DOCUMENT RESUME

ED 113 166 SE 019 670

TITLE Measurement with Metric. A Resource Handbook. Field Test Version.
INSTITUTION Oregon State Dept. of Education, Salem.
PUB DATE 75
NOTE 48p.; occasional marginal legibility
AVAILABLE FROM Documents Clerk, Oregon Department of Education, 942 Lancaster Drive, N.E., Salem, Oregon 97310

EDRS PRICE MF-$0.76 HC-$1.95 Plus Postage
DESCRIPTORS Activity Learning; Higher Education; Instructional Materials; Laboratory Procedures; *Mathematics Education; *Measurement; *Metric System; State Departments of Education; *Teacher Education; Teaching Guides; *Teaching Methods

ABSTRACT

This handbook, prepared in field-test version, is intended to provide in-service teachers with "guidance in the development of the basic concepts of measurement." The basic assumption on which this guidance is based is that "hands-on" experience is the most appropriate method of teaching metric measurement. An additional premise is that students should learn to think in the metric system, and not to convert from the English to the metric system. The handbook is divided into five sections. After the rationale for teaching the metric system is presented in part one, a variety of activities for teachers' use in developing pre-measurement and measurement skills is described in part two. Section three is designed to aid in the planning and conducting of metric workshops, and section four, on implementation, describes materials needed. A glossary of terms and a bibliography comprise section five. (SD)

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MEASUREMENT WITH METRIC

Field Test Version

A RESOURCE HANDBOOK

Measurement...with metric

A Resource Handbook

Produced by:

Oregon State Department of Education

Mr. Jesse Fasold, Superintendent of Public Instruction

SDE Metric Coordination Committee

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Developed Cooperatively by:

Basic Education Section
Vocational Education Section

August, 1974

FOREWORD

Dear Educator:

A changeover to the metric system appears to be inevitable in the United States. The International System of Measurement Units (SI) is a language that most of the world is already using. The transition is necessary in order to maintain our nation's competitive position in world trade. In fact, many businesses and several industries are already using the metric system to manufacture or measure their products. Others are developing plans for the changeover, or for new facilities for metric-based production. The metric system also offers several advantages to the educational process. It is a decimal system compatible with the U. S. monetary and base ten numeration systems. Furthermore, the units of length, mass, area and volume are interrelated and therefore easy to learn.

In response to projected needs of Oregon's students and the adult community, the Oregon State Board of Education has adopted a resolution directing the State Department of Education to develop plans for the changeover to the Metric System of Measurement as the primary system of measurement in Oregon schools, to be completely phased in by 1983. The guidelines for the new Oregon school graduation requirements included the recommended metric measures (SI) in the Personal Development Section under "Computational Skills." "Measurement with Metric" has been prepared to serve as a guide for anyone planning to conduct metric education workshops for teachers, or for the general public. Suggestions to teachers include measurement learning theory, technical information about the metric system, and many sample measurement diagnostic-learning activities.

An ad hoc metric advisory committee, consisting of representatives of industry, teachers, and administrators has provided valuable assistance in developing plans for metrication in Oregon. A "Measurement with Metric" work conference on May 2, 1974, was attended by professional educators representing kindergarten through university in several disciplines, as well as leaders of business, industry, and others. The conferees provided the basic philosophy for the handbook. We are indebted to both groups for their contribution in developing plans for assisting Oregon schools in making the transition to metric measurement.

For additional copies of this field test version of "Measurement with Metric," or for assistance in organizing workshops on metric measurement, please contact the Metric Coordination Committee (Ray Thiess, Don Fineran and Ralph Little) at the State Department of Education.

Jesse Fasold
Superintendent
Public Instruction

JF:lb

PREFACE

PURPOSE

This handbook for "Measurement with Metric" presents one approach to the teaching of the metric system. It is designed to provide guidance in the development of the basic concepts of measurement. The approach will lead to and include the use of the metric system.

BASIC PREMISE.

A basic premise of this handbook is that concrete experiences—the "hands-on" approach—is the best way to learn measurement. The "hands-on" activities are to be child-centered experiences that recognize the level of competence (readiness) of each learner and build upon and expand that competence. The use of appropriate experiences will gradually guide the learner to the discovery of measurement concepts while at the same time exciting the learner's interest and enthusiasm.

OVERVIEW

The first section of this handbook explains the rationale for adopting the metric system and the philosophy on which the suggested approach to teaching metric is based.

The second section offers a variety of activities for the instructor to use. These activities may be used to diagnose the learner's understanding of pre-measurement skills and measurement concepts of length, mass, area, volume and temperature.

The third section is designed to aid an instructor in planning and conducting workshops for teaching the metric system.

Section four, Implementation Decisions, includes information about the materials needed to implement a decision to "go metric." Minimum materials needed, their cost, the appropriateness of the materials and the use of homemade materials are considered. The preparation of teachers through in-service sessions is also discussed.

A glossary of measurement terms is given in Section Five, and Section Six provides a bibliography of sources referred to throughout this handbook.

ACKNOWLEDGEMENTS

The State Department of Education Metric Coordination Committee wishes to express its appreciation for the aid and advice received during the preparation of this handbook to the following:

1. Conferees of the "Measurement With Metric Conference" hosted by Linn-Benton Community College on May 2, 1974. *This was the "grassroots" input from individuals from business, industry, education and the lay public;*
2. Sub-group chairpersons at the May 2 conference;
3. State Department of Education Ad Hoc Metric Education Committee;
4. Mr. Jesse Fasold, State Superintendent of Public Instruction,
   Mr. Leonard Kunzman, Associate Superintendent, Instructional Programs,
   Mr. Monty Multanen, Director, Career Programs,
   Mr. Maurice D. Burchfield, Director of Basic Education,
   and others at the State Department of Education;
5. State Board of Education for their affirmative action in adopting a metric conversion policy;
6. State Textbook Commission for their endorsement of the State Board's metric conversion policy statement as it applies to textbook selection criteria;
7. Mrs. Marjorie Covey who served as conference reporter and assisted in development of the handbook;

8. Jerald R. Brown, Publications Editor, and George Sample, Graphic Artist, both of the SDE Publications Staff;

9. Numerous contributors of metric information articles from both in-state and out-of-state.

SDE Metric Coordination Staff Committee
Ray Thiess (Chairman), Specialist, Science Education
Don Fineran, Specialist, Math Education
Ralph Little, Specialist, Construction/Metals
July, 1974

THE RATIONALE AND A PHILOSOPHY FOR MEASURING WITH METRIC

RATIONALE

It is a fact that the metric system is coming to the United States. The present concern is whether it will come in a haphazard manner, by bits and pieces, or if it will be implemented in an organized manner. The adoption of the metric system in the United States can be justified by the external advantages and the internal advantages of the system.

EXTERNAL ADVANTAGES

Some of the external advantages of using the metric system are:

1. International trade and business talk the same measurement language.
2. The United States is the only major trading nation not now using or converting to the metric system as its primary measurement system.
3. Major industries in the United States are rapidly expanding their use of metric measurement.
4. More than 85% of surveyed businesses and industries in Oregon support conversion to the metric system. The favorable attitudes of Oregon businessmen were evident in their survey responses even though they recognized that increased costs would sometimes be incurred.
5. In Oregon the State Board of Education is committed to a ten-year conversion period. On June 6, 1974, they adopted a resolution that calls for a plan and procedure for conversion to the metric system in all phases of public school operation in Oregon by 1983; and that criteria for the selection of textbooks in November 1976 include metric measurement as the primary system of measurement.
6. The Oregon State Textbook Commission has endorsed the State Board's resolution.
7. Oregon school districts are preparing graduation requirements that include metric understanding and usage.

INTERNAL ADVANTAGES

The internal advantages of the metric system are:

1. The metric system is developed on the same base ten system as our numeration system.
2. The units of metric measurement are a logical system with larger units formed by using a multiple of 10 of the preceding unit.
3. The simplicity of metrics is demonstrated by the convenience of our monetary system which has the same decimal base as the metric system.
4. All metric measurement units for mass, area and volume are based on metric units of length. The interrelationships among metric units promote easier understanding and comprehension of measurement concepts than the customary nonrelated measurements we now use.

COST OF CONVERSION

The cost to public school districts can be kept to a minimum. It is recommended that textbooks using metric measurement as a primary system of measurement be adopted in the normal pattern of textbook adoption. Additional supplies for teaching metric measurements can be minimal. Many instruments, such as meter sticks and centimeter sticks and balances are already available in the school's science supplies. Other materials can be homemade. Homemade learning tools are inexpensive, and making them can serve as an effective learning activity.

EXPECTATIONS OF THE CHANGEOVER PERIOD

During the years of transition from our customary system to the metric system, the rate of changeover will vary in different sectors of society. Some competence with both systems will be needed during this period. Probably the most efficient way to handle the transition will be to have two *separate* systems of measurement. The advantage of having separate systems is that all students will learn to THINK METRIC. People should not be encouraged to rely on mental conversions between systems, as this may hinder rather than facilitate the adoption of a new system. However, some general comparisons will be helpful.

SUGGESTED SCHOOL POLICY

Children in the primary grades should learn basic measurement concepts with metric units used as standard measurement units. Children now in the upper elementary grades may be taught the metric system as the *primary* system of measurement.

TEACHERS AND COMMUNITY

Those teachers with expertise in teaching measurement are encouraged to share their knowledge with others to help them become familiar with the metric measurement system. They also can be of great service by helping the adult community learn the metric system as well as the entire vocational—technical community.

PHILOSOPHY

The method for teaching measurement with metric suggested in this handbook—the CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH—and the premise that concrete experiences ("hands-on") is the best way to teach measurement draws heavily on the learning theories of Jean Piaget, Barbel Inhelaer, Richard Copeland, Robert Karplus, Herbert Thier and others. In the booklet "Diagnostic Learning Activities in Mathematics for Children," Copeland reviews Piaget's learning theories and points out teaching implications. He then states:

> "... This knowledge develops in stages and is largely an internal process. It is not an acquired knowledge in the sense so many think of, the familiar stimulus-response sequence. This places the problem of 'teaching' logico-mathematical knowledge in a whole new context. Johnny may not be able to learn certain ideas regardless of how he is stimulated until a certain point in time when he has the necessary mental structures ... Another important function of the teacher is to provide an environment which allows the child to explore physically the objects around him."

Karplus and Thier in "A New Look at Elementary School Science" refer to Piaget in the following passage:

> "This school of thought has two related central ideas: (1) Children's intellectual capacity passes through a number of qualitatively contrasting stages before adulthood, and (2) a child's interaction with his environment plays a very significant role in his transition from one state to the next."

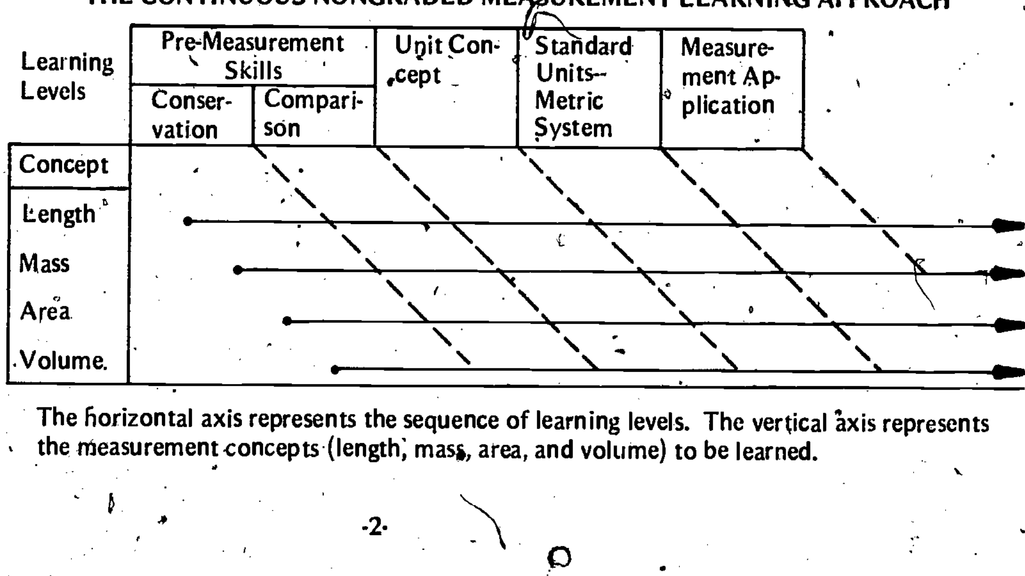
It is in this spirit that the strategies in this handbook are offered.

Teachers are encouraged to adopt programs based on both the basic concepts students need and the student's present level of readiness by using the CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH. This learning approach is nongraded because students can begin with concepts at whatever level they are ready for and then continue through subsequent learning levels in an orderly sequence. Because the background experience of each child gives him a varied amount of knowledge in different measurement concepts, it is important for the teacher to discover and build upon the student's knowledge, choosing activities appropriate to each student in each measurement concept. Activities presented in the second section may be used as diagnostic tools and/or as learning experiences.

MEASUREMENT LEARNING CHART

The following chart illustrates the nature of the CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH. It presents four major measurement concepts: length, mass, area and volume. A fifth concept, temperature, will be dealt with briefly later. The measurement concepts of time, money, and angles also should be learned. However, since these concepts are not directly related to the metric system, they are not presented in this handbook.

