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ABSTRACT

This National Science Teachers Association (NSTA) instructional aid is primarily concerned with helping youngsters develop concepts about measurement and making useful measurements in science activities. Short activities are given under each of the following headings: How are Human Senses Involved in Measurement, How to Measure by Using Aids for Our Senses, How to Make Estimates of Measurements, The Need for Standardized Units, How to Distinguish Between Basic and Derived Units, How to Form a System of Basic Measurements, and How to Make Indirect Measurements. (Author/CP)

NATIONAL TEACHERS ASSOCIATION
how to...

TEACH MEASUREMENTS

in elementary school science

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Science is knowledge and science is a process. Both are included in the goals of science teaching in the elementary school, for today the processes of science are as important as the body of accumulated theories, facts, and principles called knowledge.

The processes of science in the school curricula mean learning by doing and investigation. No matter what topics in science are considered in the elementary school, there are certain related student activities which involve investigation. Among these activities are such processes as observing, making useful measurements, and recording of data.[1]

This leaflet is primarily concerned with how to help youngsters develop concepts about measurement and how to make useful measurements in science activities.

Lord Kelvin, for whom the absolute temperature scale was named and himself a great contributor to our knowledge of science, is quoted as follows: "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; . . ."[2] In other words, measurement is a powerful method of obtaining knowledge in a form in which it can be communicated.

The importance of measurement to communication may be demonstrated in a number of ways. One such method is to ask a child to describe one of his classmates without using units or any qualities relating to measurement. This would exclude relative terms such as "big," "tall," and "heavy," or expressions like "five fingers" or "two ears." This activity allows the child to discover the necessity of measurement for the communication of information. Another activity is to have the children describe in writing some object or event inside or outside the classroom and then to ask them how many times they used specified or relative measurements in their descriptions.

Through the application of measurement to real situations the student uncovers knowledge new to him and extends his frontier of understanding in much the same way as does a research scientist. The goal of elementary science, however, is not narrowed to the training of scientists, but is to provide the student with the intellectual tools required to gain knowledge and solve present and future problems.

What is Measurement?

Many of the questions people ask in their work and in everyday living begin with "How many?" or "How much?" You could ask the class "How many students came to school today?" "How far is it from your home to the school?" The answers to these questions are alike in one respect; they both involve numbers. However, the answer to the first one is found by counting; the answer to the second is found by measuring.

For determining "How many students came to school today," the class will realize that each pupil is a separate, whole individual. There are no fractions of students in school. The students are not all exactly alike, nor are they all the same size, but each is a person, so the number can be found by counting.

[1] See Petty, Mary Clare. *How to Record and Use Data in Elementary School Science.* National Science Teachers Association, Washington, D.C. 1965.

[2] Sund, Robert, and Trowbridge, Leslie. *Teaching Science by Inquiry in the Secondary School.* Charles E. Merrill Books, Inc., Columbus, Ohio. 1967.

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On the other hand, to figure out how far it is to school, the students cannot find their answers merely by counting, because the distance between home and the school is one continuous distance. It is not made up of separate items which can be counted. We must find how long it is by measuring the distance: then the answer is a number of units of length. This may be expressed in feet, blocks, or miles. This measurement requires the location of a point called home and another point identified as school. In the process of measurement, the distance between these two points is compared with some recognized interval, such as a mile. The generic term for such recognized intervals is a standard unit of length. An inch, a meter, a mile are all standard units of length. The standard probably will not be contained in the distance between home and school a whole number of times. There is no alternative but to estimate the remaining fractional part; this estimation constitutes the degree of precision of the measurement.

Example: In Figure 1, three identical pencils are compared with three standard measures. The three standards are successively subdivided into smaller units allowing for a greater precision in the estimate of the lengths of the pencils. This activity helps elementary school students discover that rulers are subdivided into discrete parts and subparts while the pencil length is continuous. Units of measure or object length should be selected so that the recorded measurement will be different in each of the three cases (though the objects are identical in kind). This type of activity must be conducted using the ruler with the fewest intervals first and the one with the most frequent intervals last.

Example: Another activity would be to give each student a soda straw and have him measure the length and width of his desk and record these measurements on slips of paper. These records may now be tabulated on the chalkboard. Since the desks will most likely not be an even number of straw-lengths long or wide, someone in the class will undoubtedly subdivide the straw into parts or fractions. This will provide an opportunity for discussion regarding division of the straw into subunits to provide a more adequate measurement of the desks.

This subdivision method will give the students an opportunity to create their own standard subunits and beginnings of a measurement system discussed in more detail in the section *How to Form a System of Basic Measurements* (page 9).

All measurements have two fundamental parts: the number and the unit. In recording the measurement "six inches," the "six" is the number and "inches" is the unit. It is meaningless to record one part without the other in any instance.

Class activities and discussion should reveal the inadequacy of descriptions involving only one of the two basic parts of all measurements. In the previous exercise when students measured their desks in straw-lengths, it would have been meaningless if they had recorded just a number alone, without the unit "straw-lengths."

In the activities listed above the students would be using their senses, primarily sight. It is possible for them to describe some event or object also in terms of listening or feeling. Certainly smelling and tasting also should not be ruled out as ways to learn about objects; however, these senses can rarely be used in measurement.

Gross measurements such as selecting objects which are "bigger" or "heavier," or "longer," may be conducted by elementary school students quite easily if the differences in size or weight are obvious. However, as these differences become less obvious, the task becomes difficult and more subject to error. Such estimated measurements illustrate the inadequacy of our senses and suggest the necessity for some objective tools of measurement.

Measurement with our unaided senses means measurement by comparison. Measurement with tools such as yardsticks, balances, and clocks is still measurement by comparison, but is much more sophisticated and accurate. For example, when elementary school children are busily involved in an activity requiring the use of a ruler, they are comparing the length of some object to the length of a generally accepted unit of measure, such as the foot or the meter. The same holds true for measurement of weight with a balance, the measurement of time with a clock, or the measurement of temperature with a thermometer.

Activities involving any of these quantities may be conducted to show the necessity for extending our senses through the use of measuring tools.

