price is so high I can't afford to buy it."

For once, Dorinda could not laugh. Instead, she ran home to Alberto and — sobbing on his shoulder — blurted out what the traveler had said. "There, there, what of it?" Alberto said, soothingly. "Would it be so bad if there were two such beautiful bracelets in the whole wide world?"

But Dorinda was not to be soothed so easily. By now, she was full of doubts. "After all my boasting, that would be bad enough! But what if the other thing is true, too?"

"What other thing, Dorinda?"

"Some people are saying," Dorinda sobbed, "that the bracelet is not made of solid gold — that it is partly silver, or maybe even mostly silver."

"How could that be, Dorinda? You know I gave Mario four units of gold to make the bracelet. Do you think he stole some of my gold to make this other bracelet that the traveler saw?"

"I don't know. I only know that, if he did, we are much the poorer for it."

Suddenly Alberto remembered the greedy scheming look on Mario's face when he was measuring the gold. He remembered, too, how quickly Mario had pocketed the double pay, without one word of thanks. Very angry now, Alberto snatched up the long axe he used to clear his land. "We shall find out the truth about the bracelet right now!" he shouted. "I shall chop it in half and we shall know — once and for all — what it is made of. Give it to me!"

"Oh, no!" Dorinda pleaded. "You must not destroy the bracelet. It is your wedding gift to me. And I still think it's very beautiful! Surely there must be a better way to learn the truth about it."

Alberto put away the axe. "You are right, Dorinda. We must try to find a better way. Come, let us visit Ricardo, the town elder. Perhaps he can help us."

When Ricardo heard their story, he said, "I have heard some of of these rumors myself, but I cannot accuse a person without proof. I shall have to ask you to leave the bracelet here, Dorinda, so that it can be tested to see whether it is solid gold or not."

"But how will it be tested?" Dorinda asked nervously. "Will it be sawed in half, or drilled, or scratched, or damaged in any other way?"

"No, Dorinda, your bracelet will not be harmed. I will take it to a learned man in the city. He will perform experiments by taking some weight and volume measurements of silver and gold, and then some weight and volume measurements of the bracelet. Come back this same time next week, and you will learn the truth about it."

Neither Alberto nor Dorinda understood how anyone could test the bracelet without harming it, but they trusted the town elder, Ricardo, and they left it with him. Nevertheless, they spent a worried week. They were quite relieved when they returned a week later and saw that the beautiful bracelet was unchanged and unharmed in any way.

Ricardo spoke. "Your suspicions were correct," he told them. "The tests show that the bracelet is half pure gold and half pure silver. Mario has been arrested and will have to pay a large fine for his dishonesty."

Alberto and Dorinda felt very sad. They had hoped against hope that the tests would show that Mario was not a thief and that the bracelet was made of solid gold. "Maybe the tests are wrong," Dorinda said, as she picked up the bracelet and put it on. "You can see that the learned man who did the testing did not cut the bracelet open. How, then, could he possibly know what's inside?"

"Dorinda," the town elder explained, "scholars have known for a long time how to find out what amounts of pure silver are in an object without destroying it. A very great man named Archimedes discovered how to do these things many hundreds of years ago, and learned men have been using his methods ever since."

Though they still did not understand how it was done, Alberto and Dorinda accepted the explanation as truth because it came from Ricardo.

But they were now extremely unhappy. Finally, Alberto said, "I worked so hard for the gold for my bride's present. To have half of it stolen is a great loss."

"Perhaps this will make you feel better," Ricardo said, as he brought out a white box, and opened it before their eyes. Dorinda and Alberto blinked in amazement as they saw a beautiful bracelet — exactly like Dorinda's — gleaming and sparkling against the red velvet lining of the box. "Mario said that the other half of your gold is in this bracelet, Alberto," Ricardo said. "He wants you to have it to make amends for what he has done and I, too, think you should have it."

Dorinda's eyes beamed. And, for the first time in a long while, she laughed. "Whatever shall I do, Alberto, with two such beautiful bracelets?"

"You shall wear one on each wrist and look twice as grand as before!" Alberto exclaimed. And he took the second bracelet and slipped it in place on her arm.

Then Dorinda and Alberto heaped praise and thanks upon Ricardo, the town elder, for all he had done. And to show their gratitude they gave him a little lamb for a gift.

"Thank you very much," Ricardo said modestly, "but the credit really should go to the man who made the tests."

"And maybe we should be thankful for the great Archimedes, too?" Alberto suggested, very proud that he was able to remember and pronounce correctly the name of this famous man.