THE CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH

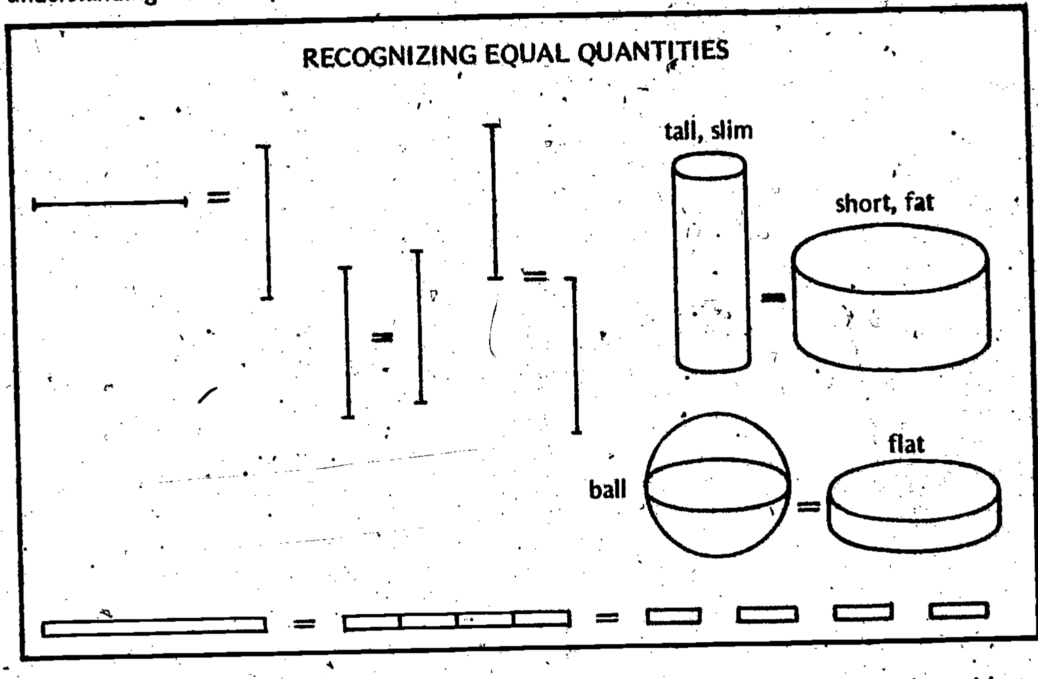


The horizontal axis represents the sequence of learning levels. The vertical axis represents the measurement concepts (length, mass, area, and volume) to be learned.

The concept of length should be introduced first, because all other measurement concepts are based on length. However, students do not need to master all learning levels in length before being introduced to mass, area and volume. Many learning activities can involve two or more concepts. The activities will often lead to student progress, represented horizontally and vertically across the chart. Students begin with the development of the premeasurement skills, progressing to the nonstandard and standard measurement learning levels. The student may progress at his own learning rate through the five levels of measurement. Individual learners may be at different learning levels for each of the measurement concepts at any given time.

PRE-MEASUREMENT SKILLS: CONSERVATION

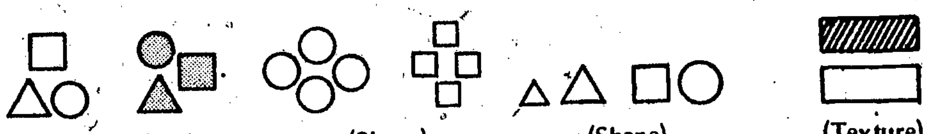
The principle of conservation (constancy) of quantity states that length, mass, area and volume do not change under deformation, rearrangement or partitioning. This is a relatively advanced concept. It takes many "hands-on" experiences using manipulative materials before conservation of quantity is fully comprehended. Indeed, leading learning theorists generally agree that understanding this concept involves several stages of intellectual development.



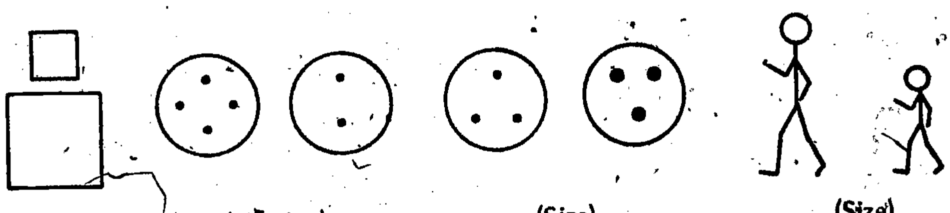
COMPARISON

Measurement is a way of describing things, usually by comparing them to other objects. Recognizing similarities and differences between and among objects is the foundation on which unit measurement is built. Simple comparison begins at a very early age and grows increasingly complex as learners develop skill in this area. Comparing and estimating can be related. One approach would have a child estimate and then verify the estimations by making actual comparisons of concrete objects.

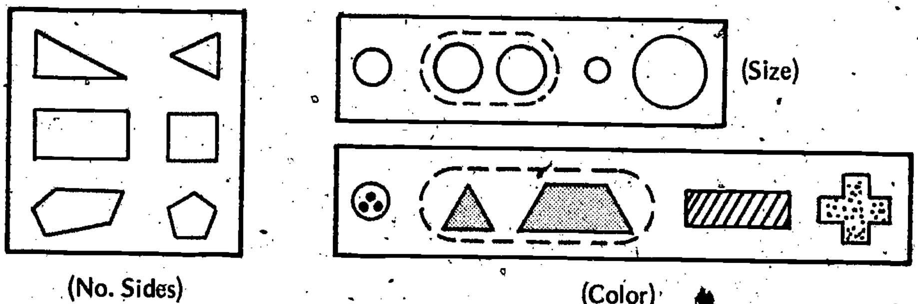
- Qualitative Comparison: identifying similar objects by one or more properties; color, shape, texture, prettiness, hardness, flexibility, etc.



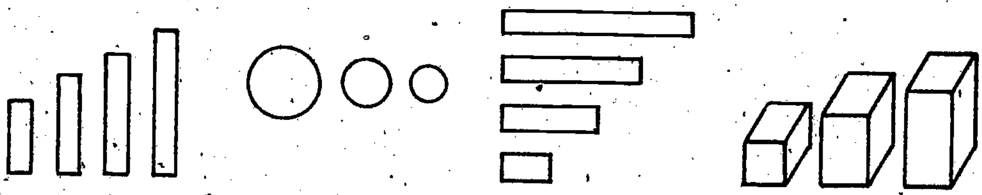
- Quantitative Comparison: recognizing objects that are larger, smaller, shorter, longer, etc.



- Matching: recognizing objects that are the same in number, color, size, shape, texture, weight, etc.



- Ordering: being able to arrange various sized objects in order from the shortest to longest, largest to smallest, lightest to heaviest, etc.



MEASUREMENT SKILLS: UNIT CONCEPT

The skills and understandings of the first two learning levels can be considered measurement readiness. Upon acquiring competence at the first two levels, the learner is ready to experience activities designed to guide him to discovering the need for "units"; i.e., the repeated use of the same quantity for purposes of comparing a second and third quantity. The learner will find that while comparison was done with the unaided senses, he now needs more sophisticated means of measurement to supplement his senses. Thus, the learner will be led to choose arbitrary units of measurement and also appropriate measuring instruments.

- Start with the use of nonstandard units, such as paper clips (large size), pencils, books, sticks, straws, floor tiles, fingers, hands, etc.

INSTRUMENT DEVELOPMENT

Experiences with a variety of measuring instruments (all nonstandard) will demonstrate that:

1. Objects can be measured in a variety of ways.
2. Efficiency in measuring comes from choosing an instrument appropriate to the object to be measured.
3. Some instruments provide a more accurate measure than others.
4. Units of various sizes are needed (e.g., paper clip units are satisfactory for measuring short distances, but not so good for longer distances).

STANDARD UNITS

Understandings acquired at levels 1, 2, and 3 provide the prerequisite foundation from which the learner will discover the need for standard units, not only to obtain *consistent results*, but also in order to *communicate* his findings with others.

- Estimation and verification of estimates with the nonstandard units (and later with metric units) should be emphasized. Such experience brings the learner to think in terms of appropriately sized units, instruments and the reasonableness of his results.

INTRODUCTION OF METRIC SYSTEM

Having discovered the need for standard units, the learner is ready to meet the metric system. Here the teacher can develop the logic of a measurement system based on ten that will correspond with our numeration system as well as our monetary system.

- Metric units of length are the basis from which units of mass, area and volume are derived. Therefore, units of length should be introduced first, with various prefixes being introduced as they are needed.

- However, for purposes of continuity and completeness, and also for illustrating the base ten nature of the metric system, students need some work with all six common prefixes. The *logic of the complete system* must be developed, even though only the commonly used prefixes will be stressed.

METRIC CHART

The following Metric Chart is presented here for several reasons: (1) to show the logic of the metric system, (2) to show the origin of prefixes, (3) to show the accepted written symbols, and (4) to emphasize the units that are commonly used.

The units in boldface type are those that will be learned early and used most often. Note that there are only four commonly used units of length, two of volume and three of mass.

METRIC CHART

Base Unit	Added Latin Prefix	Added Greek Prefix	Results	Written	Written	Commonly Used
meter*	milli		millimeter	0.001 m	1 mm	Yes
meter	centi		centimeter	0.01 m	1 cm	Yes
meter	deci		decimeter	0.1 m	1 dm	No
meter			meter	m	m	Yes
meter		deka (deca)	dekameter	10 m	1 dam	No
meter		hecto	hectometer	100 m	1 hm	No
meter		kilo	kilometer	1000 m	1 km	Yes
liter*	milli		milliliter	0.001 *l*	1 m*l*	Yes
liter	centi		centiliter	0.01 *l*	1 c*l*	No
liter	deci		deciliter	0.1 *l*	1 d*l*	No
liter			liter	*l*	*l*	Yes
liter		deka (deca)	dekaliter	10 *l*	1 da*l*	No
liter		hecto	hectoliter	100 *l*	1 h*l*	No
liter		kilo	kiloliter	1000 *l*	1 k*l*	No
gram*	milli		milligram	0.001 g	1 mg	Yes
gram	centi		centigram	0.01 g	1 cg	No
gram	deci		decigram	0.1 g	1 dg	No
gram			gram	g	g	Yes
gram		deka (deca)	dekagram	10 g	1 dag	No
gram		hecto	hectogram	100 g	1 hg	No
kilogram*		kilo	kilogram	1000 g	1 kg	Yes

BASE UNITS DEFINED

- meter: The metric base unit of length. A meter is defined as 1 650 763.73 wave lengths in vacuum of the orange-red line of the spectrum of krypton 86.
- liter: The metric base unit of volume (capacity). A liter is defined as 1000 cubic centimeters (1000 cm^3).
  Note: The symbol for liter should be signified through the use of italics or cursive form of the letter *l*, except when in combination.
- kilogram: The mass of one liter of distilled water at 4°C.
  Note: Because the gram is rather small, the kilogram has become the basic unit of mass in the metric system. The mass of 1 cm^3 of distilled water at 4°C is one gram.

METRICS AND MONETARY

The metric prefixes can be related to the appropriate values of the U. S. monetary system.

Monetary Values		Metric Values	
dollar	$1.00	1	meter
dime	.10	0.1	decimeter
cent	.01	0.01	centimeter
mill	.001	0.001	millimeter

METRICS AND NUMERATION

The metric prefixes can also be related to the place values of our base-ten numeration system.

Numeration System (Place Values)		Metric System	
Thousands	1000	1000	Kilo
Hundreds	100	100	Hecto
Tens	10	10	Deca
Ones	1	1	Base
Tenths	0.1	0.1	Deci
Hundredths	0.01	0.01	Centi
Thousandths	0.001	0.001	Milli

DECIMAL NATURE

The previous chart implies that a competency students need is the ability to multiply and divide mentally by 10, 100, and 1000. This will facilitate changing to smaller or larger metric units.

Learners should be encouraged to use decimal notation (0.5 as one-half). The use of fractions in metric measurement should be minimized.

RULES FOR SYMBOL USAGE

The proper notation (symbols) should be taught from the beginning. Correct symbol usage is important, as it is used internationally in all languages.

- Some rules for the use of the International System of Units (SI)* symbols are:

1. Symbols of base units

meter	m	Liter	*l* (not 1)
square meter	m^2	kilogram	kg
cubic meter	m^3	degree Celsius	°C

2. Metric symbols should not be capitalized nor followed by a period.

3. The symbol for the plural is the same as for the singular.

4. Units of area and volume must be written with an exponent 2 and 3 respectively: m^2, km^2, m^3, cm^3. (The pharmaceutical "cc" is not used to indicate metric volume or capacity.)

5. An ordinary lower case "l" could be mistaken for the numeral 1; therefore, the symbol should be written in italics or cursive.

6. There must be a *space* between the numerical value and the symbol of the unit.

7. If a numerical value is less than one (1), a zero must precede the decimal point: 0.5 instead of .5.

* from the French spelling Systeme International Unites

8. The degree symbol ° is necessary with Celsius (°C) in order to distinguish it from coulomb (C)—A unit for measuring electrical current. Kelvin has no degree symbol. Although kelvin is the basic SI unit for absolute temperature, Celsius is the internationally current unit of temperature preferred for most practical applications. *Note*: This was previously called "centigrade" in the United States, but Celsius in most other places.