Example: Provide the class with four pans of water. One pan should contain ice water, a second pan should contain relatively warm water, and the two remaining pans should each contain lukewarm water. Label the latter two pans A and B. Have a child put one hand into the ice water and his other hand into the hotter water. After about 30 seconds, ask him to place one hand in pan A and the other in pan B. The labels on these pans should not be seen by the experimenting student. Let him decide which is warmer, A or B, and then you record his choice on a piece of paper. Reverse pans A and B and allow another child to repeat the activity. Continue with still other students and then record their results on the chalkboard. Discuss the limitations of this method of determining temperatures.

The sense of feeling may be deceived in ways other than by temperature.

Example: Present the students with a large sponge and a metal ball and ask them to decide which is heavier by holding one in each hand. (The sponge and metal ball should be selected so that the sponge is slightly heavier than the ball.) The students and teacher as well may conclude that the ball is undoubtedly heavier. The only solution to this question is to compare the two objects using either a spring scale or, preferably, a double-pan balance.

The progress of civilization may be traced through the artifacts of a culture's measuring tools. In a like manner, many of the successes and failures of science have been dependent on instruments of measurement. For example, Galileo's attempt to measure the velocity of light failed because of the inadequacy of his time-measuring device. Likewise, children's ability to solve problems in the elementary science classroom will depend upon how well they can develop, select, and use available tools of measurement.

As an example, an observation may require measuring the length and breadth of a leaf and possibly also weighing it. An investigation, on the other hand, may be more involved. One might measure the amount of soil eroded by water on a selected portion of the playground. The weight and volume of this soil are quantitative measures and can be recorded. In experimentation, controls enter in, and the student may compare the growth of similar plants under varying conditions of sunlight, moisture, or soil nutrients.

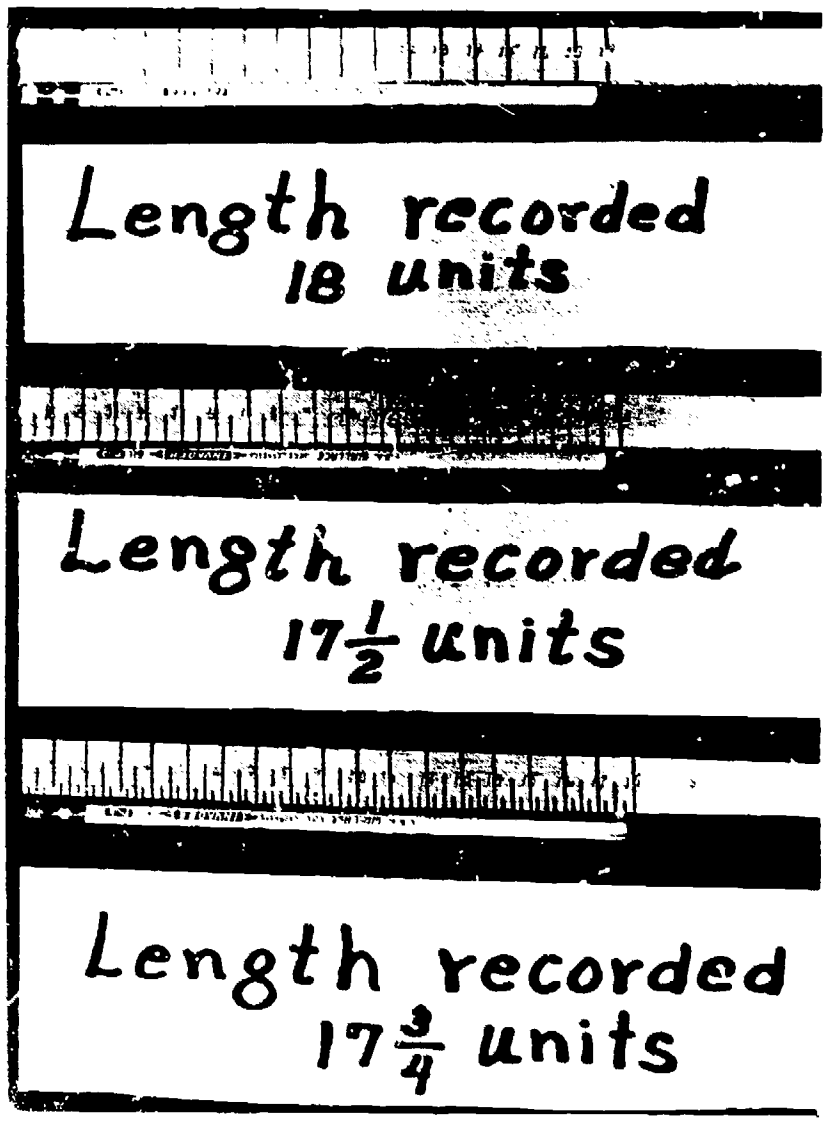


Figure 1. The measurement of these similar pencils became more precise as finer subdivisions were used.

It is through the latter method of controlled experimentation that an idea or pattern may be discovered after a long period of measurement and record-keeping. Certain activities within the capabilities of elementary school students can show the idea. For example, a series of experiments where weight measurements are made on different solid objects will show that objects heavier than an equal volume of water will always sink in water whereas objects that are lighter than an equal volume of water will always float in water.

The floating and sinking of objects in water does not in itself provide the student with an efficient means of comparing the relative abilities of different liquids to support solid bodies. If they wish to investigate this phenomenon, it is convenient to construct some sort of tool to give this quantitative information.

The soda-straw hydrometer shown in Figure 2 is such a device. It consists of a soda straw plugged at one end with wax. (The drippings from a burning candle serve very well here.) Three or four BB shot pellets are dropped into the open end of the straw where they will come to rest against the wax "plug." A small piece of cotton may now be pushed down the open end of the straw to keep the BB shots in place. The soda straw will now float upright in liquids, just as commercial hydrometers do. The height of the straw above the liquid surface is dependent on the ability of the liquid to support solid bodies. The higher the straw floats, the greater is the liquid's ability to support solid bodies (or in more technical terms, the greater is the liquid's density). Some suggested liquids that may be used for this activity are salt water, milk, vinegar, molasses, and glycerine. Be sure not to use dangerously strong acids and bases.

