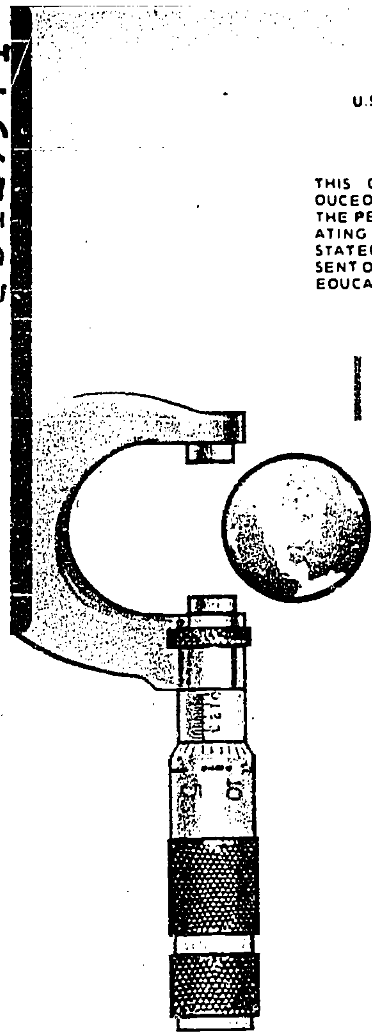
DOCUMENT RESUME

ED 129 571 SE 020 477

TITLE	An Introduction to the SI Metric System. Inservice Guide for Teaching Measurement, Kindergarten Through Grade Eight.
INSTITUTION	California State Dept. of Education, Sacramento.
PUB DATE	75
NOTE	50p.
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	*Elementary School Mathematics; Elementary Secondary Education; *Guides; Instruction; Mathematics Education; *Measurement; *Metric System; Secondary School Mathematics; Teacher Education; Teaching Guides

ABSTRACT

This handbook was designed to serve as a reference for teacher workshops that: (1) introduce the metric system and help teachers gain confidence with metric measurement, and (2) develop classroom measurement activities. One chapter presents the history and basic features of SI metrics. A second chapter presents a model for the measurement program. A third chapter presents sample activities for length, mass, time, and temperature. The instructional models are based on four stages of development which incorporate six learning processes important for conceptual growth in measurement. The handbook concludes with selected references. (Author/JW)



Inservice Guide for Teaching Measurement

Kindergarten Through Grade Eight

An Introduction to the SI Metric System

2

CALIFORNIA STATE DEPARTMENT OF EDUCATION • Wilson Riles · Superintendent of Public Instruction • Sacramento, 1975

Inservice Guide for Teaching Measurement

Kindergarten Through Grade Eight

An Introduction to the SI Metric System

Prepared by the
Mathematics Education Task Force

This publication was edited and prepared for photo-offset production by the Bureau of Publications, California State Department of Education, and published by the Department, 721 Capitol Mall, Sacramento, California 95814. In keeping with the spirit of its subject matter, the layout of this publication was designed with metric dimensions.

Printed by the Office of State Printing
and distributed under the provisions of
the Library Distribution Act

1975

Foreword

I am fond of a limerick on metrics that a first grade teacher wrote some time ago:

There once was a student named Peter,
Who asked, "Why use metre and litre?"
But when he found out,
He let out a shout:
" 'Cause metre and litre are neater!"

Yes, metre and litre *are* neater. That is why approximately 92 percent of the people in the world live in countries that officially recognize the metric system as the national standard for weights and measures. Only the United States and a few small countries use other systems predominantly.

Many attempts have been made in the United States to have the metric system adopted. Thomas Jefferson succeeded in getting the Continental Congress to adopt the decimal system of coinage but failed as to weights and measures. In 1866 the U.S. Congress authorized the use of the metric system, making it legal for those wishing to use it. A predecessor in the office I now hold—Ezra S. Carr, M.D., the seventh Superintendent of Public Instruction—called for mandatory instruction in the metric system as far back as 1879. In the *Eighth Biennial Report of the Superintendent of Public Instruction of the State of California for the School Years of 1878 and 1879,* Dr. Carr wrote:

> Every community should add the weight of its influence to any movement which assists the progress of civilization. Such a movement is the effort to establish a uniform system of weights and measures, "a blessing of such transcendent magnitude," John Quincy Adams said, "that if there existed upon earth a combination of power and will adequate to accomplish the result by the energy of a single act, the being who should exercise it would be among the greatest benefactors of the race."
>
> It is almost incredible that a system which was legalized in 1866, by Act of Congress, and now in general use among scientists, in laboratories and manufactories, used by the coast survey and in the United States service, by physicians and druggists, which is adopted in France, Germany, Holland, Belgium, Spain,

Portugal, Italy, Austria, Switzerland, Greece, Denmark, legalized in Great Britain and in India, should need to be urged upon the teachers of our public schools, not for *general* use at the present moment, but as a *thing to be mastered by every pupil.* It is my earnest hope that our Legislature will render instruction in the metric system obligatory in every grammar school.

Almost a century has passed since Dr. Carr made his proposal. Only now, however, does the widespread conversion to the metric system in the United States seem inevitable. Our current system of inches and feet, ounces and pounds, quarts and gallons is on the way to obsolescence. Metric conversion is not only inevitable, it is necessary and desirable. By converting to the metric system now, the United States will be able, for example, to eliminate needless sizes and types of products; and export markets will become more accessible.

I am determined that California education will not lag behind in the changeover to the metric system. We must act now to make sure that our schools are prepared to offer instruction in metrics and are not caught up in the confusion that will probably occur in the next few years as the United States converts to the metric system. The new state-adopted mathematics and science textbooks, to be used in the fall of 1976, will contain only metric units for measurement. And teacher-training institutions are being asked to prepare prospective teachers to use metric weights and measures. Our society and our schools can adjust to the metric system with ease only if conversion is begun now.

This publication contains important concepts and suggestions related to instruction in metrics for pupils in kindergarten and grades one through eight. I hope that the teachers who use this publication will find it useful in the important work entrusted to them.

Wilson Riles

Superintendent of Public Instruction

Contents

Preface

As the transition to metrics gains momentum, the Department of Education has been faced with an ever-increasing number of requests for guidance and assistance in negotiating the changeover. We have been asked to speak on the subject, participate in workshops, and recommend approaches for training teachers and teaching pupils the principles of measurement and the elements of the metric system known as the International System of Units (SI). Because our human resources are not sufficient to handle all such requests, the Mathematics Education Task Force has developed an inservice model for measurement using SI units which can be employed to train elementary school teachers serving in California schools. This guide, which was prepared under the direction of Marvin Sohns, Education Project Specialist with the task force, is the model which will be used by many California schools in the days ahead.

The philosophy of the guide is that measurement skills are best learned by engaging in measurement activities. Further, the transition to metrics offers a convenient opportunity for revitalizing measurement instruction and learning. In the guide, we have taken maximum advantage of the situation and have displayed an inservice model much like that recommended for use with pupils.

The guide will be distributed to every elementary school in California, and Department staff members will conduct regional meetings with leaders to train them in the use of the document with teachers. Thus, by "ripple effect," the Department of Education will bring about a change in the instructional skills of teachers with respect to metrics.

Within a three-year period, most teachers in California's elementary schools and possibly most high school teachers will possess some functional skill in the use of the SI metric system. By the 1980s, pupil measurement skills with SI units will be sufficient to meet the demands of a metric United States.

WILLIAM E. WEBSTER
Deputy Superintendent
for Programs

ROBERT F. TARDIF
Manager, Mathematics
Education Task Force

Chapter 1

Introduction

By 1976, all children attending California's elementary schools will be taught the SI metric system (the International System of Units) as the standard system of measurement. To ensure the successful transition to metrics, many inservice workshops must be held for California teachers. These workshops will be of two types: (1) introductory metric workshops; and (2) workshops on classroom measurement activities.

The introductory metric workshops will be activity oriented to help teachers gain confidence with the SI system. The objectives of the first workshops are as follows:

1. Help teachers understand the need to change to a metric system.
2. Provide teachers firsthand experience in measuring common objects with metric units.
3. Help teachers to appreciate the simplicity of a decimalized measurement system.

Workshops dealing with classroom measurement activities should be designed to accomplish the following objectives:

1. Help teachers to understand that measurement is a procedure for comparing what is to be measured with a suitable standard.
2. Provide teachers with a model instructional program that conforms to the logic of measurement and to the logic of the child.
3. Help teachers to find ways of using measurement activities as an integral part of the mathematics program.
4. Introduce teachers to techniques for implementing and evaluating activity oriented measurement programs.

This handbook has been prepared to serve as a reference for both types of inservice workshops. In chapter two, the history and the salient features of SI metrics are presented as resource information for the introductory workshops. In chapter three, a model for the measurement program is formulated which takes into account the logical capabilities of the child and the orderly development of the ideas of measurement. This model is extended in Chapter 4 through the presentation of sample activities for length, mass, time, and temperature. These activities should serve as starting points for teachers and should be adapted for individual classroom needs.

Chapter 2

Transition to Metrics

The metric system was made legal but not mandatory by the United States Congress in 1866. However, not until 1965, when the British announced their intention to convert to the metric system, did metric conversion receive serious attention in the United States. Three years later in August, 1968, the Metric Study Act (Public Law 90-472) was enacted by Congress. The resultant report of the U.S. Metric Study concluded that it would be in the best interests of the nation to join the rest of the world in the use of the metric system.

The unique position of the United States in its continued use of a nonmetric system is illustrated in Figure 1. Only the United States, Brunei, People's Democratic Republic of Yemen, and Yemen Arab Republic have not yet adopted the metric system.