"Most certainly for the great Archimedes!" the town elder agreed, as Alberto and Dorinda were taking their leave of him. Then, turning back to the work on his desk, Ricardo smiled, thinking, "What a wonderful time Dorinda will have showing off her two beautiful bracelets! My, how they do sparkle and gleam in the sunlight!"

And he was very happy about the way things turned out in the end.

. . . .

Ask the class:

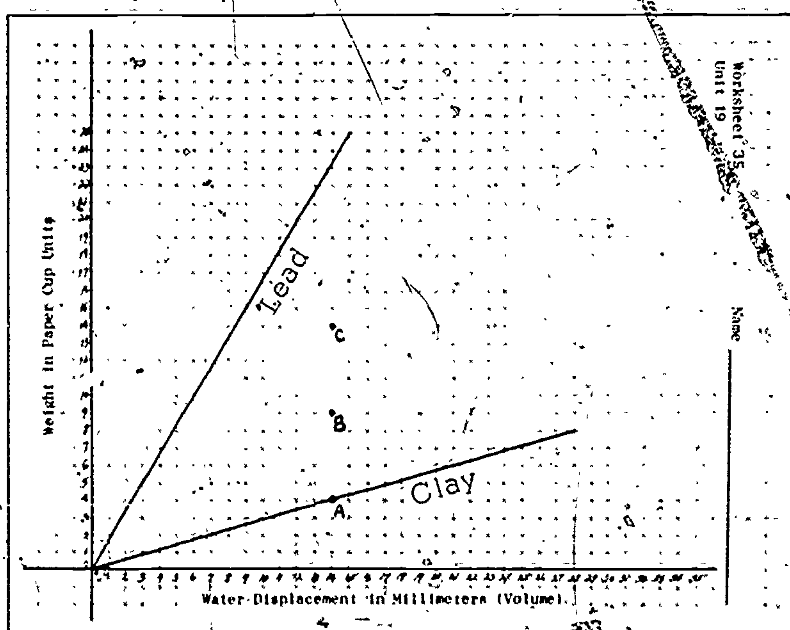
> CAN YOU THINK OF ANY EXPERIMENTS OR TESTS THAT THE LEARNED MAN IN THE STORY MIGHT HAVE USED TO DETERMINE THAT DORINDA'S BRACELET WAS PARTLY SILVER?

Let the children speculate. Then hold up the three "mystery" objects A, B and C.

> DO YOU THINK WE COULD USE THE SAME TESTS TO DETERMINE WHETHER THESE OBJECTS ARE ALL CLAY OR A COMBINATION OF CLAY AND LEAD?

Activity B

Hold up the three "mystery" objects -- A, B and C -- and elicit from the class ways to use the information they have been acquiring to find out whether the objects are all clay, mostly clay, partly lead or mostly lead. Then pick three different groups of five children each and have each group weigh and find the displacement of one of the three unknowns. Have the children doing the measuring call out their findings so that the rest of the class can record the results on the bottom of Worksheet 35. After all three objects have been measured for weight in paper cup units and for volume in number of millimeters the water rose in the scaled cylinders, have each class member plot these ordered pairs on Worksheet 35 and label each point.



Discuss with the children the location of the point for each unknown and what they might decide about the makeup of each object if they used the information shown by the clay and lead graphs. A few questions may aid the discussion:

WHICH OBJECT WEIGHS THE LEAST? (Object A.)

WHICH OBJECT HAS THE MOST CLAY? (Object A.)

WHICH OBJECT WEIGHS THE MOST? (Object C.)

WHICH OBJECT HAS THE MOST LEAD? (Object C.)

WHICH OBJECT HAS THE MIDDLE WEIGHT? (Object B.)

WHICH OBJECT HAS SOME LEAD, BUT NOT AS MUCH AS OBJECT C? (Object B.)

THE VOLUMES OF ALL THREE OBJECTS WERE ABOUT THE SAME, SO HOW DID WE MAKE OUR DECISIONS? (By the weight measurements -- the heavier the object, the more lead it contained.)

Activity C

Show the children the irregular lead shapes and tell them that they will be asked to find the volumes without using the water displacement test for measuring. Let the children think about this problem at their leisure. The next day have them experiment with the methods they have decided on. The children should not have the scaled cylinders and water available at this time. It is not expected that all the children will be able to solve this problem, but after a few find the answer by weighing their objects, finding the weights on the graph, and reading the volumes, others should be able to pick up the procedure. Finally distribute the cylinders and water and let the children check their answers by the water displacement test.

In order to evaluate the progress the children have made in understanding functional relations and graphing, let them work as independently as possible in solving the problem of finding the volume of each piece of lead.