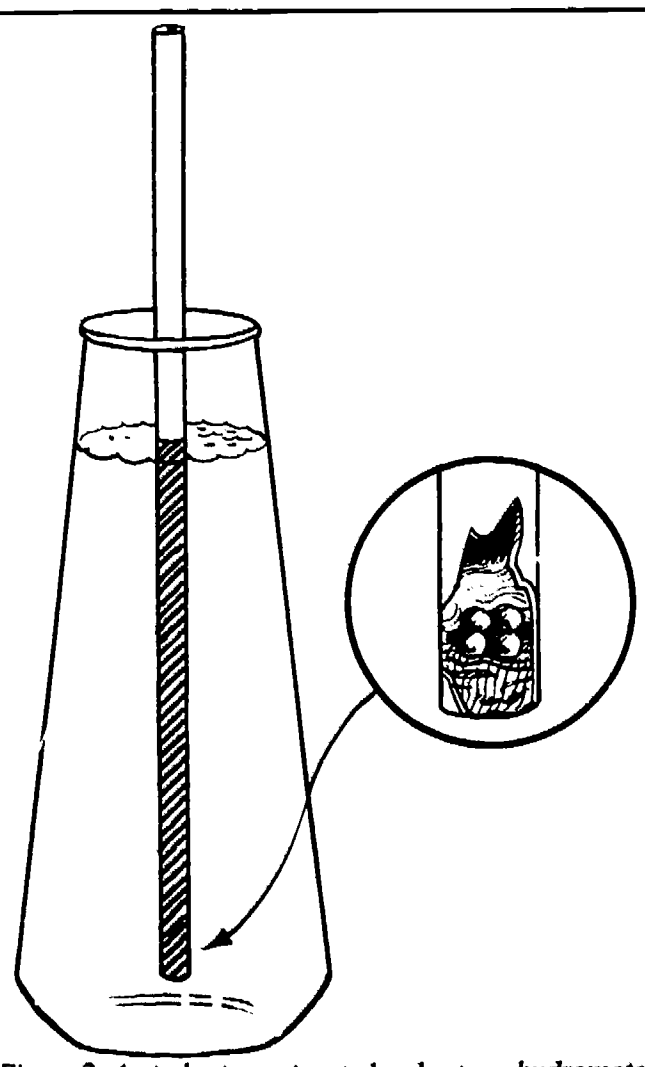


Figure 2. A student-constructed soda-straw hydrometer.

The soda-straw hydrometer is only one of many simple measuring tools which may be constructed and used by elementary school students. Some tools are used more often than are others in conducting activities. Weight and mass measuring devices, for example, have a wide range of uses in elementary school science investigations and may be useful throughout the school year. Two such devices are described and illustrated below, and a variety of other measuring instruments are described in the books listed in the bibliography.

One of the simpler devices for measuring weight is a spring scale. Commercial spring scales may be used if available, but the student-constructed spring scale shown in Figure 3 enables each child to understand the component parts of this simple weight-measuring tool before he puts it to use. Materials that may be used in the construction of such a spring scale are string, rubber bands, cardboard, paper clips, pins, and paper cups. Children should be encouraged to design various modifications of the illustrated scale.

The balance, also shown in Figure 3, is likewise simple in design, but in contrast to the scale is much more sensitive. The soda straw balance is so sensitive that even tiny air currents will cause it to move; and, in this respect, it is like the analytical balances used by professional scientists. The materials needed to construct the soda-straw balance are two microscope glass slides, a small block of wood, rubber band, wax-coated paper soda straw, plastic microscope cover slip, sewing needle, and a screw. Upper elementary school students should be able to construct the balance if they use the following directions and refer to the drawing of the balance in Figure 3.

With a single-edge razor blade, cut the straw so that it is 3 or 4 inches longer than the wooden block. Then make a one-half inch slit across one end of the straw and put a plastic microscope cover slip or reasonable substitute into this slit. This cover slip serves as the pan to hold a specimen. Find a screw which will fit snugly into the other end of the straw and turn it in about three-fourths the length of the screw. The screw will make its own threads if it is the

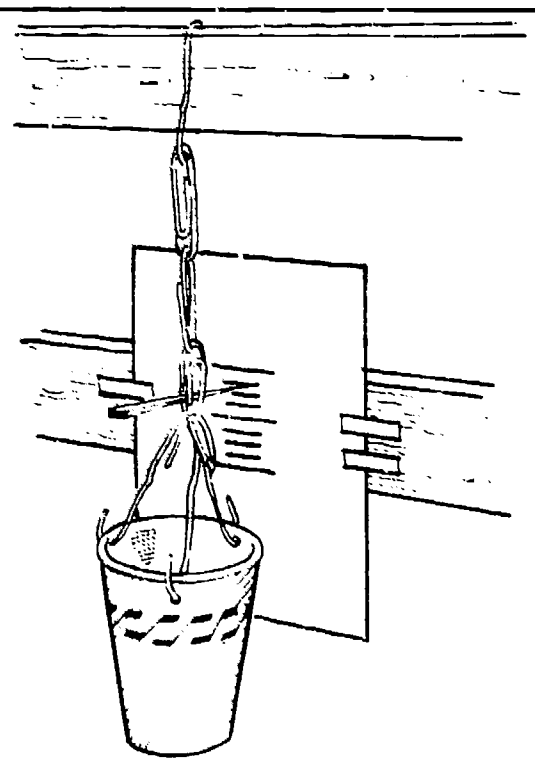
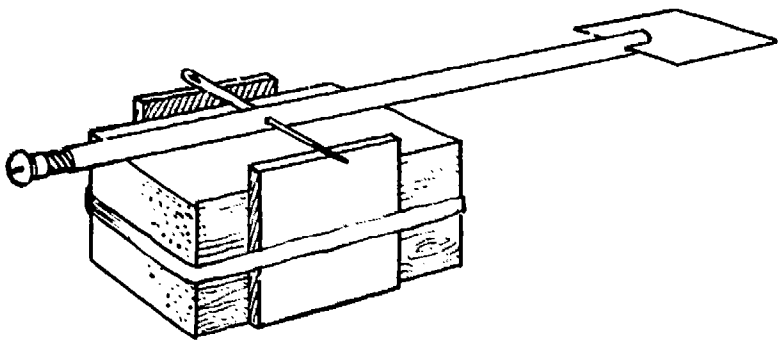