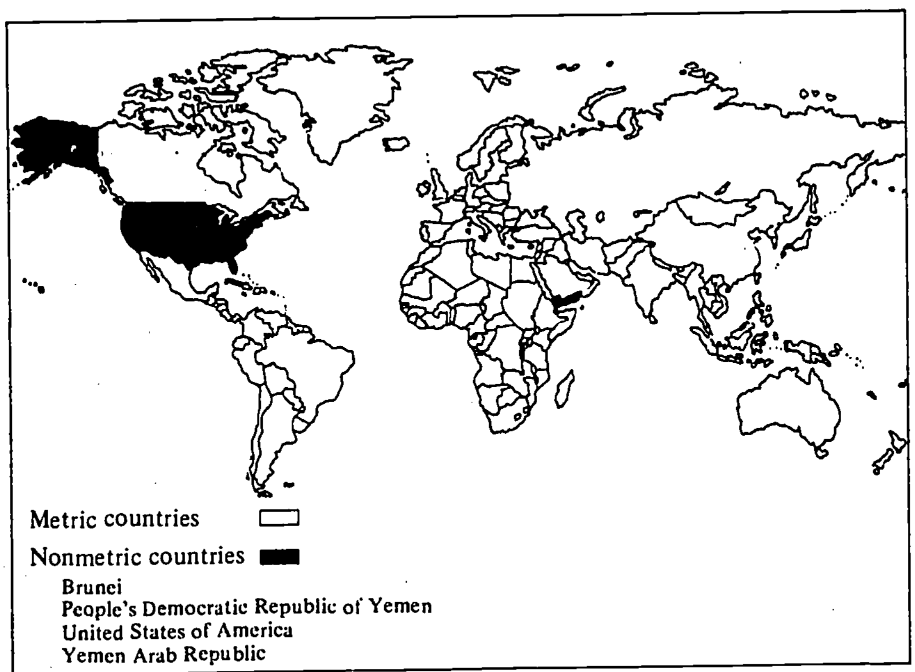


Fig. 1. A metric world

Metrics Compared to the Customary System

The chief educational advantage of the U.S. Customary system of measurement is that it has been part of our culture for several hundred years. The major disadvantage of the U.S. Customary system is that it contains many unrelated units (see Table 1). Moreover, computation with these units can be complex:

$$\begin{array}{r} 3 \text{ qts. } 1 \text{ pt.} \\ +\underline{2 \text{ qts. } 1 \text{ pt.}} \\ 5 \text{ qts. } 2 \text{ pts.} = 6 \text{ qts. } \textit{or } 1 \text{ gal. } 2 \text{ qts.} \end{array}$$

The chief educational advantage of the metric system resides in the simple interrelation of units based on multiplication or division by a factor of 10; decimals can therefore be used in all calculations. The major educational disadvantage of metrics is that the system is unfamiliar to most residents of the United States.

TABLE 1
Some Units of the Customary System

Dry measure		Liquid measure	
2 pints	1 quart	4 gills	1 pint
8 quarts	1 peck	2 pints	1 quart
4 pecks	1 bushel	4 quarts	1 gallon
36 bushels	1 chaldron	31½ gallons	1 barrel
		2 barrels	1 hogshead

The International System of Units (SI)

The International System of Units (SI) evolved from the units of length (metre) and mass (kilogram) that were created in France during the 1700s and adopted by the National Assembly of France in 1795. In 1875, the United States along with 16 other nations signed an agreement called the *Convention du Metre* (Convention of the Metre). The *Convention du Metre* provided for an International Bureau of Weights and Measures (located in France), an International Committee of Weights and Measures, and an International General Conference on Weights and Measures.

In 1948, the General Conference on Weights and Measures was requested to make recommendations on a single system of metric units that would be suitable for adoption by all countries adhering to the

Convention du Metre. The name for the chosen system of units, which was adopted in 1960 by the General Conference, was the International System of Units.

SI Units

The SI system is built on seven base units and two supplementary units (see Tables 2 and 3). These units, along with SI prefixes (Table 4), provide a logical framework from which other units can be derived.

TABLE 2
SI Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K*
Amount of substance	mole	mol
Luminous intensity	candela	cd

*Degrees Celsius (°C=K −273.15) is an acceptable alternate system of temperature measurement.

TABLE 3
Supplementary SI Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

TABLE 4
SI Prefixes

Multiplication factor	Prefix	Symbol
10^{12}	tera-	T
10^{9}	giga-	G
10^{6}	mega-	M
10^{3}	kilo-	k
10^{2}	hecto-	h
10	deka-	da
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	femto-	f
10^{-18}	atto-	a

Other Metric Units

Some non-SI metric units (Table 5) can be used with or in addition to SI units.

TABLE 5
Acceptable Non-SI Units

Quantity	Unit	Symbol	Definition
Time	minute hour day	min h d	1 min = 60 s 1 h = 60 min 1 d = 24 h
Plane angle	degree minute second	° ′ ″	$1° = (\pi/180)$ rad $1' = (1/60)°$ $1'' = (1/60)'$
Volume	litre	ℓ	$1ℓ = 1\ dm^3$
Mass	tonne	t	$1t = 10^3$ kg

Common Metric Units

Metric units that are commonly used in everyday situations represent a very small portion of all the units that are available. The units which are in general use are shown in Table 6.

TABLE 6
Metric Units in General Use

Quantity	Unit				
Length	km kilometre	m metre	cm centimetre	mm millimetre	
Mass	t metric ton	kg kilogram	g gram	mg milligram	
Area	ha hectare	m^2 square metre	cm^2 square centimetre	mm^2 square millimetre	
Volume	m^3 cubic metre	cm^3 cubic centimetre	mm^3 cubic millimetre		
Capacity (liquids)	ℓ litre	mℓ millilitre			
Time	a year	d day	h hour	min minute	s second
Speed	km/h kilometre per hour				
Temperature	°C degrees Celsius				

Using SI Metrics

The transition to SI metrics will be facilitated by adhering to a few simple rules. The following are recommended rules for usage.

Spelling. Recommended spellings are as follows: metre, not meter; litre, not liter.

Capitalization. Units named after a person have a capital initial letter; e.g., J for joule, Pa for pascal, V for volt, °C for degree Celsius, and W for watt.

Pronunciation. Measures of distance in kilometres should be pronounced "kill-o-metre." The prefix *kilo* is pronounced the same when attached to any of the base units.

The terms "mass" and "weight." Mass is a term which is seldom used incorrectly. It is *the quantity of matter in an object,* a constant unaffected by location or gravity. In the United States the term "weight" has been used to refer to the concept of mass. In some scientific applications the term "weight" has been used to refer to the concept of force due to gravity, a variable. Since the kilogram is the unit used to measure mass, it is, and has been, important that the implied meaning of the term "weight" be made clear whenever this term is used. To eliminate confusion, the California State Department of Education recommends that the term "weight" be avoided in references to the concept of mass in classroom instruction on measurement, especially in the earliest phases of the changeover to metrics. To say that "5 kg is the mass of the object" is always a correct use of terms. Such a statement is recommended as a suitable alternative to the use of the term "weight" to mean mass.

Instruction requiring understanding of the newton, the measurement unit for force, is *not* expected to be common in California elementary school programs.

Symbols. Symbols for units do not have a plural form. For example, 2 kilograms would be 2 kg, not 2 kgs.

A prefix symbol and the unit symbol form a single unit; there is no space between the prefix and the unit symbol; e.g., kg.

To signify "square" or "cubic" measure, an exponential index number is used with the symbol. For example, cubic centimetre is represented cm^3 , not cc; square metre is m^2, not sq m.

A script "ℓ" should be used as the symbol for litre to avoid confusing it with the numeral one (1).

Symbols should not be punctuated with periods (e.g., m, not m.; g, not g.; ℓ, not ℓ.). Periods are not used with SI symbols except at the end of a sentence.

Numbers. A comma is not used to separate a group of three digits. Groups of digits are separated by spaces; e.g., 15 000, not 15,000. Commas are used in many countries as decimal markers, and the use of the space helps to avoid confusion.

Fractions are easily expressed in decimal form in the metric system. Fractions such as ½ or ¼ should be expressed as decimals; e.g., 0.5 and 0.25. When numbers less than one are expressed, a zero is placed before the decimal point; e.g., 0.5 mm.

Recommended Instructional Practices

Certain techniques in classroom instruction can make the transition to SI metrics easier. These techniques are as follows:

1. Only those metric prefixes and units that will actually be used should be introduced.
2. If calculations are to be made with metric units, all units should be changed to the same units before the calculations are performed. After the calculations have been completed, the answer can be changed to the desired expression.

   5.2 kg + 220 g = 5.2 kg + 0.22 kg

   5.2 kg + 0.22 kg = 5.42 kg *or* 5 420 g

3. Numerical comparisons between SI metric units and U.S. Customary units should be discouraged; instead, familiar objects in the environment should be used to make an appropriate comparison. The following are examples of useful equivalents:

   a. One kilogram has about the same mass as nine sticks of butter.
   b. One metre is about half the height of most doors.
   c. One litre is a little larger than a liquid quart.
   d. A comfortable room temperature is 20°C.

4. Conversion between measurement systems should be discouraged, and pupils should be encouraged to *think metric.*

Chapter 3

Curricular Strategies

All measures such as length, mass, time, and temperature are based on the idea of making a comparison. Comparisons are made between what is to be measured and a suitable standard. From the child's point of view, measures used by primitive people are much more comprehensible than those used today. Historically, people have used a variety of arbitrary comparisons to satisfy their needs for measurement; then, as this became unsatisfactory, they eventually standardized their method of measurement. Instruments were provided with scales by which the consistency and the precision of measures could be improved.

Fundamental Classroom Exercises

The history of measure provides a logical scheme around which measurement activities in the classroom may be organized. Regardless of the quantity of measure (length, mass, time, and so forth), the same scheme can be applied. The following is a list of these successive stages that can be used for the organization of classroom measurement activities:

1. Making direct comparisons between objects
2. Comparing an object with a nonstandard unit
3. Comparing an object with a standard unit
4. Choosing measurement units for specific tasks

Making Direct Comparisons Between Objects

The direct comparisons of objects is the most rudimentary of measurement activities. Tools are not required at this stage of measure to make comparisons (Fig. 2). Children use direct comparison techniques to determine the proper placement of objects in an ordered series (Fig. 3).

Comparing an Object with a Nonstandard Unit

In the second stage of measurement activity, a nonstandard unit is used to make comparisons with objects. For example, a classroom exercise might involve a domino as a unit of measure, with four dominoes equaling the length of a plastic straw (Fig. 4). Another unit of measurement that can be used is the hand, a measuring device that has been used throughout history by people of all cultures (Fig. 5).