MEASUREMENT APPLICATION

Constant use and practice with the metric system are necessary to develop full understanding. Metric units should be used at every opportunity in every subject matter field.

- All metric learning should continue to develop from "hands-on" activities and experiences.
- The importance of estimating and then verifying the estimation should be stressed.
- Many activities should involve direct measurement with metrically scaled instruments.
- The actual size units should be used, not the scaled-down versions found in some commercial metric materials.

MAKING APPROPRIATE CHOICES

As students progress, emphasis should continue to be placed on choosing appropriate *units* of measurement (unit of length to measure length) along with appropriate *instruments* with which to measure (e.g., the balance to measure mass).

The importance of using the *appropriately sized* unit should be stressed. Small units for small distances and large units for large distances help provide convenience or a greater degree of accuracy in measurement.

APPROXIMATE NATURE

Learners have often been given the idea that measurement is an exact science. "Textbook measurements" like "0.37" sometimes create the impression that this measurement is exact, but "0.37" probably means the quantity is somewhere between 0.365 and 0.375. Every now and again learners should be reminded of the approximate nature of measurement. (In the interest of brevity, this handbook does not deal with precision, significant digits, greatest possible error and relative error.)

CONVERSIONS a NO-NO!

There will be little need for conversion exercises between systems. When necessary, conversion tables should be used rather than memorized conversion factors.

Some approximate comparisons are useful.

A meter is a little longer than a yard.
A liter is a little larger than a quart.
A kilogram is a little heavier than two pounds.
An inch is about 2½ centimeters.

Some common metric references may be helpful.

1 white Cuisenair rod is a cubic centimeter.
1500 m is approximately 1 mile.
1 plump raisin has a mass of about 1 g.
1 nickel has a mass of about 5 g.
0°C is the temperature at which water freezes.
100°C is the temperature at which water boils
37°C is normal body temperature.
1 *l* (about 1 quart) of water has a mass of 1 kg.
1 standard paper clip has a mass of about 1 g.
A large paper clip is about 5 cm by 1 cm; a wire diameter of 1 mm and a mass of almost 2 g.

THINK METRIC

Students need to THINK METRIC and not be dependent on a translated measurement system. Thinking metric means visualizing relative size in metric units. Students should be encouraged to use the more common metric units even when doing conversions *within* the metric system. Other conversion exercises (such as km to dm) and the addition of unlike units are generally impractical. Everyone should understand the relationships among metric units as revealed by the base ten nature of the metric system.

AIM

This section is intended as a guide for instructors planning to conduct a metric workshop. Workshops may be planned for either teacher or nonteacher participants.

The aim of the workshop will be to teach the metric system through a re-emphasis of basic measurement concepts. The model presented in this handbook, the CONTINUOUS NON-GRADED MEASUREMENT LEARNING APPROACH, is a suggested method for doing this.

FOCUS

"Hands-on" activities should be featured—generally taught as the participants will be using them in the classroom and/or daily living. Often they will focus on the slogan "THINK METRIC" by using metric estimation, then verifying the estimate with metrically scaled instruments.

RESOURCE PEOPLE

Many resource people are available in Oregon who can assist by serving as workshop resource personnel. People from these institutions and organizations may be available:

- Community colleges (most likely the institution in your area)
- Colleges and universities
- Division of Continuing Education
- Intermediate Education Districts
- Oregon Science Teachers Association
- Oregon Council of Teachers of Mathematics
- Oregon Vocational Association
- Oregon System of Mathematics Education project
- Local school district Curriculum Specialists
- Oregon Museum of Science and Industry
- Business and industry representatives
- State and Federal Agencies
- Local experts

If you desire assistance in organizing a workshop or in obtaining a workshop leader, the *State Department of Education Metric Coordination Committee* will be available to help. The members of the SDE Metric Coordination Committee are:

Ray Thiess, Specialist, Science Education
Don Fineran, Specialist, Mathematics Education
Ralph Little, Specialist, Vocational Education

FOUR MAJOR STEPS

The four major steps listed below are suggested as key considerations for developing metric measurement workshops.

a. Preliminary Decisions
b. Organization
c. Procedures
d. Follow-up

PRELIMINARY DECISIONS

Some decisions the instructor will need to make when planning the workshop might include:

1. Will the background of the metric system be covered briefly?
2. How will justification for going metric be handled?
3. What learning approach will be implemented—the CONTINUOUS NONGRADED MEASUREMENT LEARNING APPROACH an alternative?
4. How will the factual content of the metric system be presented?
5. Will the workshop operate on a THINK METRIC basis?
6. Will the workshop consider the implications that going metric will have on all curricular areas; in particular, mathematics, science, vocational-technical and social studies?
7. Will the workshop consider ways in which general public metric awareness can be assisted?

ORGANIZATION

The instructor will want to have a general plan of action prepared. Some items for consideration are:

1. Purposes of the workshop
   a. Should instructor *and* participants or a representative group of participants choose and develop workshop objectives?
   b. Should a brief assessment of participant's knowledge of the present measurement system be administered? (See sample assessment instrument at the end of this section on p. 13.)
   c. Which levels of measurement learning should be stressed?
   d. Which concepts of measurement (length, mass, area, volume, temperature) should be developed?
   e. How should the workshop be evaluated? Which form(s) of evaluation will be most appropriate to the workshop participants—demonstration activities, questionnaires, discussion, pre-test—post-test, other?
   f. Should provision be made for materials evaluation?
   g. Is the instructor willing to share the evaluation of the workshop with the SDE Metric Coordination Committee in order that suggestions may be incorporated in the resource handbook to be revised in the spring of 1975?

2. Instructional Materials
   a. Have a sufficient quantity to permit participants to work in groups of two.
   b. Use homemade materials or plan to have participants make them.
   c. Plan a variety of materials that permits working with different measurement units at various learning levels.

3. Activities
   a. Select activities that will be interesting to the participants.
   b. Choose appropriate activities for the specific group in the workshop (primary teachers, elementary teachers, businessmen, homemakers, etc.)
   c. Use activities that participants can adapt for their own use (in their classrooms, at work, at home).

4. Nitty-gritties: time, place, room, tables, number of participants, participant needs (teaching level, if appropriate).

5. Additional resource personnel who may be needed. (See "Resource People," p. 9.)

PROCEDURES

Consideration of the workshop procedures should include:

1. Having every participant actively involved in all activities. (Groups of two are suggested.)
2. Providing sufficient time for all participants to discuss and evaluate the activities.
3. Relating each activity to appropriate learning level(s).
4. Using some humor throughout and planning "interest getters," such as door prizes for "meritorious metricating," ten-cent fines for using customary units in conversation, etc.

FOLLOW-UP

Evaluation of the workshop may take the form of demonstration activities, questionnaires, discussion of the pre-test—post-test techniques.

1. A very useful workshop evaluation may be to ask participants to demonstrate competence by writing activities which are appropriate to their own teaching level and which illustrate the levels of the measurement learning approach on some measurement concept. This approach should provide materials that teachers may take back for use in their own classrooms.

2. The questionnaire might ask the participant to rate himself on a graduated rating scale to show his level of understanding before and after the workshop. It might also include rating and comments on the effectiveness of the workshop.

3. If discussion is the method used, the class may be interested in helping to decide how well the workshop met the objectives previously developed. Further discussion may concern the following points:
   Learning approach
   Advantages of the metric system

Function of estimation
Metric units and prefixes
Useful activities
Do you "THINK METRIC?"

4. A pre-test and a follow-up post-test may be used to compare levels of competency before and after the workshop. Learning theory as well as content should be considered.

SAMPLE ACTIVITY

The following activity is offered as one example of the kind of "hands-on" experience that can be used to teach measurement. It is important to note that the series of activity steps encompasses all five levels of the measurement learning approach while working only with the concept of length.

* * * * *

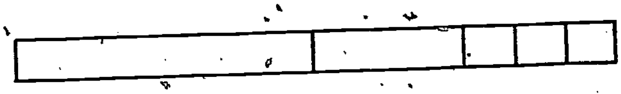
THE PAPER STRIP ACTIVITY

Action for Teams of Two

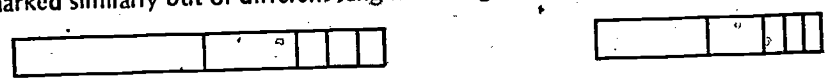
GETTING READY

Materials need to be prepared in sufficient quantity to supply each workshop team of two people with four strips of paper equal in length: 2 red, 1 blue and 1 yellow. One of the reds, the blue and the yellow strips will be pre-marked in the following manner:

1. Select a "unit" which is between 3 and 8 cm in length. Mark enough sets of 1 red, 1 blue and 1 yellow to supply about one-fourth of the teams. Mark the strips as in the diagram so the longest part is equal to 5 units, the next 2 and the shortest 1 of the chosen units.



2. Do the same for all other teams *except* the "unit" must be different from above, all different from each other, and each between 3 and 8 cm. This will result in each team having strips marked similarly but of different lengths among the teams.



CONSERVATION

Activity A. Each team does the following:

1. Place the two red strips side by side to show their lengths are the same.
2. Move one red strip to a new location. Now what can be said about the lengths of the two red strips?
3. Bend one red strip into the shape of a V. Now what can be said about the lengths of the two red strips?
4. Form a circle with one red strip. Now what can be said about the lengths of the two red strips?
5. Cut the marked red strip on the marks. Now what can be said about the length of the "train" formed when the cut red pieces are placed together end to end? What can be said about the length of the "train" and the uncut red strip?

Activity B. Each team does the following:

Cut the yellow and blue strips on the marks. Now using all the cut pieces of red, yellow and blue:

COMPARISON

1. Sort all pieces by color.
2. Sort all pieces by length.
3. Take one piece of each length and make a new arrangement from longest to shortest. Label the longest *a*, the next *b*, and the shortest *c*.
4. Mix all cut pieces into one pile. Find the labeled pieces. Find all other pieces which are the same length as the strip labeled *a* and label each with an *a*. Do the same for *b* and *c*, labeling with *b's* and *c's* respectively.

UNIT CONCEPT

Activity C. Each team continues to use their materials from activities A and B.

1. Using the unmarked and uncut red strip, show how many *a's* will equal its length. How many *b's*? Can you show this by using *b's* only? Why?
2. Have teams determine if the *a* length can be measured only in terms of *b*, *b* length only in terms of *c*. Ask the team to demonstrate their conclusions.
3. Using the unmarked red strip, have team members discover the number of ways that this strip length can be represented by using combinations of: *b* and *c*; *a* and *c*; *a* and *b*.
4. Instructor and teams identify as many objects to be measured as there are teams. Identify *a* as the unit of measurement for this activity. Have each team measure all of the objects by using their own *a*. Record the results for comparison with other team results. Note: A discussion should follow that would reveal that some teams have the same (hopefully!) numerical results, while other teams do not.
5. Have each team measure a small, a medium and a large object. Measure those objects three times, once in terms of *a*, once with *b* and once with *c*. Then discuss which unit, *a*, *b* or *c*, was found to be the most convenient for measuring the small object, the large object.

DISCOVERING A NEED-- STANDARD UNITS

METRIC SYSTEM

Activity D. Teams continue from Activities A, B and C.

1. Present the teams with a hypothetical situation in which an "order" for classroom carpeting is to be placed with a carpet supplier via a telephone call. The teams will attempt to communicate the room size in terms of their previously chosen *a*, *b* or *c* units to the carpet supplier.
2. When the teams discover that communications have broken down due to the use of their chosen units, lead them to the standard unit concept.
3. Introduce some standard units of length. (e.g. cm, m).

APPLICATION

Activity E. (a continuation of Activity D)

1. Have the teams measure the room using an appropriate standard unit. A discussion should reveal that all teams (optimistically!) have the same results. Teams will then complete their carpeting "order" using the telephone and thereby discover that communication is now possible.

Ye Olde Familiar (?) Measurement System

Fill in the blanks with the appropriate numbers.

VOLUME

1. 1 quart = ______ pints
2. 1 gallon = ______ quarts
3. 1 barrel = ______ gallons
4. 1 gallon = ______ cubic inches
5. 1 peck = ______ quarts
6. 1 bushel = ______ pecks
7. 1 fluid ounce = ______ cubic inches
8. 1 fluid ounce = ______ drams
9. 1 pint = ______ fluid ounces
10. 1 cup = ______ fluid ounces
11. 1 tablespoon = ______ teaspoons

LENGTH

12. 1 foot = ______ inches
13. 1 yard = ______ feet
14. 1 rod = ______ yards
15. 1 mile = ______ feet
16. 1 chain = ______ feet

WEIGHT

17. 1 dram = ______ grains
18. 1 ounce = ______ drams
19. 1 pound = ______ ounces
20. 1 ton (short) = ______ pounds
21. 1 ton (long) = ______ pounds

AREA

22. 1 square inch = ______ square foot
23. 1 square foot = ______ square inches
24. 1 square yard = ______ square inches
25. 1 acre = ______ square feet
26. 1 square mile = ______ acres

Evaluation Criteria

Score	
24-26	Super genius. Any measurement system is your bag!
21-23	Above average. You probably remember anniversaries, birthdays.
18-20	Pretty good. You're ahead of the average bear!
17-0	Surprised? Have you thought about switching? ---- Or would you rather fight than switch?