Lesson 27: LEARNING WITH GRAPHS

In this lesson, the children will get experience in interpreting line graphs. In Activity A the children look at a given point on a graph, then they read the horizontal and vertical values for that point. In Activity B the children plot ordered pairs on a graph and then discuss these points. A new graph of temperature vs. dates is introduced in Activity C and the children use it to answer questions.

MATERIALS

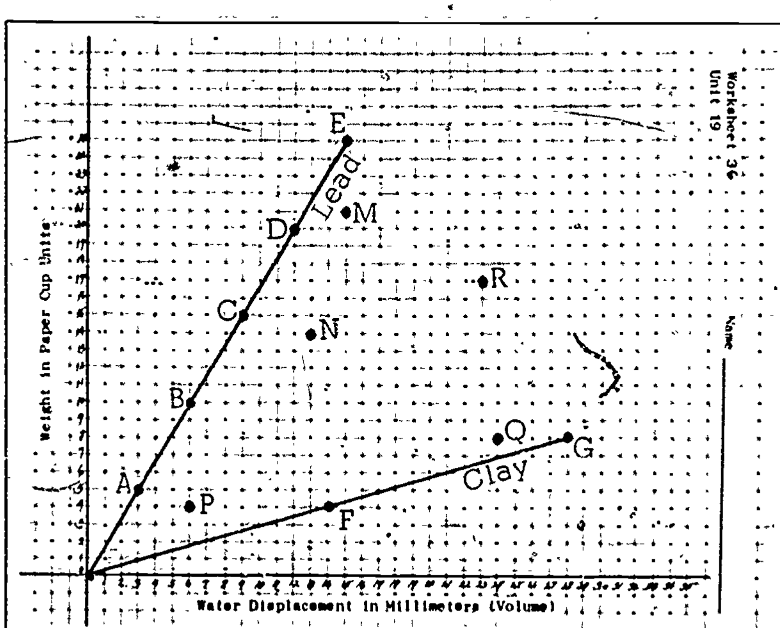
— Worksheets 36 and 37

— ruler

PROCEDURE

Activity A

Ask the children to look at Worksheet 36.



Tell them that they are going to look at points A through G on their graph and find out what each point represents. Discuss with your class what the horizontal and vertical numbers represent. Tell them that you would like to have them help you develop a chart on the chalkboard on which to record the values of points A - G. Below is a sample chart:

Points on Graph	Rise in water level in mm.	Weight in paper cups
A	3	5
B	6	10
C	9	15
D	12	20
E	15	25
F	14	4
G	28	8
H		
I		
J	8	?
K	?	6
L		

Have the children look at point A, then read its value on the "over" axis. (3.) Record this information on the chalkboard chart and ask for the vertical reading. (10.) Record it. It might help some children in tracing from the point to the axes, if they placed a ruler on the grid so that the edge of the ruler was even with the grid line on which the point was located. This method could be demonstrated on the chalkboard. Ask different children to read and record the value of other points until all lettered points have been recorded.

Use questions like the following to continue the discussion of the graph and the chart:

WHO CAN GIVE ME THE ORDERED PAIR FOR ANOTHER POINT ON THE LEAD LINE -- ONE THAT IS NOT LABELED WITH A LETTER?

WHO CAN GIVE ME THE ORDERED PAIR FOR ANOTHER POINT ON THE CLAY LINE?

IF I HAD A PIECE OF CLAY WHICH DISPLACED WATER TO THE 8-MILLIMETER LEVEL, WHAT WOULD IT WEIGH?

FROM A COMPARISON OF THE TWO GRAPHS CAN YOU TELL WHETHER A CERTAIN VOLUME OF LEAD IS HEAVIER THAN THE SAME VOLUME OF CLAY?

Ask the children to give specific comparisons, e.g., "A piece of clay of the volume that makes the water level rise six millimeters is equal to the weight of two paper cups, but a piece of lead of the same volume is equal to the weight of ten paper cups." Perhaps some children can then say that lead is about five times heavier than clay, but this is not required.

Activity B

List the following ordered pairs on the chalkboard:

M (15,21)
N (13,14)
P (6,4)
Q (24,8)
R (23,17)

Ask the class to plot and label these points on Worksheet 36. Remind the children that the first number of each pair is found on the bottom line, the "over" axis. When they have all finished plotting the five points, conduct a discussion about them, using questions similar to these:

ARE ANY OF THE POINTS WE JUST PLOTTED ON OUR GRAPH LINES FOR CLAY OR LEAD? (No.)