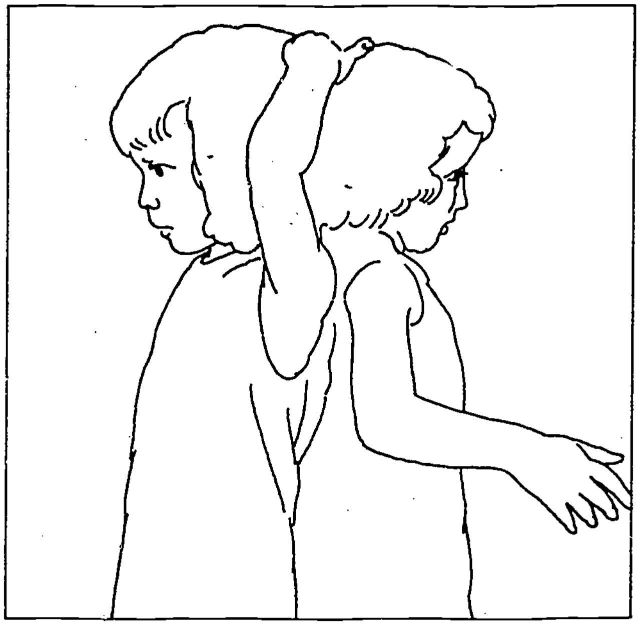


Fig. 2. Simple matching

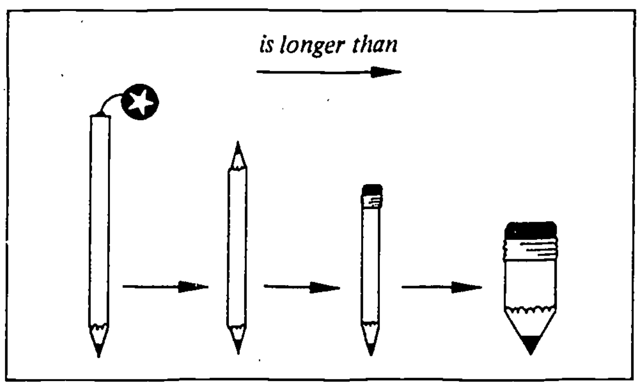


Fig. 3. Ordering

Comparing an Object with a Standard Unit

A hallmark of civilized people is their instruments of measure. In the twentieth century, metric instruments of measure provide the precision that is needed by our society. Therefore, the third stage of measurement activity makes use of the standard units of measure, SI metric units (Fig. 6 and Fig. 7).

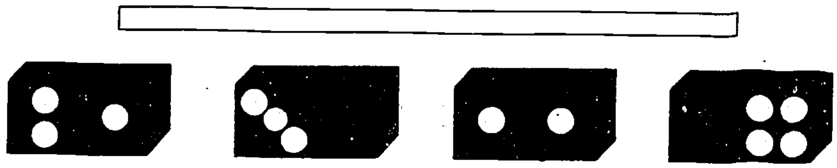


Fig. 4. Matching with a nonstandard unit

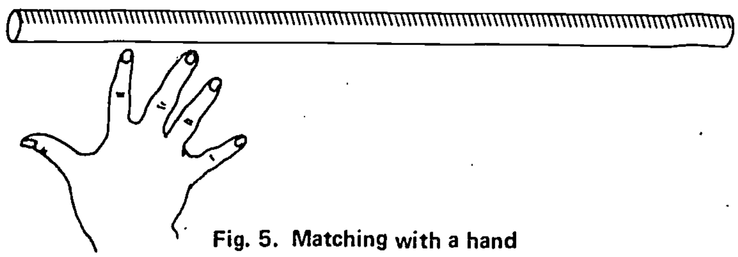


Fig. 5. Matching with a hand

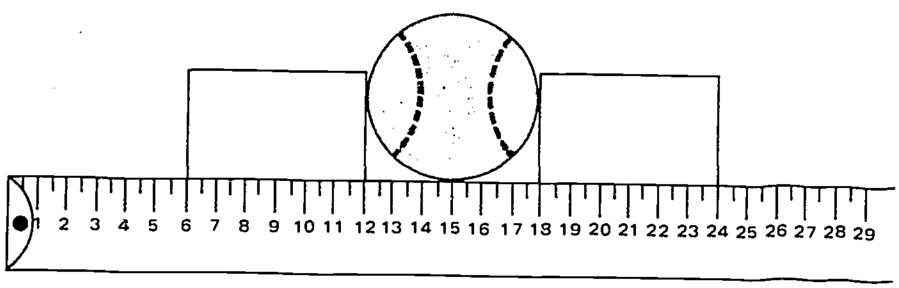


Fig. 6. Matching with a standard unit

Choosing Measurement Units for Specific Tasks

The final stage of measurement activity is focused on the appropriateness of a particular unit of measure for a specific application. For example, a micrometer is an appropriate instrument that can be used to make precise measurements of small objects such as pins, marbles, and paper (Fig. 8).

Measurement and Maturation

Experience alone cannot account for a child's ability or inability to deal with certain types of measurement activity. Children tend to gain the ability to deal with different measurement concepts at different ages.

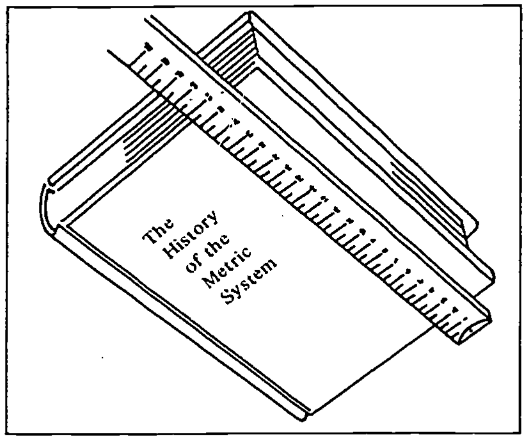


Fig. 7. Measuring an object with a metrestick

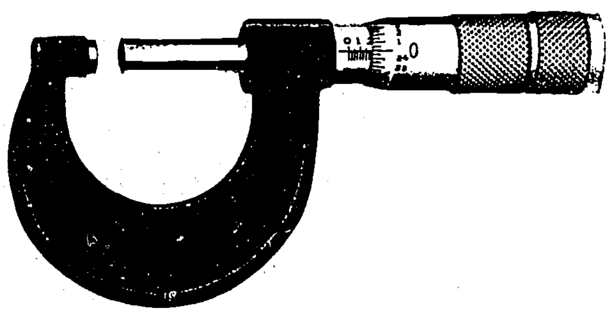


Fig. 8. Micrometer—a precision measurement instrument

For example, a child under nine may claim that a ball of clay which has been smashed into a pancake shape no longer has the same mass as it did before—the shape of the clay is confused with the mass of the clay.

Children who are able to understand that a particular attribute of an object (such as length, mass, or volume) remains unchanged despite some irrelevant transformations that occur to the object are said to have the ability to "conserve" the attribute in question. The abilities to conserve length, mass, and volume occur at different periods in a child's life. For example, conservation of length may not occur until the child is about eight or nine years of age; conservation of mass may not occur until the child is about the age of nine or ten; and the conservation of volume may not occur until the child is about eleven or twelve.

Since children have stages in their logical development when their thinking is dominated by the physical appearances of objects, instruction should be planned to allow children opportunities to discover inconsistencies in their thinking. Prior to the third grade, a child can spend time most profitably in using nonstandard units to make comparisons or to measure using direct comparisons. After the third grade, more emphasis can be placed on using a selected standard and on reducing errors of measurement.

Although formal tests of conservation developed by Piaget and his associates may be used in making instructional decisions about children, many informal assessment techniques are available to the teacher. The approach a child uses to a measurement activity is a clue to the child's measurement readiness. Extensive work with standard units of measure should not be planned until the teacher verifies through observations that the child has a stable concept of the quantity of measure to be presented.

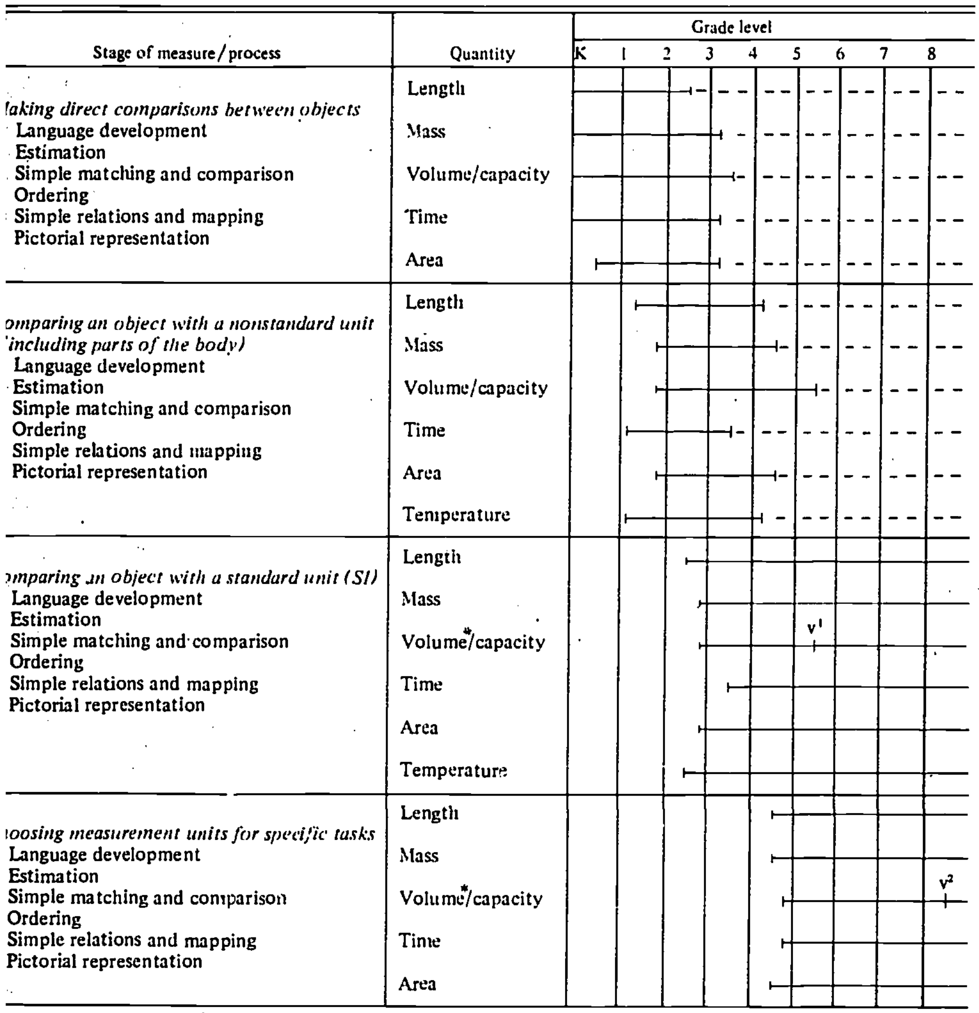
A Model for Measurement Instruction

Instruction in measurement ideally should progress through the four stages of development, with the first stage being direct comparisons between objects in the environment. During the second stage, objects in the environment or parts of the body are used as units of measure. By the time the child reaches the third stage, the child will have gained a concept of the different units of measure and will be ready to use standard SI metric units. In the final stage, children learn to select standard units of appropriate size for measures involving specific tasks.