ANSWERS

1. 2
2. 4
3. 31-42 gallons
4. 231
5. 8
6. 4
7. 1.804
8. 8
9. 16
10. 8
11. 3
12. 12
13. 3
14. 5½
15. 5,280
16. 100 or 66
17. 27.344
18. 16
19. 16
20. 2,000 lbs.
21. 1.12 short tons
22. .007
23. 144
24. 1,296
25. 43,560
26. 640

Note to instructor: The above assessment may permit participants to observe that (1) they do not know all of the present system, and (2) yet they have been able to function. Hence, it will not be necessary for everyone to learn all of the metric system in order to function. Would you agree?

ACTIVITIES

DIAGNOSTIC AND/OR LEARNING

This section of the resource handbook has been developed as a series of sample pre-measurement and measurement activities. The suggested activities at each of the learning levels may be used as diagnostic activities to determine the measurement concept understanding level of the learner, *or* as learning activities selected to meet identified needs of the learner.

This approach allows the teacher to prescribe the most appropriate learning activities progressing vertically (i.e., concept to concept on a given learning level) and/or horizontally (i.e., learning level to learning level within a given measurement concept). (See chart on p. 2.) In some instances a teaching activity may represent both vertical and horizontal progress involving two or more measurement concepts.

METRIC: A RESPONSE

It should also be noted that this handbook does not spell out specific strategies for introducing the metric system itself, except to indicate that this may occur at the learning level referred to as "standard unit." This placement suggests that introducing the metric system occurs as a *response to a discovered need for a standardized unit.*

Even then, it is generally recommended by many teachers that only those parts of the metric system be introduced which are needed by the students at that point in their development. While stressing only the *commonly used prefixes*, the entire set of prefixes will be useful in developing the base ten nature of the metric system.

Although the recommended approach to the teaching of measurement is through many "hands-on" experiences, teachers will still need to make some decisions regarding the extent of memorization (base units, system of prefixes, symbols), drill and practice. In general, the teaching of the metric system as a part of the more basic area of the *teaching of measurement*, offers many options to teachers in choosing from their personal collection of strategies, materials and methods of evaluation.

The numbering system used to identify the suggested activities is not important in using the activities, but may make it easier to refer to specific activities when offering evaluation for the SDE Metric Coordination Committee. The Roman numeral refers to a measurement concept, the capital letter refers to one of the learning levels, and the number refers to an activity.

CONCEPT I: LENGTH

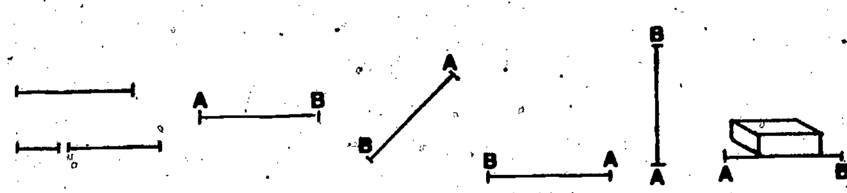
LEARNING LEVEL A: CONSERVATION

1. See "The Paper Strip Activity" in the Workshop Section, pp. 11 for a series of activities on length involving all five learning levels.

2. Provide two strips (such as paper or string) which are about the same length. The learner is asked if their lengths are the same (trim off, if necessary). Perform several experiments to see how bending, curving, folding, etc., influence the length. Then cut one strip into three pieces to determine how cutting influences the length.

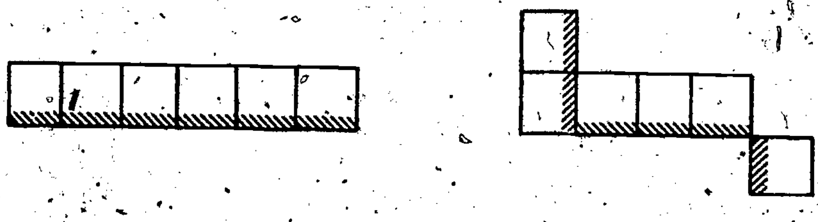
3. Provide two sticks of about the same length. Place one on top of the other but shifted a little to one side. Compare the lengths. Place one stick farther from the viewer than the other. Compare the length.

4. Determine which of two straight line segments represents a greater distance. Is the distance between A and B the same if slanted? If one is vertical and one horizontal? If an object is placed "between" A and B?



5. Have the learner form two identical rows of 10-15 squares (pre-cut). He can establish that the number of squares in each row is the same through a one-to-one correspondence. If the squares in one row are then placed in a pile, the learner can be questioned with respect to the *number* of squares in the pile compared to the number of squares in the remaining row.

6. Mark one edge of each square with short diagonal lines. Then have the student arrange the squares with the colored margins to form a continuous straight line. The squares could then be rearranged so that the line forms a zig-zag pattern. Has the total length of the colored line changed through rearrangement of the squares?



7. Have learners demonstrate on a geo-board a number of different shapes all having the same perimeter. (Strips, ribbon, string, etc., may be substituted for the rubber bands usually used.)

8. Have teams build towers, all using the same number and size of blocks. Have different teams build their towers on different levels (floor, tables, chairs, stairsteps, etc.) Discuss and compare the heights of the towers.

CONCEPT I: LENGTH

LEARNING LEVEL B: COMPARISON

1. List some common properties other than size that can be used to compare objects; e.g., prettiness, color, texture, smell, taste, etc. Compare objects by the degree of each property. Example: rose to a rose, daisy to a rose, dog to a horse, beach ball to a golf ball, a rock to a shell, etc.

2. Find a ribbon long enough to make a belt for yourself. Will a ribbon long enough to make two belts match your height? Using ribbon, string, or unmarked tape, find how many "heads" equal one waist? your height? one of your feet? how many "wrists" equal one head? one waist? one ankle?

3. Measure the height of each student. Then cut individual strips of paper equal to the height of each student. Tape the strips to a wall with each starting from the floor to form a graph of heights of the students in the class. Rearrange strips in order from tallest to shortest.

4. Keep a graphic record to show the increasing height of plants as they grow. Paper strips cut to the plant's height may be used as vertical bars on a graph.

5. Prepare a graphic record to show how tall everyone in your family is. Who is the tallest? Shortest? Where do you fit in? Arrange the record to show your family in order from tallest to shortest. You might even include pets.

6. Measure animals (hamsters, gerbils, dogs, cats) to learn if a "measuring string" or a "measuring stick" is better to measure height, length, tail, around the tummy, etc. Which animal is taller? longer? fatter? Measure the animal's cage. Is there room enough for him to stand up? lie down? stretch out? hide in a corner?

7. Measure your shadow and measure your height using string. Which is longer? (Try this at different times of the day.) Teams of three students measure each other's height, then arrange in order from shortest to tallest. Now measure their shadows. Arrange shadow lengths from shortest to longest.

8. Make direct comparisons of two objects by placing them next to each other; longer, shorter, taller, fatter, thinner, etc. Compare three objects by placing *only two at a time* next to each other (transitivity). Make comparisons of two large objects which cannot be placed next to each other (e.g., door and window) by using a third object which is smaller, such as a sheet of paper, unsharpened pencil, chalkboard eraser, etc. (This provides an introduction to the unit concept.)

CONCEPT I: LENGTH

LEARNING LEVEL C: UNIT CONCEPT

1. Learners measure various distances by making lines (trains) of sticks, straws, Cuisenaire rods, paper clips, their own foot patterns, etc. (e.g.,seven straws placed end to end). Then measure some distances by using only one object counted repeatedly (e.g., one straw moved and counted seven times).

2. By stepping off heel to toe to heel, etc., find your "foot" count for various objects or shadows. Cut out a paper pattern of your foot and use this for measuring a variety of objects. (A hand or a finger may also be used.) Compare results. As a follow-up activity, have the class choose one person's hand, finger or foot as a *common* unit, then follow the same procedures. Compare results.

3. Each learner uses his "pace" to measure a variety of objects and shadows. Learners compare results.

4. Using a string cut to match their height, ask students to find objects half as tall or twice as tall as themselves. Fold the string to form halves, each "U" may become a "unit" for measuring other objects.

5. *Estimate* the length of the chalkboard in terms of pencils, sticks, paper clips, books, paper strips, sheets of paper, linoleum tiles, erasers, etc. Then measure and verify the estimations. Tell a friend about the length of the chalkboard in face to face conversation, or by telephone. Write a letter to someone telling them how long the chalkboard is.

6. The learner makes his own measuring "stick" and measuring "tape" by using his own choice of units. The sticks may be made from unmarked molding (scraps from the local lumber yard), and tapes may be made from adding machine tape (perhaps reinforced with a strip of masking tape)or two strips of masking tape put together. The learner may wish to name his unit or his instrument to honor himself. After making estimates, the student uses these instruments in a variety of measurement activities. Have the learner compare his results to those of others.

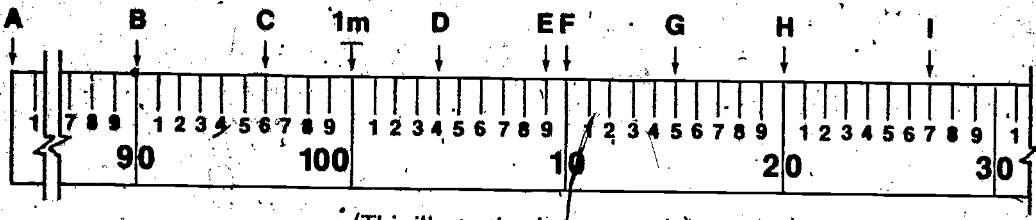
7. Make several sizes of chains from paper clips, and use each chain as a unit. Have students use one of their units to measure a pre-selected distance (known only by the teacher to be about 10 paper clips long). Measure the pre-selected distance in terms of the following chains as a unit: a chain of 2 paper clips, a chain of 5, a chain of 8, a chain of 10, a chain of 20. Measure objects of various sizes with different unit chains. Which size unit is best?

8. Measure large objects in terms of a small basic unit and "discover" the need for a larger unit which may be formed by using a multiple of the basic unit. Then measure between limits (i.e., this paper is "between two and three" pencils in length) and "discover" the need to subdivide the basic unit when smaller units will facilitate more accurate measurement. [Develop background now for later understanding of the powers of ten (decimal) nature of the metric system.]

CONCEPT I: LENGTH

LEARNING LEVEL D: STANDARD UNIT

1. Place two meter sticks end to end as in the diagram. Point A is at zero on the meter stick to the left and other labeled points are located as shown. Write the *decimal form* of each of the following lengths *in meters*: AB, AC, AD, AE, AF, AG, AH,AI. (Try FH, GH, HI.)



(This illustration is not to scale)

(Use meter sticks or actual size drawings, *not scaled down* versions. The same activity may be done with the points chosen along the millimeter marks to utilize "thousandths."

2. Renaming metric measurements: This activity provides an opportunity for some "guided discovery" exercises utilizing decimal-fraction notation which, hopefully, takes advantage of previously learned mental short-cut procedures for multiplying or dividing decimals by 10, 100 and 1000. Some well selected exercises may lead the learner to observe two generalizations; (1) to change a metric measurement to smaller units, multiply by 10, 100 or 1000, and (2) to change a metric measurement to larger units, divide by 10, 100, or 1000. After discovering this generalization, some follow-up exercises may be designed utilizing the decimal nature of the metric prefixes in order to guide learners to another general conclusion; i.e., "To rename metric measurements, write the digits so that the decimal point is just to the right of the digit in the column (place) of the unit names." Examples:

dam	m	dm	cm	mm	
3	5	7	9.	1	cm = 35.791 m

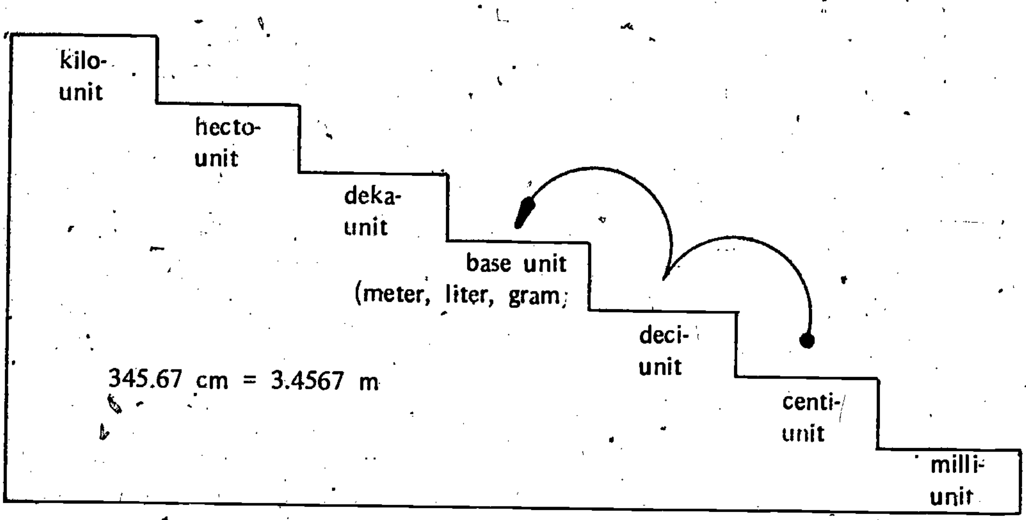
m	dam	cm	mm	
2.	4	6	8	m = 2 468 mm

km	hm	dam	m	dm	cm	mm	
3	4	5	6	7	8	9	mm = 345 678.9 cm = 3 456.789 m = 3.456 789 km

3. Teachers have used several forms of "expanded notation" in various ways to reinforce the place value concept of decimal numeration; an analogous procedure may be used to bring out the decimal feature of the metric system.