Figure 3. The spring scale (above) and the soda-straw balance (below) were made by elementary school students.



proper size. Balance the straw on your finger and push a sewing needle crossways through the straw at the point where it balances. Be certain that the cover slip pan is horizontal when performing this operation. Push the needle through near the upper edge of straw. After securing the two glass slides to the wooden block with a rubber band, the soda straw balance arm may be put in place by allowing the needle to come in contact with and resting upon the edges of the glass slides. It will now be necessary to adjust the screw until the straw rests in a horizontal position. The completed balance is now ready for the students to use.

In using the soda-straw balance, the students will be comparing the mass of an object to some selected standard mass. For example, if the children wish to conduct a detailed study of flowers, one quantitative measure they may make is the determination of the mass of each component part of the flower as well as making other measurements such as length of stem and area of leaves. The soda-straw balance will allow them to determine the mass of a petal with no great difficulty. They merely place the petal on the pan of the balance and then turn the screw out until the straw is again level. Then they can remove the petal and substitute units of mass on the cover slip pan until the straw once again balances by becoming horizontal. For determining the mass of a petal the round cutouts made by paper punches are convenient standards of mass. For objects that are more massive, other standards of mass may be more efficient. Other examples of items for which masses may be determined are seeds, scraps of cloth, small pieces of Styrofoam, metal staples, or crystals of salt.

Students find it difficult to distinguish between mass and weight. Mass and weight are not the same. Mass depends on the amount of matter in a body, whereas weight is a special kind of force exerted on a body. Technically it is not correct for students to say they are weighing the petal on the balance since they are actually comparing the petal's mass with that of a standard mass. However, since weight and mass are proportional, it would be permissible for students to say they are comparing the weight of the petal to a standard weight.

Encourage your students to select and use the most appropriate and efficient tool with which to conduct measurements. The proper choice of a tool of measurement often determines the success or failure of an activity.

Attempting to determine the mass of a petal on student-constructed balances such as those shown in Figure 4 would be extremely difficult. These are much more rugged instruments, constructed by students to accommodate much larger masses and are not suited to determine the masses of very small objects. This suggests that choosing the most appropriate measuring instrument is a decision which must be made in doing quantitative work in science. For example, measuring the rate at which a sports car travels from one point to another would require a stopwatch or stopclock that measures at least to the nearest one-tenth of a second. On the other hand, a proper timing device for measuring the speed of a tractor could be an ordinary alarm clock.

How to Make Estimates of Measurements

Measurements, by their very nature, are estimates. Counting discrete objects is exact, but measurement of a continuous quantity such as length, mass, or time is by necessity an estimation.

There is, however, another important way that estimation may be viewed and used in the scientific process. This is by encouraging elementary school students to make estimations, or intelligent

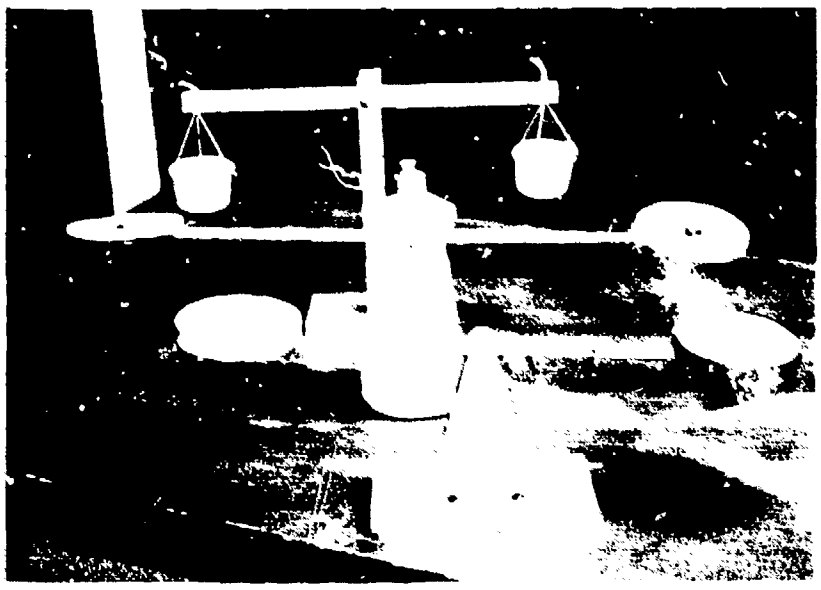


Figure 4. Three balances of more rugged design.

guesses, of the length of a line or the weight of an object before they measure it. This procedural technique accomplishes several worthwhile purposes. First, *a good estimation decreases the chances of making an error in the actual measurement.* This of course is true only after the students have become skillful in the art of estimation. If the results of the measurement do not agree at all with the estimation, this provides a warning to the student, that he has done a poor job either of estimating or measuring. Second, *a good estimate of the magnitude of a measurement before actually measuring suggests the type of measuring tool to use.* The example of the sports car and the tractor given earlier emphasizes this value of estimating before measuring. Third, *an estimation is often in itself adequate and no measurement with tools is necessary.* Again, the example of the car and tractor may be used, but this time consider a race between two cars and another separate race between a single car and a single tractor. For the race between the two cars a camera may be the only suitable tool to determine which is the winner of the race in the "photo finish." However, the car would probably win the race with the tractor by such a large margin, that no tool of measurement at all would be necessary other than the "estimation" made with the unaided eye.

A functional activity would be to have children measure the heights of different kinds of growing seed plants, such as corn, beans, and radishes. The students may use paper strips cut to equal the plants' heights each day. The strips will be of value in comparing the growth rates of corn, beans, and radishes. Estimation, however, is completely adequate to determine which of the three types of plants has grown the tallest at the end of a given number of days.