In the model measurement program presented in Fig. 9 (also presented as a foldout at the back of the book) are listed a number of learning processes under each of the four stages of measurement. These learning processes can be used by the teacher to structure the measurement activities selected for a child's use. The learning processes that have been identified as important for a child's conceptual growth in measurement are the following:

1. Language development
2. Estimation
3. Simple matching and comparison
4. Ordering
5. Simple relations and mapping
6. Pictorial representation

Decisions about the grade placement of a particular measurement activity in the teaching strategy should be made in relation to the child's ability. As mentioned before, a child develops the ability to deal logically with different measurement concepts at different ages. Grade-level lines drawn in Fig. 9 suggest the grade placement of the activities in each of the four stages of measurement. The horizontal grade-level lines in Fig. 9 indicate the levels at which a particular activity might be successfully performed by most children. Broken lines indicate that the measurement activity could be used with older children to reinforce measurement skills.



Solid volume (v^1) and displaced volume (v^2)

Fig. 9. Model measurement program

Chapter 4

Classroom Activities

Measurement must be practiced to be learned. If children have the opportunity to develop the concepts of measure through their own activity, they will readily understand that changing the standard for measure does not alter what they have learned. A metric standard requires only that the child use a familiar tool with a different scale.

Length Measurement Activities

Comparisons involving linear measure are perhaps the first measuring activities that children attempt. Therefore, exercises in linear measure will be considered first. (An overview of classroom activities is shown in Fig. 9 and in the foldout at the back of the book.)

Making Direct Comparisons Between Objects

The simple comparison of the physical properties of two tangible objects is a basic yet effective measurement exercise. Direct comparison enables young children to grasp the fundamental concepts of measurement that are prerequisites to understanding more abstract concepts.

Language development exercises. When children talk about the dimensions of things, they tend to use words that do not adequately describe the subject being discussed. For example, a child may use the word "big" when he wants to convey "tallness" or "wideness." Teachers can help children to use appropriate descriptions by introducing those words that will help the child better communicate ideas.

Estimation exercises. Young children do not use adult logic. They will often manufacture arguments to prove their answers. For example, a child may argue that he is taller than a friend because his mother told him so. Consequently, teachers should carefully consider the child's ability to be logical before requiring the child to estimate or make a guess about length measurements.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the lengths of objects:

- *Student:* Write your name on five tags. Tape your name tags on five objects taller than you.

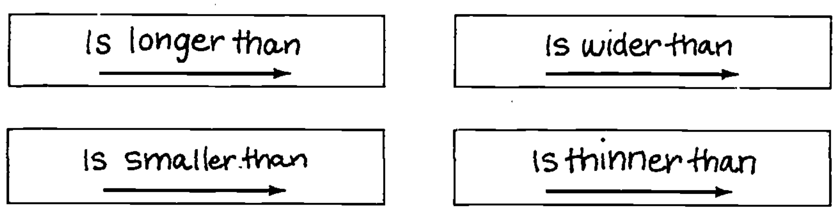
- *Student:* Cut some ribbon into pieces of different sizes. Select one piece for the following activities:
    1. Write the name of five things in the classroom *longer* than your piece of ribbon.
    2. Write the name of five things in the classroom *shorter* than your piece of ribbon.
    3. Write the name of some things you found that were the *same* length as your piece of ribbon.

Ordering exercises. The following is an exercise recommended for teaching length measurement by arranging objects according to size:

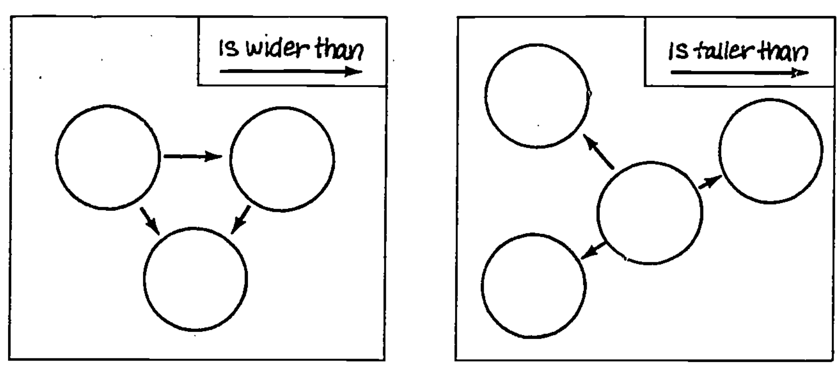
- *Student:* Collect five objects and arrange them in order from large to small. After your teacher checks your work, mix up the objects and see if a friend can put them in the same order that you originally arranged.

Simple relations and mapping exercises. The following are exercises recommended for teaching length measurement through the mapping of objects:

- *Teacher:* Collect a boxful of objects. Place two objects on each of four sheets of colored paper. Ask the child to place arrow cards between the pairs of objects. Some possible arrow cards are the following:



- *Teacher:* Make an arrow design and a label telling the meaning of the arrows. Have the student place one object in each circle so the overall arrangement corresponds with the arrows.



Pictorial representation exercise. The following is an exercise recommended for teaching length measurement by observing the dimensions of objects in pictures:

- *Student:* Find pictures in magazines of objects, animals, and so forth. Cut out the pictures. Group the pictures in pairs on a piece of paper that has previously been creased by being folded into fractional parts. Make labels such as "LARGER," "SHORTER," "TALLER," "WIDER," and "THINNER." Put an appropriate label on one of the objects in each pair.

Comparing an Object with a Nonstandard Unit

The idea of using an object or a part of the body as a unit of measure is a significant advance in the measurement process. Children learn that a selected unit is used over and over (iterated) to determine the length of an object. It is during this stage of measure that the child begins to develop a stable concept of a unit of length.

Estimation exercises. Estimation becomes an important part of the measurement process when one object (the measurement unit) must be repeatedly compared to another object. It is through the process of estimation that children gain the ability to conceptualize a unit of length.

Simple matching and comparison exercises. The following are exercises recommended for the matching and comparison of the lengths of objects:

- *Teacher:* Collect the following materials:

  1. Macaronis (large elbows or wheels)
  2. Lima beans
  3. Blocks (uniform size)
  4. Pencils (uniform size)

  Have the child select one of the materials to use as a unit of measure. Then instruct the child to place the units end-to-end like a train and thereby to measure objects. Make a record of the measurements made.

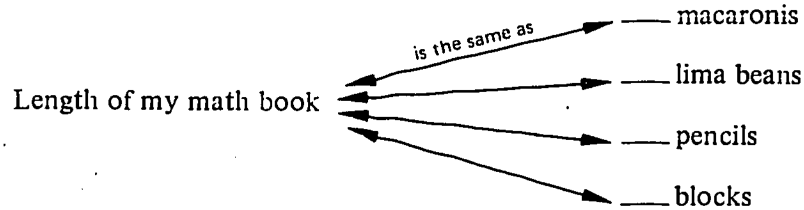
Length Measured in		Macaronis (macaronis, beans, etc.)
OBJECT	GUESSED LENGTH	RIGHT LENGTH
Crayon	6 Macaronis	4 Macaronis
All the way around a tin can		
Windowsill		

- *Teacher:* The following activities are of greater complexity for children because one unit must be moved while marking off the length. The child is not able to see the units that gave him the final count.
  1. Instruct the child to use the length of a palm, span, cubit, foot, or pace to measure the lengths and widths of the following objects. Have the child make a rough estimate before the actual measurement is made.
     a. Desk
     b. Room
     c. Bulletin board
     d. Sheet of paper
     e. Playground
  2. Have the child compare results with those of classmates and analyze the reasons for any differences.

Simple relations and mapping exercises. The following are exercises recommended for teaching length measurement through the mapping of objects:

- *Student:* Estimate and then measure the length of your math book using:
  1. Macaronis
  2. Lima beans
  3. Pencils
  4. Blocks

- *Student:* Map the results of the preceding exercise:



Comparing an Object with a Standard Unit

A distinction that can be made between a nonstandard unit and a standard unit is that a standard unit has an agreed-upon measure. From the standpoint of teaching, there is an advantage in using objects that have a standard measure in the same way one might use any other object for measuring. For example, Cuisenaire rods and inch cubes could be used in a measuring situation much in the same manner as macaronis and lima beans.

Generally, standard measures are best left until children see a need for them. In most cases, the introduction of the metre, along with the relations between the submultiples, can be delayed until the third or fourth grade.

The relationship between metric units of length are such that one would want to present the units in the following order: metre, decimetre, and centimetre. However, this is not necessary. Children can be introduced to the units separately before they are given instruction in the relationships between the different units of length.

Units such as dekametre, hectometre, and kilometre exist in textbooks but are not practical units for classroom exercises. Extremely large or extremely small measures such as the kilometre and the millimetre can be taught in the upper grades (four through eight) after the child is able to conceptualize quantities up to 1 000.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the lengths of objects:

- *Student:* Make a list of as many things as you can find in your classroom that have a measure of about one metre or that occupy a position about one metre above the floor.
- *Student:* How many paces are there in ten metres?
- *Student:* Measure off ten metres in a hall or playground with a tape measure or trundle wheel.
- *Student:* Walking in your usual manner, count the number of paces you take in ten metres. Do this at least three or four times. Keep a record of your results.

NUMBER OF PACES/10 METRES
1. ____________
2. ____________
3. ____________
4. ____________

- *Student:* What is your average number of paces in 10 metres?
- *Student:* What is the measure of one of your normal paces in decimetres?
- *Student:* Step off the measurements of buildings and distances on the playground. Then measure the same distances with a measuring tape. Make a chart of your results.