Examples: 356 = 300+50+6 356 cm = 3 m+5 dm+6 cm
25.73 = 20+5+.7+.03 25.73 m = 2 dam+5 m+7 dm+3 cm

4. Mr. Boyd Henry* illustrates the idea of decimal point placement with a simple, mechanical procedure for changing from one metric unit to another by utilizing a staircase chart. Locate the original unit on one of the steps of the staircase. Count the steps to the new unit and move the decimal point that many steps in the same direction.



* Teaching the Metric System, Boyd Henry, Weber Costello, Chicago, 1974

5. Have the learners make their own meter or centimeter "stick" or "tape" by using unmarked molding, adding machine tape or masking tape. They may use their own instrument in a variety of measurement activities. Estimate first! Have the learners compare their results to that obtained by others. Activities should eventually include some situations which create a need for sub-divisions. Perhaps an "estimation contest" may be held with team points for closest estimation, second closest, etc.

CONCEPT I: LENGTH

LEARNING LEVEL E: APPLICATIONS

1. Draw straight line segments of the following lengths by estimation first, then using a ruler draw the actual length: 1 cm, 10 cm, 10 mm, 100 mm, 0.01 meters, 0.1 meters, etc. (Outdoor activities may involve the meter and kilometer.) An alternate activity might be to give line segments of various lengths; students should (a) estimate their length, (b) verify the estimates by measuring.

2. Estimate, then measure each of the following: length and width of your forefinger, length of your shoe, length of your stride, your height, length and width of a dollar bill, length and width of a door, diameter and thickness of a quarter, length and width of a large paper clip and the diameter of the wire.

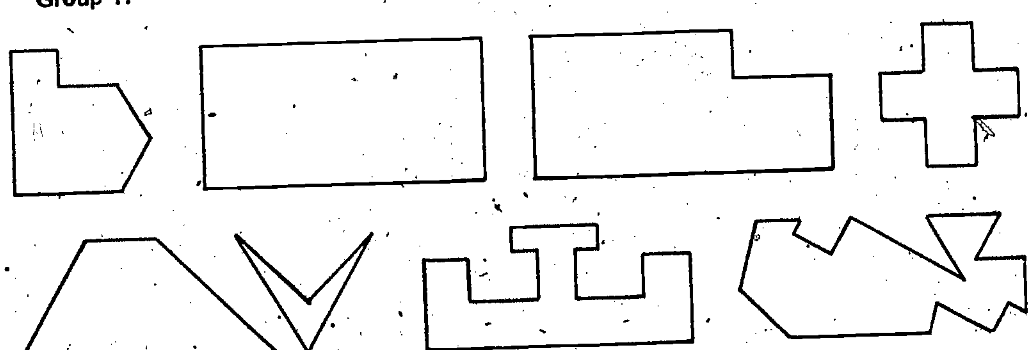
3. Measure the "bounce height" of several different balls when dropped from several different heights.

4. Measure the heights of objects and their shadows to discover a relationship. Then determine the height of other objects by measuring its shadow.

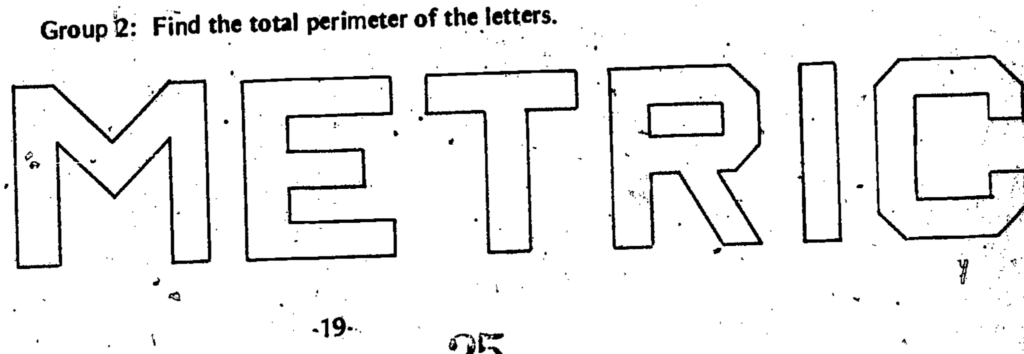
5. "Mystery Measurements" contest: First, measure assorted objects in the room— boxes, books, games, cards, furniture—include some standard-sized items—record the dimensions. (Depending on the learning level of the student(s), area or volume may be used.) Write sets of "Mystery Dimensions" on the chalkboard. Ask students to use their measuring instruments to measure objects until they can identify the mystery objects. (The next mystery contest may be played with students contributing their own mystery dimensions.)

6. Determine perimeters: The teacher needs to prepare a "worksheet" by drawing a number of geometrical shapes *using actual metric lengths*. The directions are simply "Using your metric ruler, find the perimeter (distance around) each figure." Teacher drawn shapes may include a variety with the degree of complication appropriate to the learner. Here are a few examples:

Group 1:



Group 2: **Find the total perimeter of the letters.**



7. Construct as many rectangles as you can, such that the perimeter of each is 20 cm and the width is a whole number (i.e., 1, 2, 3, . . .) of centimeters. This may be done on geoboards, metric graph paper*, or plane paper.

8. Are model cars really models? Preferably using a foreign car, obtain a model of it and the new car brochure. Use your metric ruler to measure the model's wheel base, front track, rear track, length, width and height. Determine the scale, then calculate the dimensions of the real car. Compare your results to the specifications given in the new car brochure.

CONCEPT II: MASS

LEARNING LEVEL A: CONSERVATION

1. Place a lump of modeling clay in one pan of a balance scale. Add objects to the other pan until the balance is even. Now roll the modeling clay into a long, skinny snake. Does it still balance? Does it balance if you break the snake into little pieces? Does it still balance if the clay is molded into the shape of some animal? Compare a ball of clay with the clay squashed into a pancake.

2. Using a balance, the student will compare the mass of an arbitrarily chosen unit against a small bag of "goodies" (corn chips, potato chips, etc.) After the two objects have balanced, remove the bag of "goodies" from the balance and crush the contents. (Careful with the bag!) Return the bag of "goodies" to the balance. Does it balance now? What does this show?

Additional activities:

1. Using popcorn, first balance a quantity of unpopped popcorn with a chosen unit of mass. Then pop that quantity and return the popped popcorn including the kernels which did not pop to the balance. Does it balance now?

2. Using ice cubes placed in a container, balance the ice cubes with a chosen unit of mass. Let ice cubes melt. Return the container and its contents (now water!) to the balance. Does it balance now?

CONCEPT II: MASS

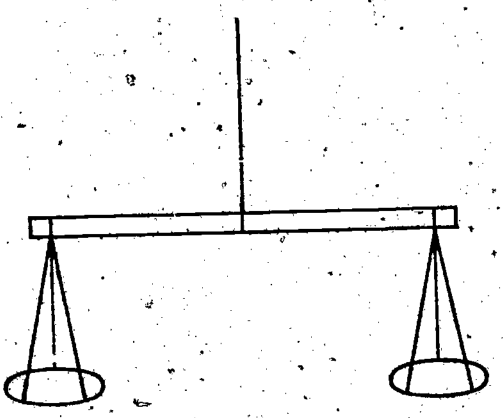
LEARNING LEVEL B: COMPARISON

1. Provide each team of two students with a variety of small objects to be hefted and compared for mass (weight). Find objects having about the same mass. By hefting, arrange the objects in order from lightest to heaviest. Verify the ordering by using a balance scale.

2. First by lifting to estimate, then by using a balance scale, compare pairs of objects to determine which has greater mass. Some suggested pairs are: ten pennies and ten dimes; 200 kernels of unpopped and 200 kernels of popped popcorn; a bottle of glue and a like bottle with water; a chunk of metal and a bag of feathers; an apple and an orange; a banana and a tangarine; 5 potatoes and 5 onions; a baseball and a football; a softball and a basketball.

3. Make a balance scale: You will need one rod (piece of molding, stick or ruler about 40 cm or more in length); two lids such as large size mason jar lids or the lids from cottage cheese cartons, refrigerator plastic containers or cutoff milk cartons; some string and masking tape. Cut the string into 40 cm lengths and tape three strings to each lid. Tape the three strings from each lid to the rod at a point about 2 cm from the end of the rod. Suspend the rod and its two "pans" from a string and adjust the string back and forth until the rod is level, then tape the string to the rod in that position. Use your balance to compare the mass of many different small objects being sure to compare them by estimation first.

*Ask science teachers where they get metric (cm^2) graph paper

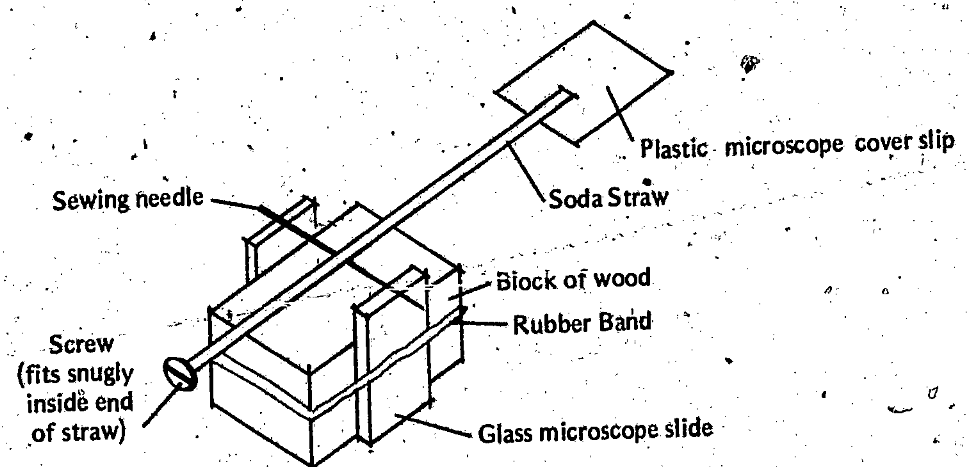


CONCEPT II: MASS

LEARNING LEVEL C: UNIT CONCEPT

1. Use the soda-straw balance to compare the mass of small objects to some arbitrarily chosen unit of mass. One quantitative measure learners may make is determining the mass of each component part of a flower. (Other measurements such as *length* of stem and area of leaves may also be dealt with.) For example, to determine the mass of the petal, place the petal on the pan of the balance and then turn the screw out until the straw is level. Then remove the petal and substitute the chosen units of mass (e.g., round cutouts made by paper punch) on the pan until the straw once again balances. Other examples of items for which masses may be determined are seeds, pieces of cloth, pieces of styrofoam, metal staples or crystals of salt.

SODA STRAW BALANCE



2. A collection of iron washers of several sizes and with a number of washers of each of the sizes is needed. Some should be very small, others quite large. Use a balance scale to measure the mass of various small objects in terms of combinations of washers. Students may have more fun by making guesses first. Record and compare your results.

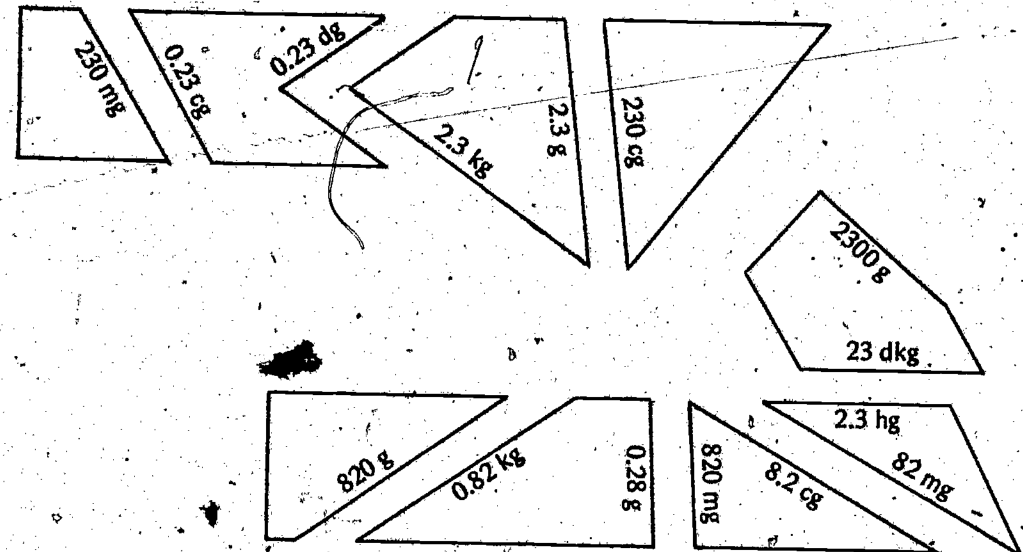
3. Problem: Determine the mass of a rock in terms of an arbitrarily chosen unit. Use a piece of clay as the mass unit. By using a balance, compare the masses of the rock and one chosen unit. If the rock has the greater mass, more units will be needed. "Manufacture" another unit of clay with a mass equal to the first unit. Compare them on the balance. Then place the two units on one pan and the rock on the other pan to see if the mass of the rock is the same as two units. Manufacture more units, if needed. It the rock when first measured was less than one unit, or on further measurement is somewhere between whole units, subunits are needed. Keep at least one whole unit intact. Subdivide another unit into halves, comparing them on the balance. If further subdividing is needed, prepare ¼ units in the same manner. Continue subdividing until the mass of the rock can be measured with a combination of units created.