The very important concept of "estimation" is not difficult to develop. The best time for students to learn how to estimate is during the process of conducting science activities which require measurements. However, some preliminary activities which focus on the process of estimation are helpful to the student, and the time required to conduct them may be justified. A few are listed below.

Example: Assemble a number of empty tin cans such as those used for tomato paste, tomato soup, and canned tomatoes. These containers would all have similar shapes and be approximately the same height but be of different sizes. The important differences between them would be the volume of each, for example, how much water each would hold. Students may be asked to estimate the number of times it would take the smallest can of water to fill the next largest can, and so on. After estimating, the students can determine the actual number of times. As a second activity involving volume estimations, the situation could be made a bit more challenging to the students by using various shapes as well as sizes of containers.

Activities for improving the student's ability to estimate may also involve discrete particles.

Example: Fill small baby-food jars which have screw-on lids with regular-shaped objects such as marbles or sugar cubes. (See Figure 5.) After estimating the number of objects in the jars, the students may then easily count the number and determine the accuracy of their estimations. This activity may also be made more challenging by filling bottles with smaller regular-shaped objects such as beads, or with irregular-shaped objects such as pebbles.

Estimations of the lengths of books, tables, or the classroom may follow without difficulty, and further activities involving the estimations of weights and time intervals will give students additional practice in the art of estimation.

Nearly every home has one or more measuring tools. Among these are the yardstick stored in the closet, the set of spring scales in the basement, the measuring cup in the kitchen, and the clock hanging on the wall. Most elementary school students, therefore, have had opportunities to become familiar with units of measure such as inches, feet, and yards; ounces and pounds; spoonfuls and cups; and seconds, minutes, and hours.

These are all accepted standardized units of measure of length, weight, volume, and time, respectively.

Example: To insure familiarity with these units, the teacher may ask students to perform certain simple activities, such as drawing a line that is one inch long, choosing an object among a number of objects that weighs approximately one pound, or specifying time intervals of one minute. Tools of measure may be or may not be used for this activity. The students will do well enough in an activity of this type to allow the teacher to stimulate a discussion by asking questions pertaining to their ability to perform the tasks. As an example, the teacher may ask, "How was it possible for you to do so well in estimating a length of one inch?" It should become apparent that meaningful communication of knowledge could not be possible without accepted standard units of measurement.

A supplementary activity to the one discussed above is:

Example: Cut a different length of string for each student and have him measure the width of his desk top with his string. Provide slips of paper for recording the measurements. The teacher or a student may collect these records and list the recorded measurements on the chalkboard. Since all the desks are the same width, it becomes apparent that there is a need for some single accepted standard of length so that only one rather than a multitude of recorded measurements result.

Figure 5. Estimation is a good way to begin measurement of discrete particles.

At least some of the students, in conducting the activity, may have assigned some name to their unit of measure such as "string length." The class must now decide which of the various "string lengths" should be chosen to be the "standard string length" so that subsequent measurements of the teacher's desk and the science table may be conducted.

To insure that the standard unit of length is not misplaced and so that duplicates may be made later for other measurement exercises, the class should select one or more of their fellow students to serve as a "bureau of standards." The students should also decide upon a standard unit of weight and also a standard unit of time. They may also wish to establish other useful standards. A standard mass unit may be arbitrarily selected, checked on the soda straw balance, and then filed with the "bureau of standards." A standard temperature unit may also be arbitrarily decided upon by using an ungraduated thermometer. An ungraduated liquid-in-glass thermometer may be placed in a mixture of ice and water and then in a container of boiling water. The two "fixed" points should be marked on the thermometer stem with a grease pencil. Choosing a standard unit of temperature involves deciding how to subdivide the distance along the stem between the two "fixed" points. For example, if the distance is subdivided once, two equal standard units will result; if it is subdivided twice, four equal standard units of temperature will result. Numbers may be assigned to specify points on the scale for use by students with number skills whereas five- and six-year olds may use a color-coded temperature scale. See Figure 6.

A series of activities involving weight, time, mass, volume, and temperature measurements using the student-selected standards should follow. In discussing these activities, students will realize that communication of information they have gathered using their standards of measurement is restricted within the classroom since anyone outside the class would not have knowledge of their particularly chosen standards. However, the foot, pound, second, and Fahrenheit degree are more generally known throughout the school and nation. Units such as the meter and the gram are widely used internationally.

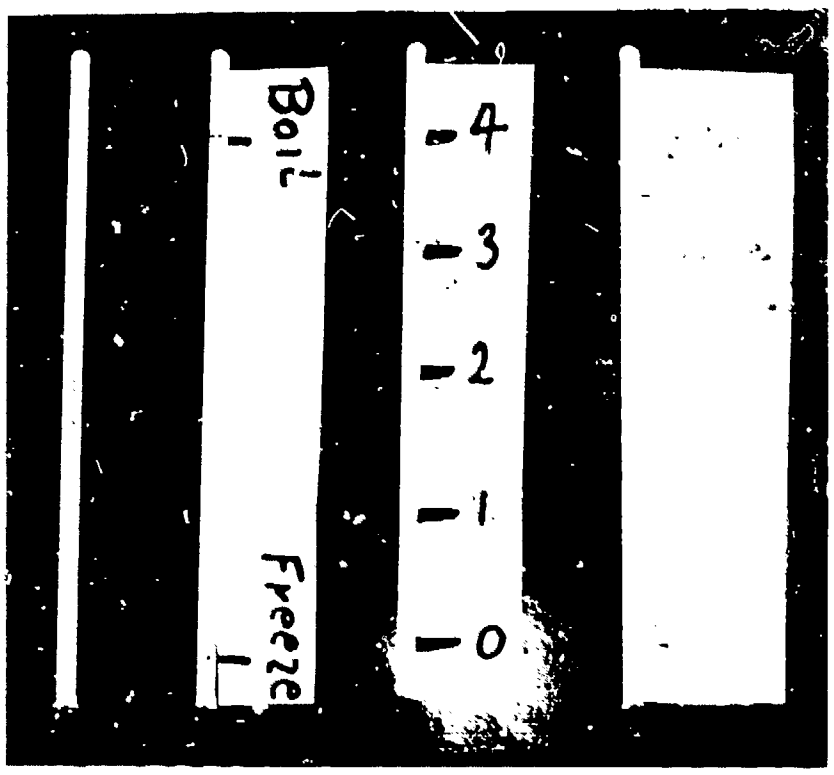


Figure 6. Colors or numbers were assigned to these unmarked thermometers to distinguish temperature variations.