OBJECT MEASURED	NUMBER OF PACES	PACED DISTANCE (METRES)	MEASURED DISTANCE (METRES)	DIFFERENCE (METRES)
Hallway				
Length of Classroom				
Width of Playground				

- *Student:* Make a list of all the things that you think are about one decimetre in length. Make a record like this:

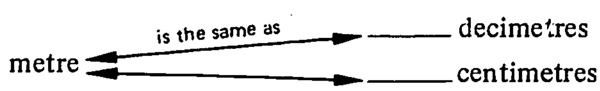
OBJECTS ESTIMATED ONE DECIMETRE	MEASURED LENGTH TO NEAREST CENTIMETRE	DIFFERENCE TO NEAREST CENTIMETRE
Chalk	8cm	2cm

- *Student:* Make a collection of cans, bottles, and boxes. Find a way to measure around each container. Estimate the number of centimetres around each container.

OBJECT	ESTIMATED MEASURE IN CENTIMETRES	ACTUAL MEASURE IN CENTIMETRES	DIFFERENCE IN CENTIMETRES
Bottle	20cm	25cm	5cm

Simple relations and mapping exercises. The following are exercises recommended for teaching length measurement through the mapping of objects:

- *Student:* Collect the following materials: (1) metrestick (unmarked); (2) decimetre rods; (3) centimetre cubes.
- *Student:* Find out how many decimetre rods and centimetre cubes have a measure of one metre. Make a map of the results:



- *Student:* Make other maps for 2, 3, and 4 metres.

Pictorial representation exercises. The following is an exercise recommended for teaching length measurement by observing the dimensions of objects in pictures:

- *Student:* Measure the length of your classmates' feet. Make a graph showing the most common size foot. Write an interpretation for your graph.

Choosing Measurement Units for Specific Tasks

The most advanced measurement activities involve selecting measurement instruments for specific applications. In becoming adept in the selection and use of more precise measuring instruments, children begin to gain concepts related to the error of measurement and the role of significant digits.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the lengths of objects:

- *Student:* Make a collection of objects that you estimate to have a dimension of 1, 2, or 3 centimetres. Record your results on a chart.

OBJECT	ESTIMATED MEASURE	ACTUAL MEASURE	DIFFERENCE (IN MILLIMETRES)
Diameter of a quarter	3 centimetres	2.3 centimetres	7 millimetres

- *Student:* Find a way to measure the distance that a nut travels up or down a bolt on one complete 360-degree turn of the nut.
- *Student:* Find a way to measure the thickness of one sheet of paper.

Simple relations and mapping exercises. The following is an exercise that can be used for teaching the decimal relations between various units:

- *Student:* Estimate each of the following measures in centimetres; then record the actual measure. Convert the measure to other decimal expressions.

ESTIMATE	OBJECT	ACTUAL MEASURE			
		m	dm	cm	mm
___	Thickness of a book	___	___	___	___
___	Your height	___	___	___	___
___	Width of a paper clip	___	___	___	___
___	Distance around your ring finger	___	___	___	___

Mass Measurement Activities

Metric units that will be used in everyday affairs are the kilogram, gram, and milligram. The teacher in the elementary grades should be concerned with the development of the concept of mass.

Making Direct Comparisons Between Objects

The concept of mass is relatively easy for children to grasp. Although there is a technical difference between the concepts *mass* and *weight*, which is of interest to adults, this difference should not be a concern for most children until they are in the upper elementary or secondary grades.

Within the classroom setting, children should be taught to use such words and phrases as "mass" and "the mass of the object." Outside the classroom, children will encounter the word "weight" being used as a synonym for the word "mass." This usage of the word "weight" should be tolerated but not advocated in the instructional program.

Language development exercises. The comparative masses of two objects cannot always be determined by visual estimates. For example, a Styrofoam ball does not have a greater mass than a ball half its size which is made of clay. Children need to be given experiences in which visual approximations of the masses of two objects is only one of the clues that are used to determine relative mass. Since experiences offered children may require the use of new words, teachers should help children to communicate their experiences using appropriate language. The following are situations in which teachers can help children communicate and expand their thinking about the concept of mass:

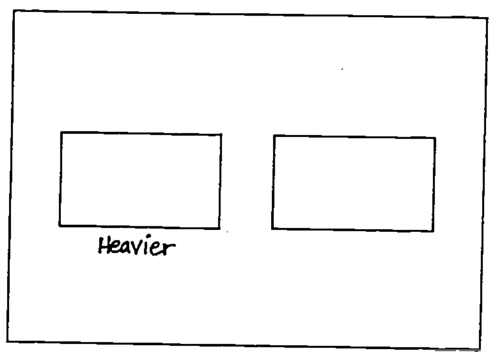
1. *Comparing identical volumes of unlike material.* When identical volumes of material are compared, children can determine the relative masses of two objects by lifting the objects. An appropriate term for children to use would be *heaviness.* For example, filled salt- and peppershakers could be compared. The saltshaker will be heavier; hence, it will have a greater mass.
2. *Comparing volumes of the same material.* If comparisons are made between objects containing the same material, then the relative volume of the two objects can be used to make a determination of relative mass. For example, terms such as "smaller" or "larger" (volume) might be used by the child to distinguish between the masses of two balls of clay. Since children do not always correctly identify which of the two objects actually has the greater volume, it may be necessary for the child to use other methods, including a balance, to determine the greater of the two masses.
3. *Using mechanical devices to make determinations of relative mass.* Balances and springs can be used to make relative comparisons of

masses. Terms such as "smaller mass," "larger mass," or "same mass" can appropriately be used to describe the results of comparisons.

Estimation exercises. Experience is necessary before a child can learn to estimate the mass of an object. Speculation about the relative mass of objects should therefore be encouraged. When the masses of two objects are nearly the same, children realize that instrumentation is necessary to determine differences.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the masses of objects:

- *Teacher:* Cut the tops from milk cartons used in the school cafeteria. Place in the work area pans filled with sand, cornmeal, beans, metal washers, and other materials. Give the children scoops to fill each milk carton with one material. Then have the children find the right way to put the cartons on cards marked as follows:



- *Student:* Make two balls of clay that have the same mass. Use a two-pan balance to check your work. *(Teacher: Children will need an exploration period before they can use the balance with assurance.)*

  Take one of the balls of clay and make a pancake. Will the pancake have the same mass as the ball? Check to see if you are right.

  Break the pancake into pieces; roll each piece into a small ball. Will the combined mass of the small balls be the same as the big ball? Check to see if you are right.

- *Teacher:* With a plank and a brick, make a seesaw. Find out which of two children has a greater mass.

Ordering exercises. The following ordering exercises are recommended for teaching concepts about mass:

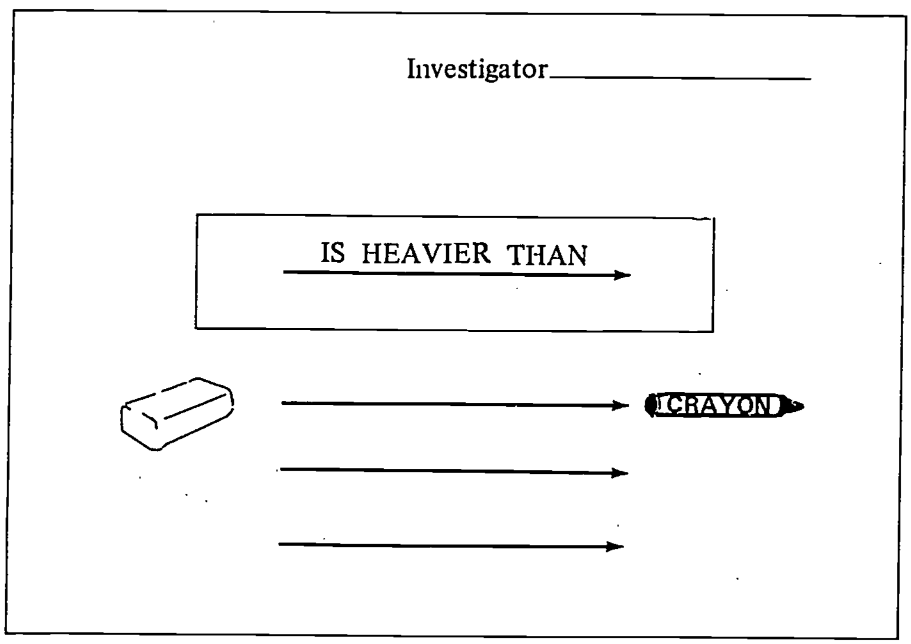
- *Student:* Fill some bowls, cups, bottles, and other containers (at least five containers) with sand. Place the containers in order starting with the one that holds the greatest mass of sand.

- *Student:* Repeat the above activity using "nesting cups" (cups graduated in size).
- *Student:* Put different amounts of material in five boxes ("mystery packages"). Wrap each box with a different type of paper. Arrange the boxes in order according to size (volume); then arrange the boxes according to their heaviness.

Simple relations and mapping exercises. The following are exercises recommended for teaching mass measurement through the mapping of objects:

- *Student:* Use a two-pan balance to determine which object in each of the following pairs is heavier:

  An eraser or a crayon?
  A pencil or a spool?
  A nail or a screw?
- *Student:* Make an arrow-map of the results of the previous exercise. Tape the objects to the map.



Comparing an Object with a Nonstandard Unit

Children should not be rushed into work that involves measurement with nonstandard units. Only after they have had the opportunity to gain an intuitive concept of how masses may be compared should more advanced work be introduced.

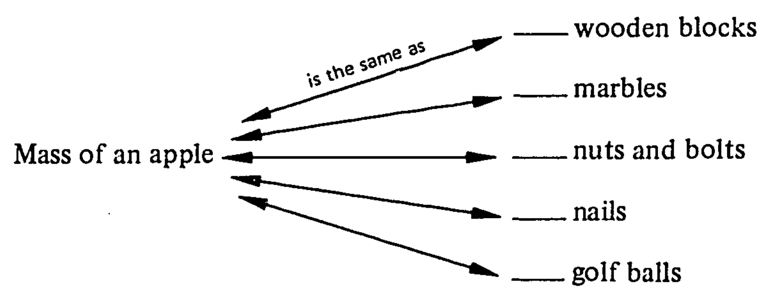
Simple matching and comparison exercises. The following are exercises recommended for the comparison of the masses of objects:

- *Student:* Use a two-pan balance to measure the masses of the following materials: wooden blocks, large nails, bag of metal washers, bag of marbles, bags of sand, and nuts and bolts. Answer the questions below:

QUESTION	NUMBER GUESSED	NUMBER FOUND
How many nails have about the same mass as a bag of sand?		
How many wooden blocks have about the same mass as a bag of marbles?		
How many nuts and bolts have about the same mass as a bag of metal washers?		