4. Make a balance: Drill a hole in the exact center of a meter stick for a hook. Cut off two half gallon milk cartons at 103 mm so that each is about 1 liter. Attach strings to the corners. Tape these to the meter stick near each end and adjust them so that the stick will be level when suspended. "Caveman bartering days" may be enacted by teams of students representing different "tribes." Each tribe chooses a mass unit–examples are a marble, an eraser, a small book, selected stones, a box of thumb tacks, a pair of scissors, a block of wood, a measured volume of water or sand. (In all selections the teams will need to have available a number of their mass units.) On the "fair-trade" bartering market *equal values* are the following mass comparisons: 2 units of rice = 3 units of beans = 4 units of potatoes = 1 unit of yellow apples = 1½ units of red apples = 2½ units of bananas = 3½ units of oranges = 4½ units of grapefruit. (Painted rocks of various colors will do.) Each tribe is given only one commodity (or rocks of only one color). Attempt to barter using the "equal values for different masses" concept (no monetary system!). Since the tribes do not trust each other, each transaction is massed on each tribe's own balance using their own chosen units. When the tribes discover "world trade" is seriously hampered, ask a "council of the tribes" to choose an "international" unit. Provide supplies to all tribes which permit them to measure with the "international" unit. After some transactions with the international unit, a discussion may bring out advantages of having an "international" unit.

CONCEPT II: MASS

LEARNING LEVEL D: STANDARD UNIT

1. Ask students to put cut-outs of the drawings below together to form a big "M." The edges that go together are marked with equal measurements of mass.



2. The mass of water in a container may be determined by using a balance scale. The first step consists of measuring 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 using the above procedure, determine the number of grams for the following volumes of water: 25 *ml*, 1 *l*, 3 *l*, 250 *ml*, 1500 *ml*, 600 *ml*, 40 cm^3, 2000 cm^3. An alternate approach to this activity would have the student *determining the volume* of the water from a given mass of water. Encourage students to look for a relationship.

3. Scavenger Hunt: Students are asked to find objects having a mass which matches various masses in a *given* list by using a balance. Suggested list, which the teacher prepares in advance by measuring the mass of a variety of objects:

   kg (the teacher)
   kg (the unabridged dictionary)
   kg (a chair)
   kg (a concrete block which happens to be nearby)

kg (a bottle with almost 1 *l* of water)
g (a math book)
g (a chalkboard eraser)
g (a spelling book)
g (the apple on the teacher's desk)
g (a metric ruler)
g (an unsharpened pencil)

4. Ask students to find "story problems" in their arithmetic books which involve weight. Ask the students to restate the problems using metric units of mass which make sense. (Students are not asked to solve the problems!)

CONCEPT II: MASS

LEARNING LEVEL E: APPLICATION

1. Estimate first; then by using a balance scale find the actual mass of many objects; such as books, a set of potatoes, canned food, stones, pieces of wood, pieces of metal, your shoes, yourself, one liter of beans, rice, sand, water, etc., erasers, marbles. This may be done as an estimation contest for teams. Teams estimate and record, then verify by using a balance scale. A scoring system may be devised such as "estimates within 1 kg are worth 1 team point, within 500 g worth 2 team points, within 250 g worth 3 team points, etc." (In particular, call attention to the mass of 1 liter of water, 0.5 *l*, 0.2 *l*, etc.)

2. Divide the class into teams. The teams choose items whose masses are to be determined. Each team records the names of the objects and the team estimate of each object's mass. Then the teams use balance scales to determine the mass of each object which is recorded. The difference between the actual and the estimated mass is calculated for each object. The team whose estimate was closest earns 5 points, next closest estimate earns 4 points, and so on. Highest total of team points wins. (Winners do not have to help put all the equipment away!)

3. Collect a variety of dry cereals in unopened containers as nearly equal in size as possible. Be sure to cover the part of the label which lists the net contents. Collect a set of the same containers which are empty. Learners calculate the mass of the net contents by using a balance to measure the mass of each container with contents and without contents. This may also be done with laundry detergents, canned food, boxed candy, etc.

4. Provide one large bag of unpopped popcorn and one small bag containing 20 kernels of unpopped popcorn. Estimate the number of kernels in the large bag. Measure the mass of both bags of popcorn and figure out the number of kernels in the large bag *without* counting them.

5. Make billfold-size cards with a centimeter scale along the margin. On one side of the card some *approximate comparisons* between customary and metric units can be printed. (You may wish to include length and mass.) On the other side might be approximate metric measurements of several carefully selected common everyday objects. If the students plan the card and choose items to be printed, the project will be more meaningful to them. If a nearby industrial arts department works with plastics, the cards may be plasticized. Laminating is another possibility. These cards may be for individual reference, gifts to parents on holidays, gifts to visitors on Parent Night during the local schools, "Metric Week" or at "Open House." They could be sold as a money-making project.

CONCEPT III: AREA

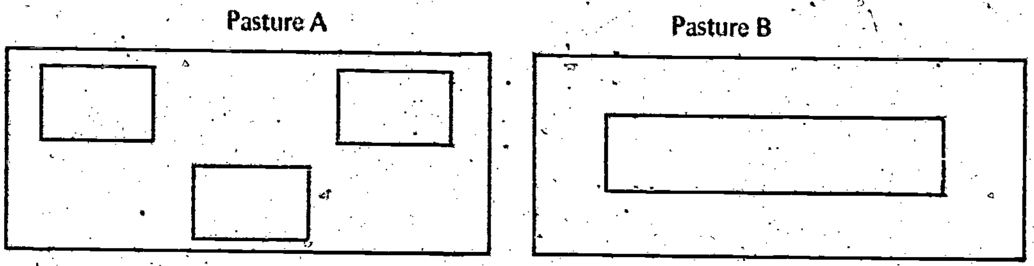
LEARNING LEVEL A: CONSERVATION

1. Have the student arrange 48 paper congruent squares on a table so that they form two large rectangles composed of 24 squares each. One rectangle could then be rearranged so that all the squares were spread out. Ask the student which group covered more of the table, the one remaining in a rectangle or the one that was rearranged.

2. Construct four different-shaped rectangular regions, each of which has the same area of 24 square units. This may be done on coordinate paper or on a geoboard. (To relate to length, ask students to find the perimeter of each of their rectangles.)

3. Provide a student with 16 right triangles cut from paper all the same size and shape. Ask the student to put them in two piles so that each pile has the same number of triangles. Have the student place the triangles from one pile next to each other on the table so that he builds some kind of "shape." Ask him to build a different shape with the triangles from the other pile. Do the two shapes have the same area? If the answer is "yes," ask (1) for an oral explanation, and (2) show they are the same by rearranging the triangles in one of the shapes to match the other shape, or by putting the triangles from one shape on top of the triangles in the other shape.

4. The "Fields of Grass" problem:



Pastures A and B are the same area. The three equal barns on pasture A when placed together are the same area as the one barn on pasture B. Which pasture has more grassland? (Illustrations can be done with drawings, cut-outs, felt board, etc.) What would you do to prove your answer?

CONCEPT III: AREA

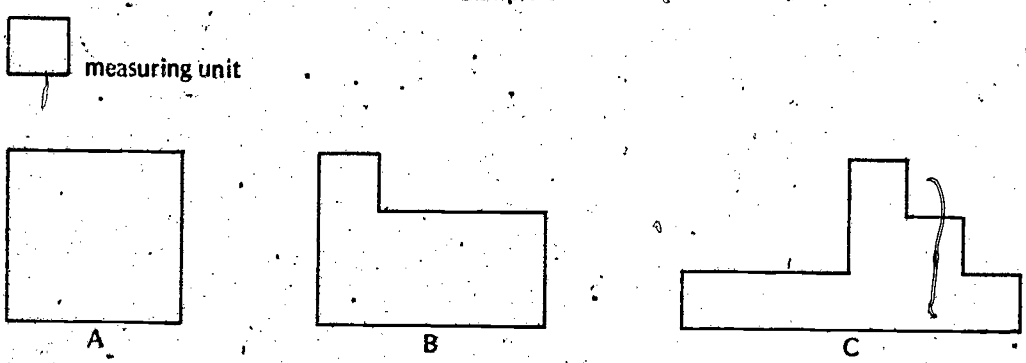
LEARNING LEVEL B: COMPARISON

1. Have each student draw an outline around his hand or foot on a piece of paper. Have him compare the size of his hand with the size of a classmate's hand. By holding the two outlines against a window pane, placing one over the other, students can accurately compare size of their hands or feet with those of their classmates.

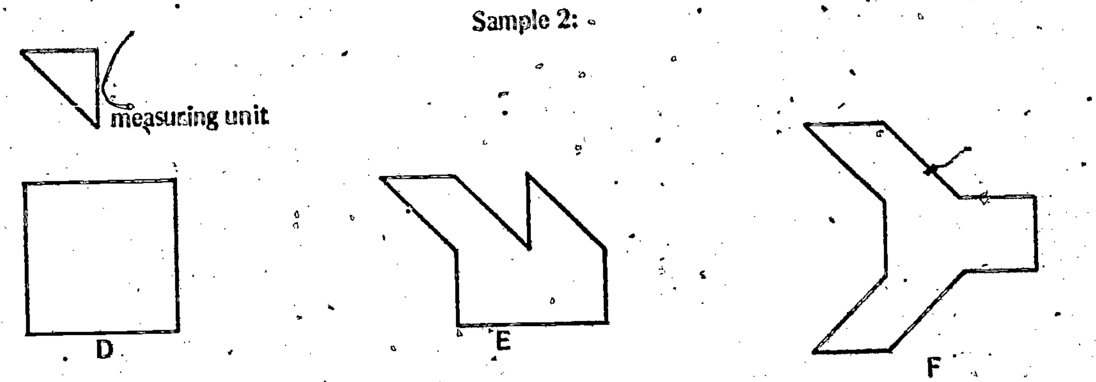
2. Distribute a picture to each student. On the picture have the student circle some specific items; e.g., the largest ball, smallest person or a small house. Next, have the student find larger or smaller items of the same kind in other pictures. Have the student explain the choices to the group.

3. The following activity involves comparison of area by counting how many small squares (or triangles) there are in the larger regions. The child should be given a cardboard unit square and a cardboard unit triangle. He will place the measuring unit on the drawings, mark off the area by tracing around it with a pencil, and count the number of units in each region. He then can order these three regions from smallest to largest or largest to smallest.

Sample 1:



Sample 2:



CONCEPT III: AREA

LEARNING LEVEL C: UNIT CONCEPT

1. Determine the area of a table top in terms of sheets of paper, linoleum tiles, erasers, newspapers, books, towels, notebooks, blankets, etc. Discuss the advantages and disadvantages of the various units used.

2. Determine the area of a table top in terms of rectangular sheets of paper, squares, triangles, trapezoids, circles, pentagons, irregular shapes, etc. Discuss advantages and disadvantages of the various units used.

3. Determine the area of a table top, the floor, a notebook cover and the school grounds in terms of little squares, middle-sized squares, large squares. Discuss the advantages and disadvantages of the various units used.

4. How many sheets of newspaper would be needed to paper the floor, or the walls of the room? a football field? the school grounds?

5. Supply students with precut figures including various sizes of shapes appropriate to the learners, such as squares, rectangles, triangles, parallelograms, trapezoids, circles and irregular combinations of these. The figures may or may not utilize whole number dimensions, according to the needs of the group. The cut-outs may be of cardboard, tagboard, plastic, etc. Students also need graph paper. Ask students to choose a unit of area and designate it by outlining "one unit" on their graph paper. Place the cut-out figures on the graph paper, and draw around the various shapes. Count the number of their chosen units enclosed by each boundary. This will probably create a problem for some discussion and decisions about approximating and the need for a common unit. This also presents an opportunity for estimating, then counting. An alternate activity may be to ask students to outline or draw a number of shapes all having the same area.

6. Each team of students selects an arbitrary nonstandard unit to measure the area of the floor and the area of the teacher's desk top. Teams will decide if they want to use the same size unit to measure both areas. After determining the two areas, each team will prepare a letter in which they place an order to a supplier for carpeting and formica. The letters will then be read to the other teams to see if there is suitable information to fill the orders. When students discover a lack of communication (the need to use standard units), they will be asked to develop a plan for meeting the communication gap.

CONCEPT III: AREA

LEARNING LEVEL D: STANDARD UNIT

1. Supply students with precut figures including various size shapes appropriate to the learners such as squares, rectagles, triangles, parallelograms, trapezoids, circles and irregular combinations of these. The figures may or may not utilize whole number dimensions. The cut-outs may be of cardboard, tagboard, plastic, etc. Students also need graph paper—centimeter scale. Ask students to outline a unit of 1 cm^2. Place the cut-out figures on the

graph paper and draw around the various shapes. Count the number of units enclosed by each boundary. Students will be faced with some approximating. Encourage the students to *estimate before* measuring. A follow-up activity may be to ask students to develop mathematical expressions which express the area in terms of dimensions; e.g., A = l x w for the area of a rectangle.

2. Centimeter graph paper will be needed. Students trace the outline of their hand on the paper, then find out how many square centimeters are covered by their hand. Discussion will bring out some thinking about approximating. Trace around a cube on the graph paper and determine the area of one face of the cube. Does it matter how you place the cube on the graph paper? What is the total area of all faces of the cube?

