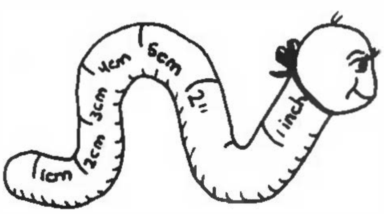
Increasing the application of math to "real world problems" was the central discussion point at four workshops held this summer by the National Science Foundation (NSF). There was a consensus at the meetings to apply math to real situations, not just in the physical world, but also in other sciences, such as geography, biology, population studies, and statistics, says Lauren Woodby, NSF precollege math specialist. This shouldn't be presented through "phony problems", he says, but should involve students in solving problems about their world. He also believes that the new math concern for stimulating more capable students is now being replaced by a goal of math literacy for all students. All of those who commented on math teaching for *EDUCATION U.S.A.* agree that teacher training is a high priority for introducing any changes.

Emphasis on the application of math will get a natural boost from the conversion to a metric system, according to Gates. "Learning the metric system is a more practical exercise than worrying about base and sets," he says, and he predicts that the metric conversion will go ahead even if Congress is slow to approve it. Only three states have moved to introduce the metric system into education, but Ohio is now using road signs with both the metric and English systems, and National Instructional Television is preparing film materials for schools on the metric system.



Inching our way toward the metric system

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"What is heavier, a pound of gold or a pound of feathers?"

"They both weigh the same," answers the bright child in whom we have carefully nurtured logical thinking.

"Wrong!" we reply. "A pound of feathers is determined by avoirdupois weight and measures 7,000 grains. A pound of gold is determined by troy weight and measures 5,760 grains. Thus a pound of feathers is heavier. Clear? Let us try once more. What is heavier, an ounce of gold or an ounce of feathers?"

"An ounce of feathers?"

"Wrong!"

"They both weigh the same?"

"Wrong again! A pound of gold consists of 12 ounces because it is determined by troy weight. Therefore an ounce of gold is equal to 480 grains. But there are 16 ounces in an avoirdupois pound. Therefore an ounce of feathers equals 437.5 grains."

It should come as no surprise that many people in North America have ceased all critical thinking with respect to measurement. A full-page advertisement for a certain small car in the 18 October 1971 issue of *Newsweek* boldly proclaimed a 57-inch overall outside width while it is a full five feet across on the inside! How many readers noticed the discrepancy?

Anyone who feels smug and confident regarding his knowledge of the North American system of weights and measures is invited to test his mettle on the following questions:

1. How many cubic inches are there in a gallon?
2. What is the difference between a liquid quart and a dry one?
3. How many square feet are there in an acre?
4. A common aspirin tablet is five grains. How many scruples does that represent?
5. What is the number of pennyweights in a troy ounce?

There will be a few who can answer all the above correctly. Yet the list could have been made much longer and more difficult by including references to rods, furlongs, square perches, poles, chains, cord feet, fathoms, cables, nautical miles, leagues, pecks, gills, drams, hogsheads, and barley corns. And it must not be overlooked that though a bushel generally represents 60 lb. avoirdupois, it is equal to only 48 lb. of barley, 32 lb. of oats, 56 lb. of rye or Indian corn. And do not forget the regional differences. In Massachusetts a bushel of potatoes is 60 lb. but only 56 lb. in North Carolina or West Virginia.

Is it any wonder that 14 countries are presently preparing to "go metric" and join the 114 countries and territories that have adopted the metric system already? Increasing world trade and the fact that Britain is in an advanced stage of change-over from the inch-pound to the meter-gram system make a similar change mandatory for the economic survival of the few remaining nonmetric countries (see Appendix A). Most think as Canada (*White Paper*, 1970, p.5):

> The government believes that adoption of the metric system of measurement is ultimately inevitable - and desirable - for Canada. It would view with concern North America remaining as an inch-pound island in an otherwise metric world - a position which would be in conflict with Canadian industrial and trade interests and commercial policy objectives. The Government believes that the goal is clear, the problem lies in determining how to reach this goal so as to ensure the benefits with a minimum of cost.