Simple relations and mapping exercises. The following are exercises recommended for teaching mass measurement through the mapping of objects:

- *Student:* Use a two-pan balance to measure the mass of a banana or an apple.
- *Student:* Use a two-pan balance to measure the mass of each of the following:
  1. Wooden blocks
  2. Marbles
  3. Nuts and bolts
  4. Nails
  5. Golf balls
- *Student:* Map the results of the previous exercise.



Comparing an Object with a Standard Unit

The SI base unit for mass is the kilogram. Although it is important for children to gain an initial concept of the kilogram, children will find that smaller units are also needed. Since the common units are the kilogram,

gram, and milligram, a useful smaller unit would be the gram. The milligram should not be used until there is a need for it.

Language development exercises. All ordinary weighing instruments can be used to determine the mass of an object. On some weighing instruments, the known mass of one object is used to determine the unknown mass of another object. With a spring balance, differences in the force of gravity that may exist from place to place can be compensated for by adjusting the spring balance.

Since students will make determinations of mass and not the force of gravity, it would be incorrect to refer to the *masspieces* that are used with a two-pan balance as *weights*. It would also be incorrect to say, "The object weighs 5 kg." The correct statement would be, "The mass of the object is 5 kg."

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the masses of objects:

- *Student:* Fill a plastic freezer bag with one kilogram of sand. Make some estimates of those things that will have a mass of nearly one kilogram. Check your estimates.

OBJECT(S) ESTIMATED TO BE ONE KILOGRAM	LESS THAN ONE KILOGRAM	ABOUT ONE KILOGRAM	MORE THAN ONE KILOGRAM
5 Math books			X
Dictionary	X		
Milk carton filled with water		X	

- *Student:* What are the masses of the different parts of your body? Use the following to find out:

  1. Spring scale (25 kg capacity)
  2. Bathroom scale (metric)
  3. Piece of cloth for use as a sling

  Lie face up on the floor. Have a friend use the spring scale and the cloth sling to measure the mass of the following parts of your body:

  Head ______________ kg
  Arm ______________ kg

  Lie face down on the floor. Find the mass of one leg.

  Leg ______________ kg

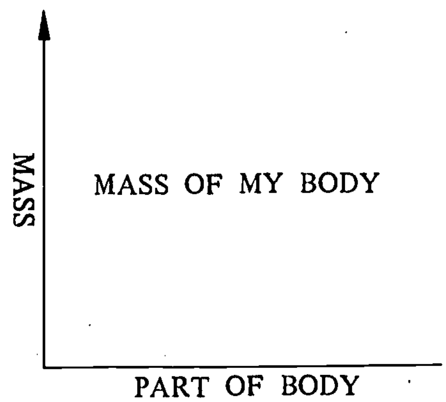
What is the mass of your entire body?

Whole body ____________ kg

What is the mass of your torso?

Torso ______________ kg

- *Student:* Make a bar graph to show how the parts of your body contribute to your total mass. Then write an interpretation of your graph.



- *Student:* Make a 10-gram masspiece with a plastic freezer bag and sand. Make a collection of objects that you think have a mass of 10 grams each. Compare on a two-pan balance each of the objects with your masspiece. Make a record of what you find.

OBJECT	LESS THAN 10 GRAMS	ABOUT 10 GRAMS	MORE THAN 10 GRAMS
Pencil	X		
Chalk		X	

Simple relations and mapping exercises. The following are exercises recommended for teaching mass measurement through the mapping of objects:

- *Student:* Use sand and plastic freezer bags to make the following masspieces: two 20-gram masspieces and one 30-gram masspiece. Using your masspieces, make some packages of dried beans that have the following masses:

MASS OF BEANS	MASSPIECES USED
30 g	___+ ___+ ___= ___
40 g	___+ ___+ ___= ___
50 g	___+ ___+ ___= ___
70 g	___+ ___+ ___= ___

- *Student:* Find a way to make a 10-gram package of beans using the masspieces from the previous exercise. Tell how you were able to find the mass of the beans.
- *Student:* Find the masses of 2 nickels, of 4 nickels, and of 6 nickels. Then complete the following chart:

NUMBER OF NICKELS		MASS
2	nickels have a mass of about	___
4	nickels have a mass of about	___
6	nickels have a mass of about	___
___	nickels have a mass of about	___
___	nickels have a mass of about	___
___	nickels have a mass of about	___
20	nickels have a mass of about	___

- *Student:* Can you predict how many nickels would have a mass of one kilogram?
- *Student:* How much would you receive if you could have the number of nickels that are equal to your mass?

Choosing Measurement Units for Specific Tasks

The most advanced measurement activities involve selecting measurement units and instruments for specific applications. In becoming adept in the selection and use of measurement instruments, children enhance their observation abilities.

Language development exercises. The concept of density might usefully be introduced in the upper elementary grades to further develop the child's concept of mass. However, many concrete experiences will be necessary before the child will be able to deal intuitively with the concept that *mass* = *density* X *volume.*

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the masses of objects:

- *Student:* Make a collection of very small objects: pins, paper clips, tacks, staples, coins, buttons, and so forth. Estimate which objects in your collection have a mass of about one gram. Check your estimations using a one-gram masspiece and a two-pan balance. Keep a record of what you found.

OBJECTS ESTIMATED TO HAVE A MASS OF ABOUT ONE GRAM	MASS LESS THAN ONE GRAM	MASS EXACTLY ONE GRAM	MASS MORE THAN ONE GRAM

- *Student:* Find items in the supermarket that have their mass stated in metric measure. Make a collection of some of these items. How truthful are the labels on the packages? Keep a record.

ITEM	MASS OF CONTENTS	NET MASS STATED ON LABEL	DIFFERENCE

Simple relations and mapping exercise. The following is an exercise recommended for teaching mass measurement through the mapping of objects:

- *Student:* Estimate the mass of each of the items listed in the following chart. Then measure their masses using an appropriate scale. Record each measure both in grams and kilograms.

ESTIMATE IN GRAMS	ITEM	MASS IN GRAMS	MASS IN KILOGRAMS
____________	Apple		
____________	Your own mass		
____________	Seven pennies		
____________	Egg		

Time Measurement Activities

Time is a very abstract concept. Children have difficulty with this concept because ideas about time tend to be introduced before children are able to understand the underlying relationships upon which time is based.

Making Direct Comparisons Between Objects

It is through rather unsophisticated classroom experiences with the notions of time that children will come to a more adequate conception of time. Since the temporal notions of young children are related to the present rather than to the past or future, instruction should begin with the "here and now." Two abilities that should be developed are (1) the ability to understand that events have a definite order; and (2) the ability to relate events that occur at differing rates to a time interval.

Language development exercises. Observing how events are ordered can be stimulating and challenging to an elementary schoolchild. Such terms as "before," "after," and "same time" are useful in describing how events are ordered. Also, numerical-order terms such as "first," "second," and "third" help to establish the sequence of events. However, the use of terms such as "quicker" or "slower" should, at least in the earlier grades, be limited to situations in which events can be simultaneously compared. Later, children more readily learn to use an interval of time to compare events that do not occur simultaneously.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of events that occur within the same time period:

- *Student:* Do the following activities with a friend. Be sure to begin at the same time so things are fair.

  1. Write your name.
     Who was quicker? ____________
     Who was slower? ____________
  2. Take your shoe off; put it back on and tie it.
     Who was quicker? ____________
     Who was slower? ____________
  3. Make a tower with eight blocks.
     Who was quicker? ____________
     Who was slower? ____________
  4. String ten wooden beads.
     Who was quicker? ____________
     Who was slower? ____________

Ordering exercises. The following are exercises recommended for the development of the concept of time and order:

- *Teacher:* Make a book with the title *A Day in My Life.* After a child draws pictures illustrating each of the following chapters, print the "story" the child dictates about each drawing:

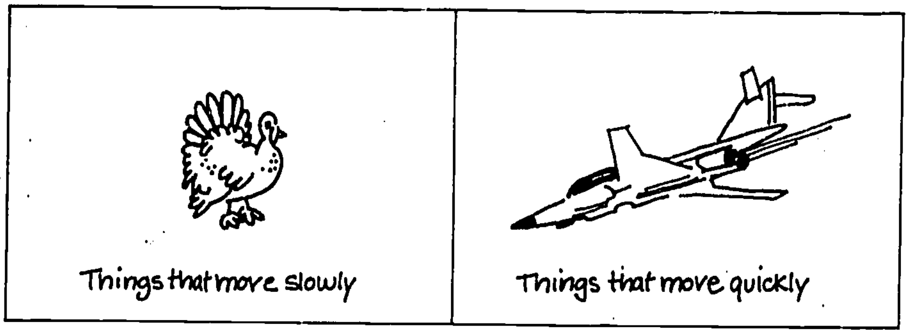
  1. In the morning
  2. Before lunch
  3. After lunch
  4. At night

- *Teacher:* Place five hooks along a wall on which objects can be hung. Give children instructions using the terms "before," "after," "first," "second," "third," and so on. For example, if objects that are on the hooks are a ruler, notebook, pencil, cup, and hat, then the instructor might give the following directions:

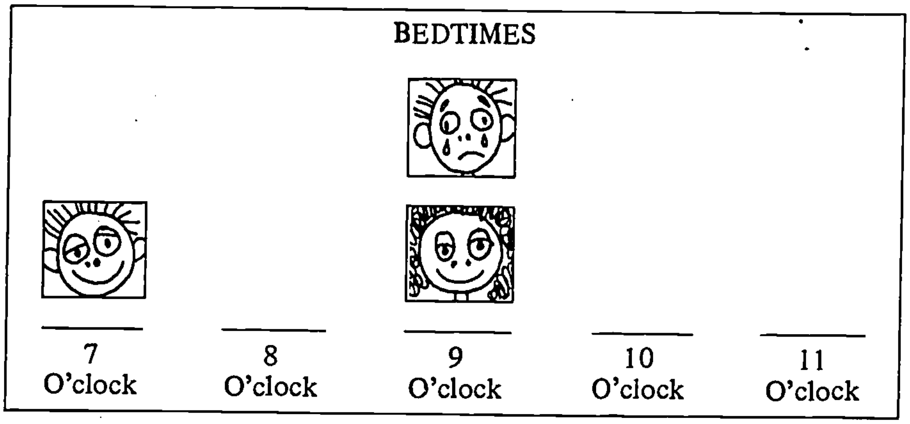
  1. Take the object that comes after the cup.
  2. Give the third object to the child whose turn came before yours.
  3. Take all of the objects and put them back in the right order.

