Some Comments on Methodology

1. Think Metric: 100% Immersion

There is consensus that the best approach to teaching and learning the metric system is by 100% conversion. It is unnecessary and unsatisfactory to teach a dual system. In particular, conversion from metric to Imperial units, and vice versa, is awkward, memory-taxing, and conceptually disruptive.

If measurement is being introduced to a Grade 1 class, only metric units should be used; if the advanced grades have been using Imperial units, they should be given a "crash" transitional programme to develop a background in metric units and then carry on exclusively with the metric system. (Adults will probably want to make comparisons to the Imperial system because it is an engrained part of their thinking.)

2. Learn Measurement by Measuring

The best cardinal capsule for the method of teaching and learning measurement is the Dewey principle, "Learn by doing." Measure, measure, measure.

3. Conceptualization of Measurement

How does a pupil develop the concept of measurement? What is the learning pattern? Consider the following four steps:

A. The identification and understanding of what is being measured. We measure different attributes, each distinct and discrete, e.g., length (1-dimensional), area (2-dimensional), volume (3-dimensional) time, speed (length/time), acceleration, force, work, power, etc. Confusion as to what is being measured leads to very muddled thinking. We teach this phase in elementary grades by using examples: length refers to our height, the width of the room, the depth of the sea, how far we can step, how high we can jump, the distance to the zoo, or to the movie, how long the worm is, the thickness of a book, the distance around the yard. We sharpen our understanding of the attribute being measured by comparison: John is taller than Jim, the door is twice as high as it is wide, it is further to Edmonton than to Calgary, etc. Further understanding is developed by ordering various objects according to some measure, e.g., arranging rods in order of length, arranging cups in order of capacity, arranging stones in order of mass.

B. Identification and selection of a unit. An appropriate unit must possess the same attributes as the one being measured. You use a toothpick, or a bobby-pin or a piece of string to measure length because they have the common attribute of length. Appropriate units may be non-standard and we usually (but not always) begin with non-standard units to accentuate the understanding of what we are measuring. However, we soon discover the inadequacies of non-standard units and introduce standard units. Metric, of course.

C. Measuring. The actual activity of measuring involves counting the units. In every case, we are faced with the problem of counting part of a unit -- part of a centimetre, or of a gram, or of a second. Counting of units is facilitated by using scales - really number lines with points matched to the number of units. The reading of scales, or rulers, or clock faces, or dials, needs to be carefully developed. On the metric system, parts of a unit are in the decimal system of notation rather than in the fractional system. We develop a thinking pattern of "two point three kilograms of meat" (2.3 kg). We subdivide in multiples of ten rather than in halves, quarters, eighths, etc.

D. Symbolization. Finally we express in some meaningful way the measurement. In the metric system. The problem of symbolization has been carefully considered for universal application and understanding. The SI conventions for symbolization should be meticulously followed.

4. The Use of Estimating

The practice of estimating a measurement is educationally very worthwhile. It promotes and augments conceptualization. It reinforces the imagery of the unit that is being used, it makes one "think" of the attribute that is being measured.

Look (at the object to be measured) -- *Visualize* (the unit to be used) -- *Estimate* (really "counting" of units in your mind) -- *Measure* (using standard units and your skill of reading scales) -- then *Compare* (your measurements to your estimate) to sharpen and develop the whole conceptualization process.

5. Utilitarian vs Structural Approach

How should we select and sequence measurement concepts? By their utilitarian value or by a rational, structural plan? For example, should we teach centimetres, metres and kilometres only, because they are the units of length that are commonly used, or should we teach all the subunits from milli- to kilo- (including decimetres, decametres, hectometres) because together they form a rational, well-structured system? The answer to this dilemma and controversy is probably some kind of synthesis. Certainly, attention must be given to the common, everyday application of units of measurement in order to have enough relevancy to maintain the familiarity and understanding of the units.

On the other hand, understanding is enhanced by having some rational structure. A good solution is probably to select one attribute--length is undoubtedly the best one--and teach all the subunits, millimetre, decimetre, metre, decametre, hectometre, kilometre, in order to have a complete example, a referent, for the decimal structure of the metric system. Even though a decametre may never be used in the big wide world of applied measurement, the unit has a place in the logical scheme of the metric system and should be taught for educational (cognitive) reasons.

Having one complete example, it is probably unnecessary to include all the subunits in the measurements of other attributes, e.g., in mass, the units of kilogram, gram, milligram and megagram (tonne) will suffice.