If such governments are correct in their assessments, then the need to begin this process of change as quickly as possible is obvious. The longer the decision is delayed, the more the eventual cost of the change will be increased.

The implications for the educational system are clear. The children presently in school will be in their early 30s in the year 2000. Presumably the whole world will be metric by that time. Inches, pounds, and yards will have gone the way of the fountain pen, the kerosene lamp, and the log cabin: picturesque memories of the past, surviving in a few standard expressions and in museum exhibits, but otherwise of historical interest only.

In preparation for that time, there is an immediate need for greater emphasis on teaching the metric system and a consequent need for retraining teachers and revising books. This is urgent already because of the years that elapse between the introduction of new texts and the graduation of the students who have used them.

As soon as primitive men learned to speak and communicate, a need for expressing quantities must have arisen. No doubt the first expressions were vague and inexact, but they served a purpose, just as similar statements of measurement serve a purpose today. We are still told to gather an "armful" of wood for the fire and to add a "handful" of flour or a "pinch" of salt to a certain cooking recipe. The grocery store may advertise that a "truckload" of watermelons has arrived just in time for the weekly special. The term "truckload" serves a purpose because no one except the storekeeper cares whether that means 600 watermelons or 1000. All these measurements are easy to visualize and often directly relate to physical experiences. A nomadic Eskimo reckons distances by so many "sleeps". A German farmer may explain that he owns six "mornings" of land, meaning the land area that can be plowed by a man in six mornings. We do comparable things in North America when we measure distance by stating that it is a "three-hour drive" or when we measure areas by "city blocks". Sometimes such measurements survive in our language even though they can no longer be easily visualized. Electoral districts are called "ridings" from the distance a man could cover on horseback. And just as primitive man developed new measures as the need arose, so do we: we talk about a "pack" of cigarettes and a "roll" of paper towels.

But such inexact measures were hardly sufficient for trade or barter; they left too much room for disagreement because they meant different things to different people. Even where agreement existed, it still could be very confusing. For example, a last (load) of herring was 12 kegs, but a last of gunpowder was 24 kegs. A last of brick was 500 bricks, but a last of tile was only 144 tiles. A last of wool was 12 sacks.

If one goes to a marketplace in Europe, one can still buy goods by the "ell". An ell of cloth is a length of cloth stretched between the hand and the shoulder. This measure survives in our word elbow. But when purchasing by the ell, watch the salesman closely to see that he indeed stretches his hand and arm completely while measuring your purchase. Preferably buy from people with long arms and under no circumstances buy elastic that way.

To make trade possible, a local baron or chieftain often established certain standards of measurement. His foot was always a popular standard. So was his thumb. A certain Anglo-Saxon king defined the yard as the length of his girth. Picture the foot-, the thumb-, and waist-measuring ceremonies. Imagine all the resulting confusion. Not only did these measures differ from place to place, but also they changed with the advent of any new ruler. And life expectancy was rather short in those days.

Charlemagne was among the first national rulers in the western world who attempted to create order from this confusion of weights and measurements. Tradition has it that the French foot of 12.79 inches was the exact measurement of Charlemagne's extremity. He failed, as did many governments after him, until the 18th century came around. As long as trade occurred primarily at the local level, the situation was not disastrous. People did not question why cloth should be measured by the ell, land by rods, and a horse's height by hands. Converting from one measure of length to another was difficult because our number system with Indian-Arabic numerals had not yet spread over Europe.

With the growing acceptance of the decimal system, the beginning of science and industry, and the development of more powerful national governments that were extremely interested in the flow of goods for purposes of taxation, the situation changed. Voices became adamant in favor of a more rational system of measurement, a system that would be universal and that would have the various units of length, area, and capacity related in a simple manner. If the new system was to be truly universal, with all measures related as much as possible, then the selection of a basic unit was important. Several possibilities were considered. The time of the swing of a pendulum is directly related to its length. The length of a pendulum that would describe one complete swing per second was suggested as the fundamental unit of the new linear measure. But that would hardly be universal, critics pointed out. A pendulum swings faster at the north and south poles than it does at the equator. Moreover a measure defined in that way would presuppose a definition of a second, which was in itself a questionable measure.