3. Students may construct their own "area ruler" (area grid) to use for measuring area. Construct a centimeter scale grid on a sheet of clear plastic. A unit is one of the squares, 1 cm by 1 cm. By placing this sheet on various drawings, the areas may be found by counting the squares within the boundary. The drawings may include squares, rectangles, triangles, parallelograms, trapezoids or combinations of these which form irregular shapes.

4. This activity involves Cuisenaire rods, but only 2 to 4 "ten rods" and only 5 to 15 "one rods" should be provided. Use the rods to discover a *plan* for finding the area of the bottom of several boxes which are small rectangles or squares whose dimensions are each 55 cm or less. This activity may also be done with cardboard cutouts. Five to 15 squares 1 cm by 1 cm and 2 to 4 rectangles 1 cm by 10 cm are needed. The small boxes may be used again or drawings of rectangles and squares will serve. The more adventurous leaders may rise to the challenge of developing a *plan* for determining the area of triangles, parallelograms, trapezoids, etc.

CONCEPT III: AREA

LEARNING LEVEL E: APPLICATION

1. Supply students with precut figures (or actual size drawings) including various sizes of shapes such as squares, rectangles, triangles, parallelograms, trapezoids, circles and irregular combinations of these. The figures may or may not utilize whole number dimensions. The cut-outs may be cardboard, tagboard, plastic, etc. Students also need metric rulers. A decision must be made as to whether to provide formulas to the students. Ask the students to *measure the figures*, then calculate the areas. A follow-up activity may be to ask students to construct as many rectangles as possible having an area of 24 cm^2 with a length which is a *whole* number of centimeters. Determine and compare the perimeters of these rectangles. Another follow-up activity may be to construct rectangles of the greatest possible area and the least possible area, each having a perimeter of 16 cm.

2. Play "Mystery Measurements" game using area measurements. See directions in the length/application activity number 5. (p. 19)

3. Each team of students will develop a redecorating plan for their classroom. Choosing appropriate metric measuring devices and units, each team will measure and determine the materials needed to do the following: 1) carpet the floor, 2) paint the walls and ceiling, 3) prepare drapes for the windows, and 4) cover the teacher's desk and a classroom table with formica. Try "telephoning" their order for materials to another team to see if communication is possible.

4. The student is asked to determine the area of an irregularly shaped object such as leaves of various trees or shrubs. Find the mass of a sheet of graph paper. Determine the number of squares on the page. Then calculate the mass for one square. Trace the leaf pattern on the graph paper and cut it out. Now find the mass of the cut-out and compare it to the mass of one square to determine the number of squares covered by the leaf. (Be alert for possible confusion between the quantities of mass and area when mass measurements are being used to determine area.) Compare the results found by this method to those determined by *counting* the squares inside the outline of the leaf.

CONCEPT IV: VOLUME

LEARNING LEVEL A: CONSERVATION

1. Balance one group of blocks against a different group. Do the groups still balance if you build one group into a house?

2. Pour a quantity of liquid or sand from a short wide glass into a taller, narrower glass to find that the volume does not change when the shape is changed. A half-gallon milk carton cut off at a line about 10.3 cm from the bottom and a one-quart milk carton cut off at the fold can be used. (Each will contain about 1 liter.) Pour from one container into the other. Jars and cartons of various shapes and sizes could also be used.

3. Pour about 650 m*l* of colored water into each of two containers which are the same size and shape. Four tall narrow glasses and four short wide glasses or cups are also needed.

   1. Ask if the two containers contain the same amount of water. Adjust, if necessary, until the learner agrees they do.
   2. Pour all the water from one of the containers into the four narrow glasses. Ask which is more, the liquid in the four glasses or the liquid in the container.
   3. Pour all the water from the four narrow glasses back into the original container. Then pour all of it from that container into the four wide glasses. Ask which is more, the liquid in the four glasses or the liquid in the container.
   4. Pour all the liquid from the other large container into the four narrow glasses. Ask which set of glasses has more. Verify by pouring from each set of glasses back into the original containers and comparing again.

4. Ask the student to predict what will happen when a solid cylinder of aluminum is submerged in a container of water and then replaced with a solid cylinder made of another material. (Reminder: 1. The cylinders must always be the same size and shape; 2. The cylinders can be cut from rods of different materials; e.g., aluminum, steel, plastic, wood, etc. These are obtainable from local metal shops, lumber yards and craft stores.) Verify the predictions.

CONCEPT IV: VOLUME

LEARNING LEVEL B: COMPARISON

1. Provide students with a variety of containers of different shapes. Teachers may wish to choose sizes to include 250 m*l*, 500 m*l*, 1 *l*, 1 pint and 1 quart. The containers may be labeled A, B, C, D and E respectively, but the volumes should not be indicated. Using sand or water for repeated filling and pouring, a) order these five containers from largest to smallest, and/or b) discover which containers are equal to multiple amounts of a smaller container.

2. Provide students with hollow models of cubes, rectangular prisms, triangular prisms, square base pyramids, cylinders, cones and spheres. (A funnel will also be helpful.) The cubes and square-base pyramids should have equal bases, and the length of their bases should equal the diameters of the cylinder, cone and sphere. Compare the volumes of the 3-D figures by filling with water, sand, beans, etc., and pouring into the other containers. Some students may discover several specific volume relationships among the models.

CONCEPT IV: VOLUME

LEARNING LEVEL C: UNIT CONCEPT

1. Show the learner one container with a given amount of water (three to five vialfuls) and ask him to determine how many vialfuls were poured in. First start with full vialfuls, then half vialfuls, and finally a number of various-sized containers to pour into the larger container.

2. Determine the volume of a box in terms of books, bricks, candy cartons, toy blocks, Cuisenaire rods, cereal boxes, packing cases for refrigerators, etc. Discuss advantages to be gained by a convenient choice.

3. Determine the volume of a box in terms of toy blocks, golf or ping-pong balls, cans, milk cartons, perfume or pop bottles, cylindrical tile, etc. Discuss advantages to be gained by a convenient choice.

4. Determine the volume of several different sized boxes, the room, or the gymnasium in terms of Cuisenaire rods, toy blocks, middle-sized cubes, and large cubes. Discuss the advantages to be gained by a convenient choice in each case.

5. Provide the following equipment: eye dropper, one measuring spoon, three containers (small, medium, large), source of water, Using the eye dropper, find how many drops of water fill the measuring spoon. Calculate the number of drops of water required to fill the largest of the three containers. Pourings are permitted. Explain how the answer was obtained.

6. Formulas or recipes given in parts emphasize the need to select units of measure. Students measure to make play-doh, bread dough, cookies, punch, finger paint, or papier-mâché. Such as:

Chemical Garden

1 part household ammonia
3 parts water
3 parts table salt
3 parts bluing

Mix together and pour over rocks, sand, sponges, wood, or bits of brick. Spread out on a metal tray. Let stand. Watch the crystals grow.

Punch

1 part fruit concentrate
4 parts water
1 part sugar

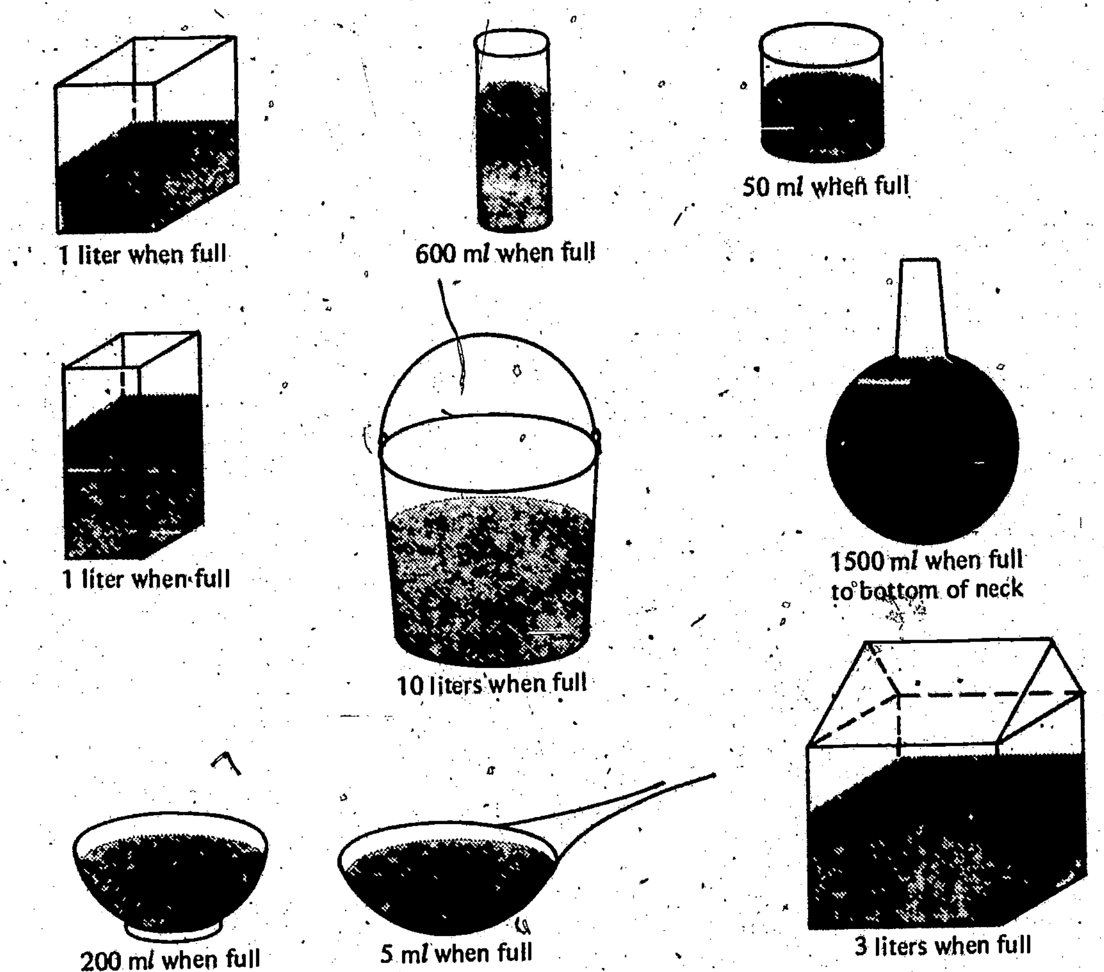
How much will the pitcher hold? How many little cans of concentrate can be used so the pitcher will be filled with punch? How many cans of water will be needed? How much punch is needed to serve the class? Suppose everyone wants "seconds?" Suppose half the class wants "seconds?"

CONCEPT IV: VOLUME

LEARNING LEVEL D: STANDARD UNIT

1. Provide each team with three or four bottles or jars of various sizes (100 m*l* to 1000 m *l*) and shapes and also throw-away I.V. bottles from the local hospital. (They are graduated one liter bottles.) Ask students to observe the numbers and lines on the I.V. bottles. They should find numbers for 100, 200, 300, . . . 1000, with a little mark between the hundred marks. Ask students what amounts are indicated by the little marks. Ask students what amounts are approximated when the water level is halfway between one of the little marks and the number marks on either side of it. Have students list some of the amounts that can be measured with the I.V. bottle; e.g., 600, 625, 650, 675, 700 . . . . What metric unit will be involved with the number 625? Now have the teams estimate the volume of their other bottles to the nearest 25 m*l*. After their estimations are recorded (to the nearest 25 m*l*), teams will use the I.V. bottles to verify the estimates. This activity could be an estimation contest with points awarded; so many team points for estimates within 25 m*l*, fewer team points for estimates within 50 m*l*, etc.

2. Estimate the amount of liquid in partially filled containers of known volume. Give one estimate in liters and one in milliliters for each container. After estimates are recorded, measure by pouring into calibrated containers. This may be an estimation contest with team points determined on a scale of so many points for estimates within 1 *l*, 500 m*l*, 100 m*l* . . . 10 m*l*.



3. Determine the volume (in ml and in cm^3) of objects by noting the amount of water displaced by the object. The objects may be regular or irregular shapes made of modeling clay or other small, *sinkable* objects. Estimate the volume of the objects in milliliters and in cubic centimeters. Verify the estimates by immersing the objects in water in a graduated container. Calculate the difference in the water level to find the object's volume in milliliters. Students may already know 1 cm^3 of water is 1 ml, but if they don't, some measurements of the regular objects may be used to calculate the capacity in cubic centimeters. This result should be compared to the volume in milliliters. After discovering the relationship, the cubic centimeters in the irregular objects can be found easily.

4. Estimation Contest: A set of calibrated measuring containers and a collection of containers of varying sizes and shapes will be needed. (Include bottles that contained shampoo, mouth wash, hand lotion, detergents; ice box containers; jars; syrup bottles; milk cartons, etc. Some should be decorative (irregular), but some should have a simple, more common shape. Arrange the containers in pairs, so that within the pair the containers will have different volumes, but not so different that it is obvious which is larger. By estimation students guess which container in each pair has the greater volume. After recording their guesses, students will use the calibrated measuring containers to verify their guesses. A scoring system may be used to determine the "Champion Guesstimater."