By using these accepted standards, the students' power of communication is greatly enhanced. Students should understand that it doesn't really matter how long a foot or an inch is, or how heavy a pound or an ounce is. What is really important is that everyone means the same thing when he specifies a foot, inch, pound, or ounce. In other words, measurement needs to be standardized to communicate information so that it means the same thing to everyone.

The establishment of accepted standard units of measurement, such as the foot and the pound, was not easily or quickly accomplished. The men of earlier times turned to the tools and units of measure that for them were the most convenient – those attached to and making up their own bodies. A class may think it strange that the length of a man's arm or the width of a man's hand would be chosen as units of measure. However, a brief discussion will bring out the fact that parts of the human body are indeed logical and convenient tools since everyone has them and they are always available. The problem arises when using body parts as standards, since peoples' arms, hands, and feet come in a multitude of lengths and widths.

A brief consideration of the history of measurement should help students understand how measurement systems evolved and the arbitrariness of measuring units. In teaching the history of measurement, elementary school teachers may make use of many excellent references, some of which are listed at the close of this leaflet. In the historical review of measurement, it is better to emphasize the evolutionary aspect rather than the study of selected units just for the sake of knowing the out-of-date units.

Relationships Between Basic and Derived Units

Measurement of length, mass, weight, and time can be thought of as "basic" measurements. There are also the "derived" measurements, or combinations of "basic" measurements. Area and volume are often measured in the elementary school. These are "derived"; that is, area is the product of two lengths, and volume is the product of three lengths.

Most elementary school students have an intuitive feeling for speed, which is a measure of how far (length) an object moves in a given time interval. Therefore, speed is derived from two basic measurements: length and time. Another derived measurement is density, which is determined from a combination of mass and volume. In other words, density is the mass of an object for a given unit volume. Most substances have unique densities, e.g., the density of water is defined to be one gram per cubic centimeter (g/cc).

As students become involved in investigations, they will encounter situations requiring the combination of basic counts and measurements or they will be developing their own derived units. Some of the many possibilities are shown in Table 1.

MEASUREMENT	EXPRESSED AS	EXAMPLE
counts per length	counts/foot	6 twigs/foot of tree branch
counts per area	counts/square foot	2 rats/ft^2 of cage
counts per time	counts/second	16 revolutions/second of a wheel
counts per volume	counts/cubic foot	18 earthworms/ft^3 of soil
length per time	feet/second	30 feet/second (defined as speed)
weight per volume	pounds/cubic foot	5 lbs/ft^3 (defined as density)
weight per area	pounds/square inch	21 lbs/in^2 (defined as pressure)

Table 1 These measurements were made by elementary students and may be used in their investigations.

COMPARISONS	EXAMPLES
area vs. length	How do the areas of butterflies' bodies compare with their wingspans?
time vs. an occurrence	How long does it take water to freeze?
shape vs. purpose	How do the streamlines of a fish body help the fish to swim in an upright position?
occurrence vs. pressure	How does the boiling point of water depend upon air pressure?
composition vs. reaction	How does the composition of a ball, i.e., whether it is rubber, plastic, etc., affect the height of its rebound off a hard surface?

Table 2. The comparison of measured quantities contributes to investigation.

Further investigation by elementary students will disclose the need for comparisons of certain basic and/or derived measurements. These will come about when they attempt to find patterns or establish relationships between quantities. A few examples are shown in Table 2.

How to Form a System of Basic Measurements

Student understanding of many of the aspects of measurement may be enhanced by allowing the students to develop their own system of measurements. In doing this, the students must decide which quantities they will use as their basic measurements. Generally, these basic measurements will be length, mass, and time, or length, force, and time, but other combinations are possible.

What the students have learned concerning the importance of measurement in communication, the necessity of standard units in using measurements, and the relationships between basic and derived measurements will be helpful to them in conducting this activity. Additional emphasis should now be placed on the subdivision and use of these units.

Example: The students may be motivated to develop their own system of measurements if the teacher asks them how they would measure length, mass, and time if they found themselves on a distant planet without any tools or standards of measure. The teacher may create this artificial situation by collecting all rulers and balances and by covering the clock face. If it is a rocky planet, it may be of interest to present the class with a small rock and ask the students to measure the thickness and height of it without the aid of any standards. One means might be to use a paper strip as the basic unit. The students will in all probability find the rock to be more than one strip in length but less than two. This will be quite inadequate for most students and the necessity to subdivide the basic standard will be evident. The answer to "How many subdivisions do you want to make?" should be agreed on by the class. One series of subdivisions may be easily developed by folding as shown in Figure 7. Other ways may be suggested by the students and should be encouraged.

The mass of the rock could be determined using a balance somewhat similar to those discussed earlier, but it would still be necessary to have a standard. The mass standard could be a piece of clay from the "other planet." (The teacher and students just happen to have a supply of modeling clay.) Once the standard is agreed upon it will again be necessary, unless the students guess the clay standard to be identical in mass with the rock, to make subdivisions. This time it will not be so easy since any division of the standard itself would destroy the standard. One way of avoiding this hazard is to make a replica of the standard (comparing it on the balance). Divide the replica into two pieces, place them on the balance, and remove clay from the more massive and add to the less massive until both are identical. The students now have units and halves of units. This process may be continued within the limits of the balance being used.