A second suggestion for a unit was a sector of the equator. But the length of the equator would be difficult to measure. Besides, few countries touch the equator, and thus the new measure would not be truly universal.

Finally, a third proposal was agreed upon. *A portion of a meridian would be used as a general standard.* Although few countries were on the equator, every nation was on some meridian. (It was generally accepted at that time that every meridian was of exactly the same length as any other meridian, a belief that was later proved wrong.) But what portion of the meridian should be used? One millionth, a ten-millionth, a hundred-millionth? Practical aspects of daily life as well as trade and commerce had to be taken into consideration. Since the approximate circumference of the earth along a meridian was already known from astronomical calculations and since dividing that length by 40 million would yield a length of about one yard, that was the unit decided on for the basic measure. An intermediate standard based on the astronomical calculations was accepted for the time being.

Meanwhile a committee of scientists was appointed to determine the exact distance from Dunkirk to Barcelona. It was known that both cities were on the same meridian and both were at sea level. Therefore multiplication of that distance by a proper constant would yield the figure for the circumference of the earth. It took seven years for the scientists to accomplish their mission, and it involved many dangers and hardships. This was a time of revolution and turmoil. But when all calcualtions had been completed, it turned out that the astronomical observations had been surprisingly accurate. The intermediate measure of length that was based on it differed less than one-half of one per cent from what the surveyors found. Nevertheless, the new standard was quickly made into law, and the intermediate one abolished. The new measure was called the meter (in French metre from the Greek metron, measure). In turn the basic measure was multiplied or divided by powers of ten to establish other linear measures. Greek prefixes to the term meter were used to denote multiples of the unit, while Latin prefixes indicated subdivisions.

The result was as follows:

1 kilometer	=	1000 meters
1 hectometer	=	100 meters
1 dekameter	=	10 meters
1 meter	=	1 meter
1 decimeter	=	0.1 meter
1 centimeter	=	0.01 meter
1 millimeter	=	0.001 meter

For a unit of area the square dekameter was decided on. A square meter would have been too small for practical purposes, a square hectometer too big for this land where fields were small. A square 10 meters by 10 meters roughly equaled the size of a woman's herb and vegetable garden, thus making it easy to visualize. The new unit of area was called an are.

At first glance one would expect an extension of this new measure by the proper prefixes to create the whole increasing and decreasing sequence. But a square equal in area to 10 are would have the length of $10\sqrt{10}$ meters (approximately 31.6 meters), thus upsetting the simplicity of the system. Hence acceptable extensions of this measure are the following:

1 hectare	=	100 are
1 are	=	1 are
1 centiare	=	0.01 are

Of course one can always speak of a square kilometer or a square meter if the needs require it.

The basic measure for volume (capacity) posed no great difficulty. Reason demanded that it be defined in terms of the meter. One cubic meter was clearly much too big (approximately 250 gallons); a cubic centimeter too small. Hence the only reasonable choice was the cubic decimeter, which is equal in capacity to about one quart. The new measure was called a liter (French: litre). Again the derived measures followed the same pattern as for the meter:

1 kiloliter	=	1000 liter
1 hectoliter	=	100 liter
1 dekaliter	=	10 liter
1 liter	=	1 liter
1 deciliter	=	0.1 liter
1 centiliter	=	0.01 liter
1 milliliter	=	0.001 liter

Convenient though the liter was for purposes of measuring liquids, it was not satisfactory in all cases. For firewood, for instance, a cubic meter would appear much more reasonable. It was adopted as such and called the stere (from Greek stereo: solid). The stere was used nearly exclusively for wood, and as a result no names for powers of the stere were ever adopted because there existed little need for them.