5. Test Your Eye Game: Materials include one graduated container, a set of three glasses distinctly different in shape, a set of three bottles distinctly different in shape and an unmarked container capable of holding up to two-thirds of the capacity of the graduated container. Game procedure: (1) Put whatever amount of water you wish in the unmarked container, (2) pour *all* of that water into the three glasses so that each glass has the same amount. Pouring back and forth to adjust the amount is permitted if the graduated container is not used. (3) Check your result by pouring the water, one cup at a time, into the graduated container. Record the results; next, play the same game using the set of three bottles.

6. Make a cubic decimeter by cutting out six squares each 10 cm by 10 cm and taping the squares together to form a cube. What is another name for the capacity of the cubic decimeter? Verify by filling your cube with a quantity of beans which have been measured in a standard liter container. Ask students to find a way for measuring $100 cm^3$, $200 cm^3$, etc., using their own dm^3.

CONCEPT IV: VOLUME

LEARNING LEVEL E: APPLICATION

1. Supply students with a set of 3-D solids of various sizes and shapes such as cubes, rectangular prisms, triangular prisms, spheres, cylinders, etc. Cardboard boxes of varying sizes and shapes may also be used. Students need metric rulers. A decision must be made as to whether to provide formulas to the students. Ask the students to *measure the figures*, then calculate the volumes. (A review activity may be to ask students to determine the surface area. Another approach may be to ask students to draw on paper a "cover" for the entire 3-D figure.)

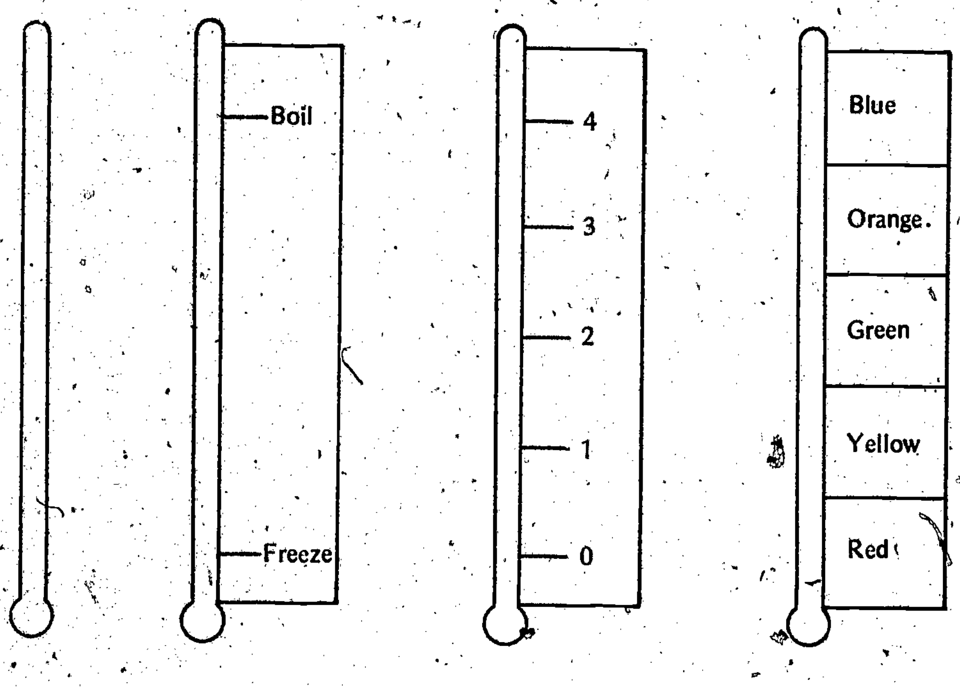
2. Play "Mystery Measurements" game using volume measurements. See directions for the length/applications activity number 5. (p. 19)

3. Students may indirectly measure volume of an irregular solid rock. Pour water to a predetermined point in a graduated cylinder. Record the predetermined level of the water. Immerse the rock in the water. Note the change in water level and record the new level. Determine the volume of the rock in milliliters.

4. Ask a team of six students to divide an unspecified quantity (approximately a half liter) of fruit juice *equally* among the team members. Provide the team with (clean): (a) 100 m*l* graduated cylinder, (b) 10 m*l* graduated cylinder, (c) a dropper, and (d) six cups of different sizes and shapes. Upon successful completion of the activity, permit the team to drink the juice!

CONCEPT IV: TEMPERATURE

1. Use an ungraduated liquid-in-glass thermometer to make arbitrary units of temperature. The ungraduated 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. Subdivide the distance along the stem into equal "units" between the two "fixed" points. Numbers may be assigned to specify points on the scale. Keep in mind that number skills are needed here; the five- and six-year-olds may use a color-coded temperature scale (See diagram.).



2. Have the learner measure the temperature of two pans of water. The temperature of the two pans should differ by about 10°C. Then give the child a third pan of water that is still another temperature. By feeling the water the learner estimates the temperature of the water in each pan. The learner will order the three pans of water from the coolest to the warmest. Verification of the ordering is determined by the use of the student-made thermometer.

3. Have students estimate the temperature by feeling, then by using a Celsius thermometer.

   Group 1: cold tap water, hot tap water, ice water, ice water with salt

   Group 2: air temperature in the classroom near the ceiling, in the classroom near the floor, surface of a radiator, hallway, outside temperature in the sun, outside temperature in the shade, in a refrigerator, in a freezer.

4. Recording the daily temperature could provide a use for the thermometer the student has made. The Celsius thermometer could be used instead.

5. Ask students to use a Celsius thermometer to measure the temperature of water at five minute intervals. Place boiling water in containers, such as coffee mug, styrofoam cup, tin cup, aluminum pan, thermos jug, ordinary bowl, heavy soup bowl. Let the water stand, take readings at five minute intervals and record the results. Use equal quantities of water. Graph the results. Predict the results if you were to start with ice water.

PROGRAM IMPLEMENTATION

The decision to "go metric" is a major decision that involves the total school district. The success of a curriculum change of this scope depends on support and cooperation at all levels in the district.

ADMINISTRATIVE DECISIONS

While school systems have differing problems related to the implementation of curriculum changes, there are certain areas of concern that are common to all. The district superintendent is the person who has the legal status to make curriculum decisions. Therefore, it is imperative that the superintendent and his administrative staff have a real *understanding* of the project including the demands on staff time and the cost commitment involved. Some of the costs to be considered are: 1) compensation of release time and/or money to properly implement the change; 2) needed consultant assistance; 3) appropriate in-service education; and 4) new material requirements.

STAFF INVOLVEMENT

"Going metric" is a decision that will involve the total school staff: principals, supervisors, custodians, bus drivers and cooks, as well as teachers and students. Common staff-oriented concerns are: 1) a lack of in-depth knowledge about curriculum goals; 2) apathy; 3) opposition to change usually because the need to change is not clear; 4) a lack of process skills; 5) a lack of exposure to exemplary models; and 6) a lack of involvement in the decision-making process. Many of these concerns can be alleviated by involving administrators, local curriculum specialists and teachers from all disciplines, K-12, on a curriculum committee that will develop curriculum meeting local needs. This kind of broad-based committee will strengthen the interdisciplinary approach within the school program as it uses this opportunity to look at the present curriculum and to make needed changes at all levels.

COMMUNITY INPUT

Community input may be gained through a district advisory committee made up of the lay public, school board members, parents and students. Such a committee will not only help plan the school curriculum, but also assess the needs of the general adult community and recommend programs for developing awareness and education.

SUCCESSFUL IMPLEMENTATION

To make a curriculum change like "going metric" successful, it seems essential not only to develop a curriculum that meets local needs, but also to construct a specific strategy for implementing it. This could include identifying all groups that will experience the impact of the change, developing a hierarchy of responsibility of individuals involved in the change, identifying the components of the program, constructing a timeline to be followed, obtaining all required guides, materials and equipment before beginning, and above all, insuring that the philosophy and objectives of the change are understood by all concerned.

IN-SERVICE

An important part of the preparation for "going metric" will be to insure that all teachers are familiar with and confident in using the metric system. The aforementioned curriculum committee can be of great assistance in anticipating in-service workshop needs and helping plan the workshop. (It is encouraging to note that the experience in some districts suggests in-service programs on metrication do not need to be extensive in time or cost.) Identified needs to be met by the workshops may include some background in learning measurement theory, teaching measurement strategies, choice of teaching materials and/or factual information about the International Metric System.

MATERIALS

Teaching measurement with metric can be done effectively with relatively low-cost materials. Some metric instruments are needed, but one inherent advantage of the "hands-on" approach is the opportunity to have students make their own measuring instruments. Hence, two minimal lists of materials are suggested here. (A few textbooks and a greater number of supplementary printed materials presenting the metric system are available now. Those used as references for this handbook are listed in the bibliography. The Oregon State Textbook Commission has adopted a policy statement directing the revision of textbook selection criteria to be effected for the November, 1976, adoptions. The revised criteria will call for textbooks that present the metric system as the primary measurement system.)

COMMERCIAL MATERIALS

Some commercial materials essential for teaching measurement with metric are:

Meter sticks, metric rulers, metric tape measures, metric trundle wheels, calipers;
Balance scale with set of metric weights (1 g to 1 kg), platform scale in metric;

Calibrated beakers, flasks, vials, cylinders;
Set of hollow geometrical models with metric dimensions;
Set of blocks with metric dimensions;
Celsius thermometer;
Metric graph paper;
Cuisenaire rods;
Funnels.

HOMEMADE, COLLECTED MATERIALS

Some homemade or collected materials for assisting teaching measurement with metric through the "hands-on" approach might include:

String, ribbon, adding machine tape, masking tape, paper clips (large size preferred), sticks, molding, dowels, straws, cups, bottles, jars, cans, tubes, toy blocks, milk cartons, ordinary water glasses, cottage cheese containers or other refrigerator dishes, area pattern blocks, newspapers, sheets of notebook or construction paper, floor tiles, linoleum blocks, geoboards, water (and sink), sand (and sand box), beans, rice, play doh, modeling clay, potatoes.

INVITATION—PILOT PROJECTS

The SDE Metric Coordination Committee anticipates the opportunity to work cooperatively on 1974-75 pilot projects with local district people in a manner that will be of mutual benefit. This handbook is a working paper and will be revised in the spring of 1975. The cooperative effort with a number of pilot projects will provide assistance from the SDE Metric Coordination Committee to the local district in carrying out the Oregon Board of Education policy on the transition to metric by assisting in curriculum development and planning, organizing workshops for teachers or general adult groups, securing resource people to assist with workshops, and cooperatively developing new activities or alternate approaches to teaching measurement.

At the same time this effort will give the local district an opportunity to assist with the evaluation of this working paper, evaluate the suggested approach in teaching measurement, evaluate the suggested activities, help to develop new activities, identify additional persons who may become resource personnel in other districts and assist with local and statewide metric awareness.

To become a teammate in this type of cooperative-mutual benefit pilot project, contact any member of the SDE Metric Coordination Committee.

GLOSSARY

A minimal glossary is presented. The handbook was written with as little technical terminology as possible. For the most part, metric terms are defined in the same context in which they are used.

DIRECT MEASUREMENT — A procedure for determining the measure of an object, its length, area, volume or mass, by a counting process to obtain the number of units of length, the units of area, the units of volume, or the units of mass, respectively; as opposed to obtaining a measure by an analogous measure such as measuring the length of the mercury column of a thermometer to determine temperature.

INDIRECT MEASUREMENT — A procedure for determining the measure of an object, its length, area, volume or mass, by measuring one property of one object to obtain the measure of a different property of a different object; such as an odometer "counts" revolutions to determine linear distance; also, a procedure for determining the measure of an object through the use of formulas and computational procedures.

CONSERVATION — Preservation of length, area, volume or mass when objects are changed by deformation, rearrangement, or partitioning; constancy of a quantity.

QUALITATIVE COMPARISON — Classifying (comparing) objects by noting the degree of a common property, such as prettiness, hardness, texture, color, taste, smell, etc; premeasurement classification.

QUANTITATIVE COMPARISON — Classifying (comparing) objects by size.

METER — The basic unit of length in the metric system; defined as 1/650 763.73 wave lengths in vacuum of the orange-red line of the spectrum of $krypton_{86}$.

LITER — The basic unit of volume (capacity) in the metric system; defined as 1000 cubic centimeters.

KILOGRAM — The standard basic unit of mass in the metric system; based on a cylinder of platium-iridium alloy kept by the International Bureau of Weights and Measures in Paris; the mass of one liter of distilled water at $4^{o}C$.

METRIC PREFIXES — In the metric system the value of the basic unit is changed by placing a prefix in front of it. The relationship of these quantities corresponds to the place values of the base ten numeration system. Some prefixes are used more commonly than others.

	tera		10^{12}	
	giga		10^{9}	not commonly used
	mega		10^{6}	
Greek prefixes	kilo	(thousands	10^{3}	
	hecto	(hundreds	10^{2}	not commonly used
	deka	(tens	10^{1}	
Basic Unit	no prefix	(one		
	deci	(tenths	10^{-1}	not commonly used
Latin prefixes	centi	(hundredths	10^{-2}	
	milli	(thousandths	10^{-3}	
	micro		10^{-6}	
	nano		10^{-9}	
	pico		10^{-12}	not commonly used
	femto		10^{-15}	
	atto		10^{-18}	

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"1 . . . to Get Ready, a Selected Bibliography on Metrication," To obtain, write to: Joint Committee of AASL/NCTM, 50 East Huron Street, Chicago, Illinois 60611, (5 for $1)

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