The standardization and subdivision of time is somewhat more difficult than either of the previous two. In the measurement of length and mass it was necessary to use some tool of measurement; likewise in the measurement of time some device which repeats an event at regular intervals is needed. Some examples would be a swinging pendulum such as a child's swing, a bobbing weight

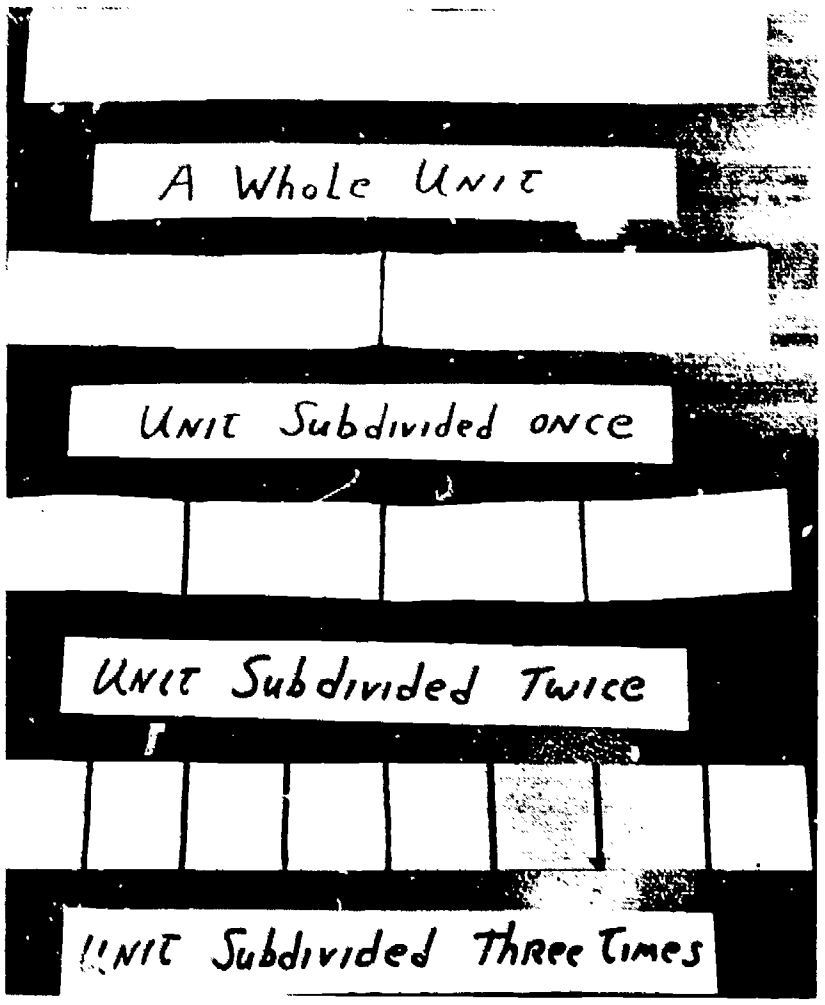


Figure 7. This unit of length was subdivided by folding once, twice, and three times.

suspended from an expansion spring, and a liquid dripping from a small hole in a container. A one-gallon plastic bleach bottle with a pin hole in the bottom provides an interesting tool for establishing a standard of time. (See Figure 8.) Fill the bottle to a premarked level and suspend it from some suitable hanger in the classroom. Water will drip from the hole at the bottom of the bottle at

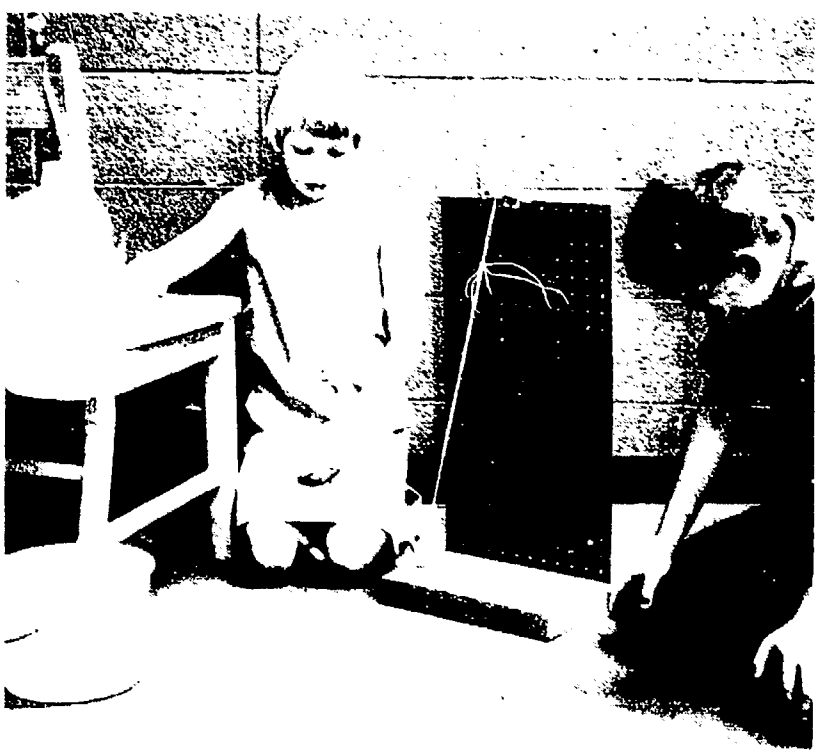


Figure 8. The number of swings of a pendulum per unit of time can be measured by a bleach-bottle timer.

reasonably regular intervals. If you place a container under the dripping bottle, sound will be produced with each drop. This sound may be made louder if a small aluminum pie tin is turned upside-down in the collecting container. The interval between the drops represents the smallest interval of time and becomes the standard time unit. Students should be encouraged to invent systems other than those suggested for measuring time and other quantities.

In developing a system of measurements, the student "bureau of standards" should once again be placed in operation. It is important, once a system of measurement is established, that the agreed standard units be preserved. The student-made system of measurements may provide an excellent system for the distant planet, but it suffers from the fact that it does not allow for adequate worldwide communications. Therefore, just as in the earlier case where student-chosen standard units proved to be limited, and the students learned that more widely accepted units like the foot and the pound gave them greater power of communication, the students will see again that some even more widely accepted system of measurements should be adopted. The two most widely used systems of measurement are the English and the metric. Students gain much by studying the historical development of both of these systems, and many of the references listed at the end of this leaflet include such information.