6. Appropriate Teaching (learning) Materials

Teachers should select materials that relate clearly and directly to the ideas that are being taught. Rulers are a good example. If the centimetre unit is being introduced, the ruler should clearly and directly show the centimetre scale; it should not be obscured with millimetre, decimetre or metre markings. If measurement using decimetres to one place of decimal is being taught, the ruler should show decimetre markings with each decimetre divided into decimal parts (called centimetres!).

7. Decimal Notation vs Fractional Notation

Because the metric system is based on powers of ten, we should capitalize and exploit this principle. Parts of a unit are expressed by decimals. In most cases each place of decimal can be associated with a subunit, e.g., 6.75 m means 6 metres, 7 decimetres and 5 centimetres. The fractional notation 6 3/4 m does not have this added association to subunits.

Fractional notation for parts of a unit should be avoided with the exception perhaps of ½, ¼ and maybe other unit fractions. These examples have a "visual imagery" impact and are therefore meaningful. But decimal notations will have greater dividends and lead naturally to other important ideas such as precision.

Decimal notation should be introduced in specific context. For example, we have always introduced two places of decimals in the context of writing dollars and cents. "Two dollars and sixty-five cents" is written as "$2.65." In the same way "Two metres and sixty-five centimetres" can be written as "2.65 m."

8. Precision and Approximations

All measurements made by you and me and our pupils are approximations. (The only exact measurements are those that are defined, e.g., the length of 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels 2_{P10} and $5d_5$ of the krypton-86 atom is exactly 1 metre). We should avoid saying "Johnny is exactly 135 centimetres tall" (or even 1 352 millimetres!).

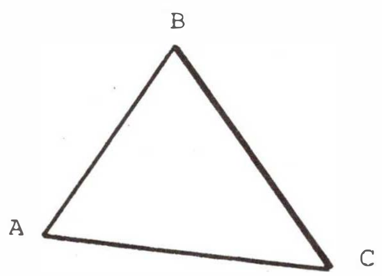
The idea of approximate measurements leads us to a consideration of precision, or "tolerances" as the tradesmen and engineers would say. This is an important educational idea - one that we have practically ignored in elementary grades.

Any notation of a metric unit gives the precision of the measurement, e.g., 1.925 m (my height) is a measurement precise to the nearer millimetre.

This attention to precision will lead in higher grades to the idea of scientific notation and significant digits.

9. "Ragged" Decimals

Before measures can be added or subtracted, they must have the same degree of precision. For example, consider the following problem:



If Amy measured the side AB as 2.4 m and Betty measured the side BC as 2.78 m and Christine measured the side AC as 2.923 m, what is the perimeter of the triangle?

2.4 m
2.78 m
2.923 m

?

Do we merely fill in the gaps in the "ragged" decimals with zeros? This ignores the precision of each measurement. Amy was content to measure to the nearer decimetre, Betty to the nearer centimetre, Christine to the nearer millimetre. In order to find the perimeter to a known degree of precision, either Amy and Betty should remeasure and use the same precision as Christine did, or we must reduce the precision of the last two measures to Amy's standard, i.e.,

2.4 m
2.8 m
2.9 m

10. Problem Solving

Most of the mathematical problems in elementary textbooks (and in real life) involve measurements. As we look at methodology for teaching measurement, it is therefore relevant to look at the methods used for problem solving.

The usual initial step in solving a math problem is to formulate the problem situation, that is, to determine the essential components of the problem. When measurement is involved, it is useful at this stage to identify, select and visualize the units of measurements. Very often a diagram is a possibility.

The next step is usually to translate the problem situation into a mathematical sentence. Here, a clear understanding of the units used is important. Precision of units should be consistent.

The next step is usually computational. The comments made above in sections related to decimal notation, precision and ragged decimals are relevant.

Finally, in the interpretation of the solution to the problem, the complete understanding of units of measurement play an important part.

The work in problem solving will mean that decimal computation will be emphasized with a corresponding de-emphasis for fractional computation.

11. Concomitant Referents: All Subject Areas

As the change is made to the metric system, teachers should be aware of the appearance of metric referents in the environment. Metric units will appear more and more frequently in the supermarket and on packaging. Watch for them -- refer to them.

Although the math and science teachers will probably be the "experts" in metrication, all teachers should be informed of the basic principles of the metric system. Maps in social studies can easily be changed to metric by changing the scale; references to measures in language and reading should be interpreted in metric terms. Of course, many references are merely expressions and carry with them little measurement connotation, e.g., "There was a crooked man, who walked a crooked mile" or "I love you a bushel and a peck." Do not destroy the charm of these euphemisms by insisting on the metric translation "I love you 36.368 72 litres and an additional 9.092 18 litres."

From *Think Metric, a Workshop on the Metric System of Measurement*, prepared by Sidney A. Lindstedt, Consultant, Alberta Department of Education.