To us, living in the second half of the twentieth century, the unit of weight (more properly, mass) agreed on is surprising because it is so small. But at the time the unit was selected relatively few goods were sold by weight. Notable exceptions were precious metals and spices, which were sold in small quantities, of course, but which played a very important part in the economic structure of the country. And the scientists themselves often dealt in very small quantities in their laboratories. At any rate, the unit of mass selected was the mass of one cubic centimeter of water at its greatest density. This was called the gram (French gramme). Again the usual derivations were agreed on:

1 kilogram	=	1000 grams
1 hectogram	=	100 grams
1 dekagram	=	10 grams
1 gram	=	1 gram
1 decigram	=	0.1 gram
1 centigram	=	0.01 gram
1 milligram	=	0.001 gram

For the measure of angles the traditional 90-degree angle, called a grade, was divided into decigrades, centigrades, and milligrades. (It is for that reason that the term "centigrade", as applied to temperature, is incorrect. It is more properly called Celsius, after the Swedish scientist Anders Celsius, who created that particular temperature scale.) The renaming of angles never caught on, however, because of the cumbersome fractions involved. For instance, the traditional 60-degree angle became 66 2/3 centigrades. It is clear that this change was no improvement. (See Appendix B for a list of some people and dates associated with the development of the metric system.)

What most hampered the acceptance of the metric system in non-French countries, however, was the excessive zeal displayed by the metric creators in other areas. They fashioned a new "week" of ten days' duration, thus doing away with the Sabbath. They began an entirely new calendar starting with the year one. As a result the whole metric system came to be associated in the eyes of many with a "godless atheism", a system "conceived in sin and born in iniquity", as some put it. Combine this with a common veneration for matters old and familiar as well as the distaste of the English-speaking world for anything French that resulted from the Napoleonic wars.

Now Great Britain has discarded the inch-pound system, and Canada has declared its intention to go the same way. The time for decision in the United States has come. On August 6, 1971 Senator Pell of Rhode Island introduced a bill (S.2483) "to provide a national program in order to make the international metric system the official and standard system of measurement in the United States and to provide for converting to the general use of such system within 10 years after the date of enactment of this Act." The bill has been passed by the Senate.

The ultimate decision to GO METRIC appears inevitable. Teachers would do well to start acquainting their students with the system more thoroughly than in the past. THINK METRIC should be the only slogan in the teaching of measurement for the child who will spend most of his adult life in the 21st century.

APPENDIX A

The only countries in the world not committed to the metric system are: (De Simone, *A Metric America,* 1971):

Barbados	Jamaica	Naura	Trinidad
Burma	Liberia	Sierra Leone	United States
Gambia	Muscat and Oman	Southern Yemen	
Ghana		Tonga	

APPENDIX B

Some People and Dates Associated with the Development of the Metric System

1586 - Simon Stevin (1548-1620) - Dutch mathematician publishes a pamphlet *Thiende* which deals with decimal fractions. He advocates decimal coinage and decimal weights and measures.

1670 - Gabriel Mouton (1618-1694) - Vicar in Lyon generalizes some of Stevin's proposals and proposes a comprehensive decimal system that uses as a basic measure the length of an arc of one minute of a great circle.

1789 - Charles Maurice Talleyrand (1754-1838) sponsors the original draft to the French National Assembly for introducing a uniform system of measures.

1790 - Antoine Laurent Lavoisier (1743-1794) is appointed secretary and treasurer of the committee to secure uniformity of weights and measures. As such he has a great influence on its acceptance. He dies under the guillotine in 1794.

1792-1799 - Jean Baptiste Delambre (1749-1822) - French astronomer measures the arc of the meridian from Dunkirk to Barcelona. This becomes the basis for calculating the meter.

1793 - Joseph Louis Lagrange (1736-1813) French-Italian mathematician becomes president of the commission for the reform of weight and measures. This committee later introduced the metric system to France and other countries.

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