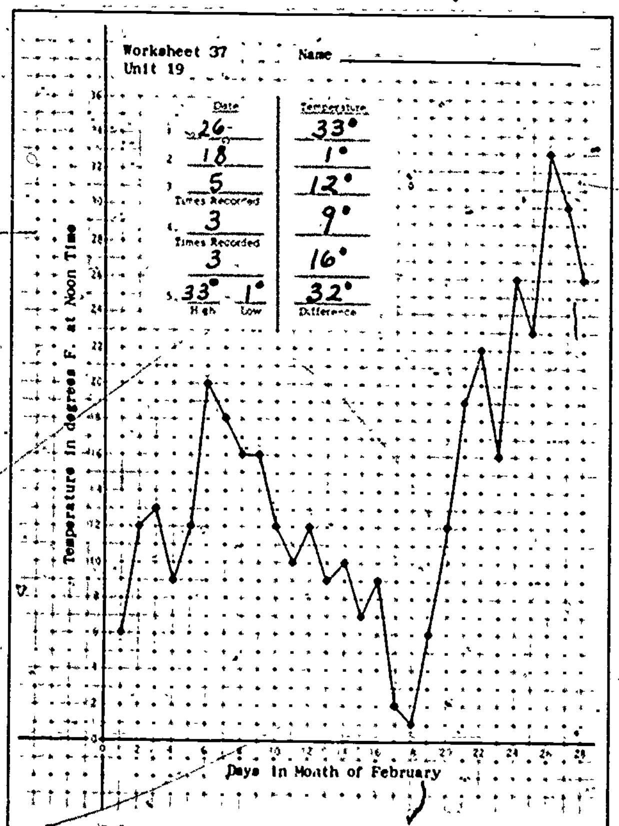
WHICH OBJECTS REPRESENTED BY THE POINTS M - R COULD BE MADE UP MOSTLY OF LEAD? (M and N.) WHY? (They are nearer the lead line.)

WHICH OBJECTS REPRESENTED BY THE POINTS M - R COULD BE MADE UP MOSTLY OF CLAY? (Q.) WHY? (It is nearer the clay line.)

THROUGH WHICH POINTS COULD YOU DRAW A LINE THAT WOULD BE ABOUT AN EQUAL DISTANCE FROM THE CLAY AND THE LEAD LINES? (Through points P and R.)

Activity C

Ask your class to turn to Worksheet 37.



Talk about the values represented by the horizontal and vertical axes. Call the children's attention to the place on the worksheet where they are to record their answers to the questions you will read aloud. Read the following questions and ask the class to study their graphs to find the answers. Have them record the answers in the proper blank on the worksheet.

ON WHAT DATE WAS THE HIGHEST TEMPERATURE RECORDED AND WHAT WAS THE TEMPERATURE? (26, 33°).

ON WHAT DATE WAS THE LOWEST TEMPERATURE RECORDED AND WHAT WAS THE TEMPERATURE? (18, 1°).

WHAT TEMPERATURE WAS RECORDED THE MOST TIMES? HOW MANY TIMES? (12° was recorded 5 times.)

WHAT TEMPERATURE WAS RECORDED THE SECOND

GREATEST NUMBER OF TIMES? HOW MANY TIMES WAS IT RECORDED? (It was a tie: 9° was recorded 3 times; 16° was recorded 3 times.)

WHAT IS THE DIFFERENCE BETWEEN THE HIGHEST AND LOWEST TEMPERATURE READINGS? ($33^{\circ} - 1^{\circ} = 32^{\circ}$)

SUMMARY

Upon completing this unit a child should:

— have increased his tendency to look for relationships between changes that he observes and to make these relationships evident by accumulating data in tabular and graphical form.

— be able to look at a graph he has made and explain it simply e.g., "This graph shows how tall my plant was on different days," or "This graph shows the relation of the height of my plant to its age." He should <u>not</u> be expected to say, "This graph shows the functional relation between the age and height of my plant."

— understand that the movements of the three hands of the standard twelve-hour clock represent different durations, and that in "telling time," durations are counted from twelve. He should have started to do some clock reading and should be given practice in this during the rest of the school year.

— know how to plot ordered pairs on a grid. He should know that the first numeral of the pair is always plotted on the "over" axis, and that the second numeral of the pair is always plotted on the "up" axis. He should know, for example, that the point (3,2) on a grid is not the same as the point (2,3).

— have improved his measurement skills somewhat, particularly in reading the millimeter scale and in using the beam balance.

This unit can be considered to have achieved its purpose if your children have made progress along the lines noted above. Remember that each of these skills and concepts will be reinforced in later units.