Pictorial representation exercises. The following are exercises recommended for teaching time measurement by using pictures and graphs:

- *Student:* Find some pictures in magazines and arrange the pictures on a large piece of paper. Compare the subjects that move slowly and that move quickly.



- *Teacher:* Make a chart listing possible bedtimes. Have children draw pictures showing how they look at bedtime.



- *Teacher:* Discuss the following questions with the children:
  1. How many children go to bed before nine o'clock?
  2. How many children go to bed after eight o'clock?
  3. At what time do most children go to bed?
  4. At what time do the fewest children go to bed?
  5. How many children go to bed before you do?
  6. How many children go to bed after you do?

Comparing an Object with a Nonstandard Unit

Time has been marked in many ways by man prior to the invention of the modern clock. It is useful for children to explore the ways man has marked time. Through these activities, children will develop concepts about the measure of time.

Language development exercises. Terms such as "faster than" or "slower than" are based on the rates of doing things. To make these types of comparisons, a child must develop the concept of time intervals.

Children find the need to rely on a common time interval when events that are to be compared do not begin together. Many ways can be used to measure a time interval. Probably the most common way that children measure time is through counting. For example, in the game of hide-and-seek, counting by ones or fives is used to mark time. The ability to use numbers in a cardinal sense is closely related to the ability to conceptualize a time interval.

Estimation exercises. As in other measurement activities, estimation should be used to aid the child in conceptualizing units of time. Since the concept of a time interval can be extraordinarily difficult for a child, the teacher should not force children to make estimations of long time intervals.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of periods of time:

- *Student:* Make a salt timer. Ask your teacher to help you. You will need these materials:

  1. Salt
  2. Two large plastic pill bottles from a drugstore
  3. Paper punch
  4. Construction paper
  5. Masking tape
  6. Scissors

  Cut a paper circle the same size as the pill bottles. Punch a hole in the center of the circle. Fill one of the bottles a little more than half full of salt. Tape the bottles together at their mouths with the paper circle sandwiched between. Then do the following:

  1. Let the salt run through your timer. Why does some of the salt not run through?
  2. How far do you think you can count before the salt stops running? How far did you count?
  3. Can you bounce a ball or jump a rope and not make a mistake until the salt stops running?
  4. How many different things can you do before the salt stops running?

- *Student:* Make a water clock. Here are some materials you will need:

  1. Small disposable drinking cup
  2. Clay
  3. Small bucket

  Put some clay in the bottom of the drinking cup. Fill the bucket with water. Will the cup float in the water? If the cup floats, have your teacher burn a hole with a hot pin in the side of the cup above the clay. Then do the following:

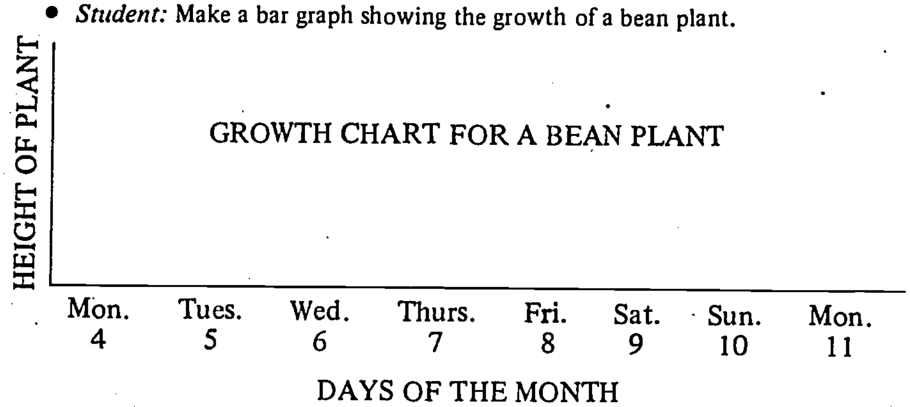
1. Compare your water timer with your classmates'. Do all of the cups sink at the same time?
2. Discuss with your teacher what you found.
3. Guess how far you can count before your cup sinks. How far did you count? Was your guess correct?
4. How many times can you walk around the room before your cup sinks?
5. Make a list of the things you can do before your cup sinks.

- *Student:* Adjust a metronome so that it moves slowly. Find someone who will mark time for you. Take turns doing things. Keep a record.

TASK	TIME (NUMBER OF TICKS)	WHO WAS FASTER?
Clean your desk.	___ ________ (Name) ___ ________ (Name)	
Dribble a ball along a path.	___ ________ ___ ________	
Have a walking race (5 ticks of the timer).	___ ________ ___ ________	

Pictorial representation exercise. The following is an exercise recommended for teaching time measurement by using a graphing activity:

- *Student:* Make a bar graph showing the growth of a bean plant.



Comparing an Object with a Standard Unit

Methods for measuring standard units of time usually involve the use of some type of clock. To use a clock, a child needs to know how it is read and to have some concept of the time intervals that the clock measures.

Language development exercises. Learning to read the face of a clock is a skill that requires a considerable amount of practice. In light of research on telling time, children should first learn to tell time by the minute. Before a child can successfully tell time, the child must be able to count by ones to 60 at a quick, even pace, and the child must understand the relationship that exists between the minute and hour hands of the clock. After these concepts are mastered, a child can then learn to read to the nearest minute after the hour.

When the minute hand of a clock is at 12, a child should learn to say "o'clock." Since the metric symbols (abbreviations) used for time intervals differ from those used in the past, children should learn the new symbols:

1. Second (s)
2. Minute (min)
3. Hour (h)

Simple matching and comparison exercises. The following are exercises recommended for the development of concepts related to standard time periods:

- *Student:* Use a stopwatch or a watch with a second hand to determine the number of seconds it takes to do the following:

ACTIVITY	ESTIMATED TIME	ACTUAL TIME
Say your first and last names.		
Count backwards from ten to zero.		
Bounce a ball five times.		

- *Student:* Use a watch with a second hand to do the following activities:
  1. How many times do you breathe in one minute?
  2. How many times can you write your name in one minute?
  3. What are some things you can do that take about one minute?
- *Student:* Make a pendulum with a piece of string and a washer. Place the string through the notched end of a tongue depressor, allowing the washer to swing freely. Then do the following:

1. How can you speed up or slow down the back-and-forth movements of the pendulum?
2. Will the increasing mass of the washer change the speed of the swing?
3. See if you can make your pendulum so that it takes one second for it to make one complete back-and-forth motion.
4. Can you predict what the length of the pendulum string will be that takes two seconds to make a complete swing?

Simple relations and mapping exercise. The following is an exercise recommended for teaching time relations:

- *Teacher:* Take the minute hand off an alarm clock. See if children can estimate the position of the minute hand during different times of the day (before recess, lunchtime, and so forth). Give each child mimeographed copies of clock faces on which to record their estimates.

Choosing Measurement Units for Specific Tasks

Activities in this section deal with more complicated uses of time. In problems in which a time rate is measured, children will learn how a unit of time is combined with another unit to express a rate of time.

Simple matching and comparison exercises. The following are exercises recommended for the refining of time observations:

- *Student:* How accurate is a sand timer? Use a three-minute sand timer to complete the following chart:

TRIALS	TIME (SECONDS)
1.	________
2.	________
3.	________
4.	________
5.	________
6.	________
7.	________
8.	________
AVERAGE TIME	________

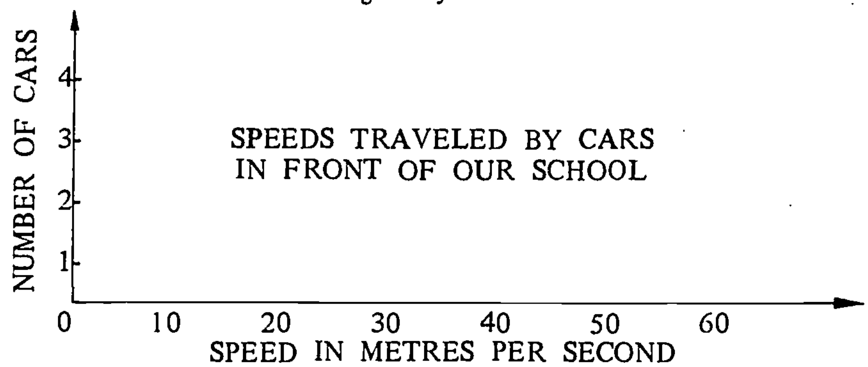
- *Student:* While watching your favorite TV program, determine how much time is taken by commercials and other interruptions. Do some programs have more interruptions than others? Report what you find to your class.

Simple relations and mapping exercises. The following are exercises recommended for developing concepts about the measurement of time rates:

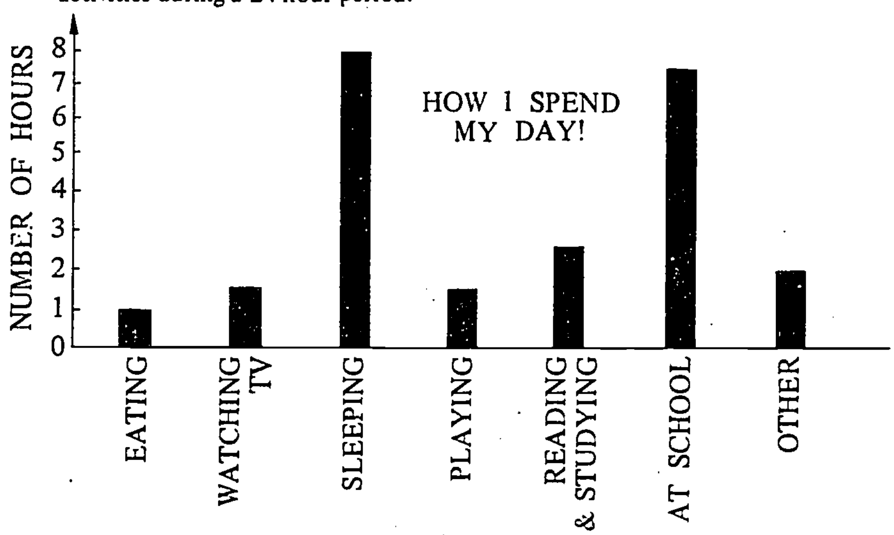
- *Student:* How many words a minute can you read? To find out, read a page in one of your books. Time yourself. Count the number of words on the page, and then determine the number of words you read in the minute.
- *Student:* Do you have any leaky faucets? Find out how many litres of water can be lost during one year by finding the rate at which water is lost in one hour.