Elementary students should be urged to learn and use the metric system of measurements in conducting all of their investigations. It is far more manageable to use, and most of the nations of the world, with the exception of a few English-speaking countries, use it as their official system of measurements. Furthermore, the United States also recognizes the metric system as legal, and it is quite probable that this system of measurements will be in common use within the lifetime of the elementary students now in school. The logic and regularity of the metric system make conversion to larger or smaller units of measure much easier.

Perhaps the best way to teach the metric system effectively and efficiently is to allow the students to become familiar with the standard units, gain an understanding of the superiority of a decimal subdivision, and then urge the students to use the metric system in all of their measurement activities. Since the monetary system of the United States may be thought of as a decimal system, it provides a starting point for teaching the metric system. The dollar may be considered as the basic money unit. One-tenth of a dollar is the dime,

U.S. MONEY SYSTEM			METRIC LENGTH			METRIC MASS			METRIC VOLUME		
millidollar	= mill	= $0.001	millimeter	= 0.001	m	milligram	= 0.001	g	milliliter	= 0.001	l
centidollar	= cent	= $0.01	centimeter	= 0.01	m	centigram	= 0.01	g	centiliter	= 0.01	l
decidollar	= dime	= $0.1	decimeter	= 0.1	m	decigram	= 0.1	g	deciliter	= 0.1	l
DOLLAR ($)		= $1	METER (m)	= 1	m	GRAM (g)	= 1	g	LITER (l)	= 1	l
dekadollar		= $10	dekameter	= 10	m	dekagram	= 10	g	dekaliter	= 10	l
hectodollar		= $100	hectometer	= 100	m	hectogram	= 100	g	hectoliter	= 100	l
kilodollar		= $1000	kilometer	= 1000	m	kilogram	= 1000	g	kiloliter	= 1000	l

Table 3. Comparison of metric system to the U.S. monetary system.

one-tenth of the dime is the cent, and one-tenth of the cent is the mill. Table 3 provides an analogy between the United States monetary system and the metric quantities of length, mass, and volume. If presented to the students in such a manner, the logical pattern of interrelationships among units and subunits is a great asset in learning the metric system.

The metric system of measurements or any other system may be applied to two fundamental types of measurements, direct and indirect. All measurements discussed thus far in this leaflet would be considered as direct measurements. In some instances, however, direct measurements are not efficient, while in other cases they are not even possible.

For the purposes of elementary school students, indirect measurements may be thought of in the broadest terms as measurements arrived at without the direct application of tools. For example, the height of a flagpole in the school yard may be determined by using the length of the shadow of the flagpole as it compares to the length of some measure stick. Suppose a stick is four feet long and casts a shadow two feet long while the flagpole casts a shadow 30 feet long. The flagpole therefore must be 60 feet tall. Another example would be to determine the height of the school building by measuring the height of one of the bricks and multiplying this measure by the number of bricks high. This same method may be used to determine indirectly the dimensions of a classroom by counting single rows of floor tile, ceiling tile, and/or wall blocks.

In more practical applications the students may find the need for determining the area of irregular shaped objects such as leaves from various types of trees or shrubs. See Figure 9.

Example: Weigh a sheet of graph paper and determine the number of squares on the page indirectly by counting rows and columns and multiplying the two quantities. The total weight divided by the number of squares results in the weight of one square. Trace the leaf pattern on the graph paper and cut it out. Weigh the cut-out and compare it to the weight of one square to determine the number of squares covered by the leaf. (Take special note that weight measurements are being used to determine area. Precautions should be taken to avoid confusion between these two quantities.)

The balance may also be used to determine the mass of water in a container. The first step consists of determining the mass of an empty graduated container. The combined mass of the container and a measured volume of water is now determined. Subtraction of these two values gives a measure of the water's mass by indirect methods.

Students may indirectly measure the volume of an irregular solid such as a stone in a very simple manner. Pour water to a predetermined point in a graduated cylinder which is large enough in diameter to accommodate the stone. Record the

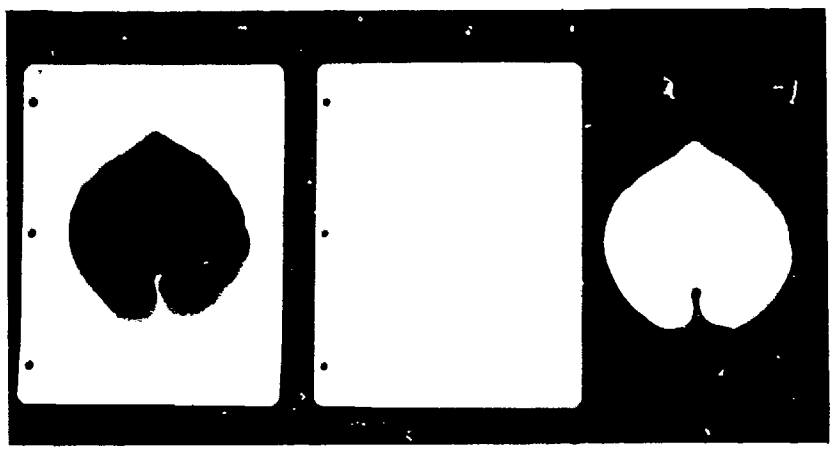


Figure 9. Students can find the area of a leaf by counting squares of graph paper and weighing.

predetermined level of the water. Lower the stone into the water in the graduate, and the water level will rise. Record the new level of the water and subtract the two values. The difference in cubic centimeters or milliliters will be the indirect measure of the volume of the stone.

The exercises described in this pamphlet are only a few of many through which elementary school students develop the concepts of measurement. By constructing and using their own measuring tools, they gain valuable skills and an appreciation of the various ways of solving problems and discovering relationships. Through their own attempts at description they discover the need for effective communication in measurement through the use of standardized units.

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