Pictorial representation exercises. The following are exercises recommended for teaching time measurement through graphs and charts:

- *Student:* How fast do cars travel in front of your school? To calculate this, mark a distance of 100 metres. Determine the number of seconds it takes a car to travel the distance. Then calculate the speed of each car in metres per second. Make a chart showing what you found.



- *Student:* Make a bar graph showing how much time you spend doing different activities during a 24-hour period.



Temperature Measurement Activities

Children have many experiences with hot and cold objects. At an early age, they learn to avoid objects associated with extreme heat. However, a child normally has little need to refine his observations, which classify things simply as hot or cold. Refinement will occur only when the child compares materials that differ slightly in temperature.

Comparing an Object with a Nonstandard Unit

Temperature comparisons can be made by touch; however, slight differences in temperature can be detected only through the use of an instrument that is heat sensitive. Teachers will find it instructive for children to use simple devices that show temperature differences.

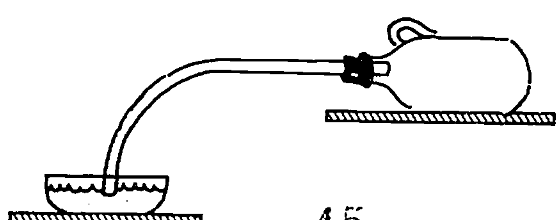
Language development exercises. Words such as "hot," "cool," "warm," and "cold" are part of the adult's everyday vocabulary; children learn to use these words by imitation. Since words like "hot" tend to be used in an absolute rather than a relative sense, experience will be necessary before the child learns that the common terms describing heat are imprecise descriptions.

Since a child encounters many changes in the temperatures in the environment, language experience techniques can be used by the teacher to focus the child's attention on relevant aspects of the environment. For example, children can be encouraged to discuss the weather; following such a discussion, language-experience techniques can be used to help children symbolize their experience.

When heat energy acts on a thermometer, the heat causes the material inside the thermometer to expand. Children should understand how a thermometer works. Preliminary experience with expansion and contraction of liquids, gases, and solids should therefore be undertaken. Terms such as "expansion" and "contraction" should be introduced while the phenomena are being observed.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the temperatures of objects:

- *Student:* Make a list of things that feel cool or warm in the room. Why do you think that some of the things you touched felt warm and others felt cool?
- *Student:* Make a simple air thermometer. Use a large jug with some clear plastic tubing. Connect the tubing to the jug and place one end of the tubing in a pan of water.



Warm the air in the jug and let the water rise in the tube as it cools. Now you are ready for the following exercises:

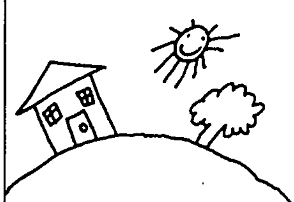
1. Make a temperature scale for your thermometer. You may wish to mark spots on the tubing such as:
   a. Cold day
   b. Cool room
   c. Warm room
   d. Hot day
2. Can you think of other ways to make a simple thermometer?

Ordering exercises. The following is an exercise recommended for teaching temperature measurement by arranging objects according to temperature:

- *Teacher:* Using a series of pictures mounted on a tagboard, see if children can arrange the pictures in order from hot to cold using visual clues.

Pictorial representation exercises. The following are exercises recommended for teaching temperature measurement by observing pictures:

- *Teacher:* Find pictures that show hot and cold objects. Make a picture display of those items that are hot and those that are cold. Encourage children to discuss how they determine what pictures go together.
- *Teacher:* Make a linear calendar on a ruled piece of butcher paper. Let children take turns drawing the weather conditions on the calendar. Each picture can be accomplished with one of the following labels: cold, warm, cool, and hot.

WARM  Monday April 1	Tuesday April 2	Wednesday April 3

Comparing an Object with a Standard Unit

After a child has had an opportunity to use nonstandard devices, he or she will have some idea how the Celsius thermometer works. Once the child automatically equates certain temperature readings with some physical event (e.g., 0° C is the freezing point of water, 20° C is the temperature of a pleasant day, and 37° C is the temperature of the human body), then the Celsius thermometer can be used as a tool for investigations.

Simple matching and comparison exercises. The following are exercises recommended for the comparison of the temperatures of objects:

- *Student:* Use an uncalibrated thermometer to establish 0°C and 100°C. *(Teacher: Children should use ice and boiling water to establish these points.)* Make marks every ten degrees on the thermometer. How well can you read your thermometer? Make a record of your temperature readings.

MEASUREMENT	EXPERIMENTAL THERMOMETER	CALIBRATED THERMOMETER
Body temperature		
Room temperature		
Temperature in direct sunlight		

- *Student:* How cold is an ice cube? Is an ice cube colder on the inside than on the outside?
- *Student:* When salt is adu . d to ice, the temperature will drop. Can you find out how much the temperature will drop?
- *Student:* What other substances can be added to ice to make the temperature suddenly fall or rise?

Pictorial representation exercises. The following are exercises recommended for teaching temperature measurement by observing pictures:

- *Student:* What is the hottest part of the day? Make a bar chart showing the temperature at different times during the day.
- *Student:* Collect some squares of cloth. Find out if the color of the cloth noticeably affects the amount of heat that is absorbed by the cloth. Make a chart to display your results.

Selected References

Biggs, Edith E. *Mathematics for Younger Children.* New York: Scholastic Book Services, 1971.

Biggs, Edith E., and James R. MacLean. *Freedom to Learn: An Active Learning Approach to Mathematics.* Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1969.

The Concepts Mass and Weight. MP4. Pretoria, South Africa: South African Bureau of Standards, 1971.

Copeland, Richard W. *Diagnostic and Learning Activities in Mathematics for Children.* New York: Macmillan, Inc., 1974.

Copeland, Richard W. *How Children Learn Mathematics: Teaching Implications of Piaget's Research.* New York: Macmillan, Inc., 1970.

Flavell, John H. *The Developmental Psychology of Jean Piaget.* New York: D. Van Nostrand Co., 1963.

Fletcher, Harold. *Mathematics for Schools.* Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1970.

Goldstein, Marc. *Your Body: Living and Measuring.* New York: Penguin Books, Inc., 1972.

Hyde, D. M. G. *Piaget and Conceptual Development.* New York: Holt, Rinehart, and Winston, Inc., 1972.

Inhelder, Barbel, and Jean Piaget. *The Early Growth of Logic in the Child.* New York: W. W. Norton and Co., Inc., 1969.

The International System of Units (SI). National Bureau of Standards Special Publication 330. Washington, D.C.: U.S. Department of Commerce, 1972.

Lovell, Kenneth. "Concepts in Mathematics," in *Analyses of Concept Learning.* Edited by Herbert J. Klausmeier and Chester W. Harris. New York: Academic Press, Inc., 1966, pp. 207–22.

Lovell, Kenneth. *The Growth of Understanding in Mathematics: Kindergarten Through Grade Three.* New York: Holt, Rinehart, and Winston, Inc., 1971.

Marsh, L. G. *Teacher's Guide: Children Explore Mathematics.* New York: Arco Publishing Co., Inc., 1967.

Nuffield Foundation Mathematics Project. *Beginnings.* New York: John Wiley and Sons, Inc., 1967.

Nuffield Foundation Mathematics Project. *Mathematics: The First Three Years.* New York: John Wiley and Sons, Inc., 1972.

Phillips, John L., Jr. *The Origins of Intellect: Piaget's Theory.* San Francisco: W.H. Freeman and Co., 1969.

Piaget, Jean. *Science of Education and the Psychology of the Child.* New York: The Viking Press, Inc., 1970.

The Royal Society. *Metric Units in Primary Schools.* London: University Printing House, 1969.

Schools Council. *Mathematics in Primary Schools: Curriculum Bulletin No. 1.* London: Her Majesty's Stationery Office, 1969.

Schools Council. *Metres, Litres, and Grams: Introducing Metrication in the Primary School.* New York: Scholastic Book Services, 1971.

Sinclair, Hermine. "Number and Measurement," in *Piagetian Cognitive-Development Research and Mathematical Education.* Edited by Myron F. Rosskopf, Leslie P. Steffe, and Stanley Taback. Washington, D.C.: National Council of Teachers of Mathematics, 1971, pp. 149–59.

Sohns, Marvin L. "A Comparison Between Certain Piagetian Logical Thinking Tasks and the Subtraction Ability of First, Second, and Third Grade Children." Unpublished dissertation. Stockton, Calif.: University of the Pacific, 1973.

Thyer, Maggs. *Teaching Mathematics to Young Children.* New York: Holt, Rinehart, and Winston, Inc., 1971.

To the Householder: Metric Conversion and You. Melbourne, Australia: Metric Conversion Board, 1972.

U.S. Metric Study Interim Report: Education. National Bureau of Standards Special Publication 345–6. Washington, D.C.: U.S. Department of Commerce, 1971.

Willbrook. *Discovery Mathematics for Top Infants and Lower Juniors.* Essex, England: Educational Supply Association Limited, 1968.

Williams, Elizabeth, and Hilary Shuard. *Elementary Mathematics Today: A Resource for Teachers, Grades 1–8.* Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1972.

87920—300 Reprint 6/75 10M OSP

74-17 (Reprint) 03-1062 300 5-75 10M

Model Measurement Program

Stage of measure/process	Quantity	K	1	2	3	4	5	6	7	8
Making direct comparisons between objects Language development Estimation Simple matching and comparison Ordering Simple relations and mapping Pictorial representation	Length									
	Mass									
	Volume/capacity									
	Time									
	Area									
Comparing an object with a nonstandard unit (including parts of the body) Language development Estimation Simple matching and comparison Ordering Simple relations and mapping Pictorial representation	Length									
	Mass									
	Volume/capacity									
	Time									
	Area									
	Temperature									
Comparing an object with a standard unit (SI) Language development Estimation Simple matching and comparison Ordering Simple relations and mapping Pictorial representation	Length									
	Mass									
	Volume*/capacity							v^1		
	Time									
	Area									
	Temperature									
Choosing measurement units for specific tasks Language development Estimation Simple matching and comparison Ordering Simple relations and mapping Pictorial representation	Length									
	Mass									
	Volume*/capacity									v^2
	Time									
	Area									

* Solid volume (v^1) and displaced volume (v^2)