No Child Left Behind: Teaching the Metric System in US Schools

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Abstract

This article addresses the importance of the International System of Units or SI. It compares the metric system with the customary system of weights and measures. There is a brief discussion involving the evolution of the decimal system from Roman numerals to Hindu-Arabic numerals followed by a longer discussion involving the evolution of SI. Closing arguments support the full adoption and mandatory teaching of the metric system in the United States.

Keywords: SI, metric system, customary system, decimal system, weights, measures

1. Introduction

"In some countries the electrical system runs on 110 Volt and in others it is 220 Volt. In some countries the electricity runs on 50 cycles per second and in others it runs on 60 Hertz. The internal telephone systems in some countries have 6 Volt, while in others it is 12 Volt. In some countries the zero is next to the one on the dial, in others it is next to the nine. In some countries ring-ring means the phone is busy, in others it means that the phone is actually ringing" (Heller, 1989, p. 18). And in some countries people drive on the right while in other countries they drive on the left.

But the greatest inconveniences and perplexities stem from different languages and different systems of weights and measures. "The several Nations of the World do not more differ in … Languages, than in the various kinds and proportions of … Measures" (Wilkins, 1668, p. 191). This situation is however improving as English becomes the lingua franca and as the metric system becomes the global standard. In fact, "the United States is now the only industrialized country in the world that does not use the metric system as its predominant system of measurement" (NIST, 2011).

There are times to lead and there are times to follow. It is time for the United States to follow the rest of the world by using metric units. This would facilitate both science and business. Why waste time and money on two sets of tools and two sets of books? The metric system is the International System of Units (SI). And fixing the standard of weights and measures is an enumerated Congressional power under the US Constitution. Congress could and should adopt SI now. "Metrology (or the science of weights and measures) attracts but few … (yet) commerce between nations is undoubtedly impeded by the existence of conflicting systems of weights and measures" (Evans, 1904, p.6).

2. The Metric System

The metric system "is founded on seven base units … that by convention are regarded as dimensionally independent" (Nelson, 1993, BG-15). These quantities, base units, and symbols are (in no particular order):

length, meter, m
mass, kilogram, kg
time, second, s
temperature, kelvin, K
electric current, ampere, A

amount of substance, mole, mol
luminous intensity, candela, cd

"All other units are derived units, formed coherently by multiplying and dividing units within the system without numerical factors" (ibid). Some examples of these quantities, derived units, and symbols are (in symbolic alphabetical order):

capacitance, farad, F
ionizing radiation, gray, Gy
frequency, hertz, Hz
work/energy/heat, joule, J
force, newton, N
pressure/stress, pascal, Pa
electrical potential, volt, V
power, watt, W

One noticeable oddity "of the metric system is that units named for specific people are written without capital letters … but their symbols are … capitalized" (Robison, 1993, p. 69).

"Supplementary units … are derived units having dimension 1 (so-called dimensionless derived units)" (ibid). "Dimensionless supplementary units include radian (rad) for plane angle and steradian (sr) for solid angle ... (but) angular degrees are permissible in appropriate contexts" (International System, 2006, p. 94).

"An important function of the SI is to discourage the proliferation of unnecessary units. However, it is recognized that some units outside the SI are so well established that their use is to be permitted" (Nelson, 1993, p. BG-16). These include: the second, minute, and degree with respect to plane angle; the hectare with respect to land area; the liter with respect to volume; the metric ton with respect to mass; and Celsius with respect to temperature. And although the second is the basic unit with respect to time, "other common time units such as minute, hour, and year will continue to be used in SI when appropriate" (International System, 2006, p. 94). There is some slight confusion since seconds and minutes can be used to measure either an angle or the time and since degrees can be used to measure either an angle or the temperature. But "for the measurement of time, there is no need for a table of metric-imperial equivalence. We should be thankful that our present non-metric system of time and calendar is universally adopted, thereby avoiding the chaos that would result from confusion in that sphere of our lives" (Wrigley, 2011, p. 57). The Western, Christian, or Gregorian calendar is widely accepted even though other calendars remain in use, e.g. Chinese, Hebrew, Indian, Islamic, etc.

Although there are seven base units in SI, "it is claimed … that five is the smallest number of base quantities that is sufficient to define all derived quantities and allows the description of all natural phenomena … length, mass, time, temperature and electric charge … The first four … coincide with the current list of base quantities in SI" (Kaptay, 2011, p. 242). There is a proposal to replace electric current with electric charge and to eliminate both the amount of substance and luminous intensity. But major alterations to the metric system are well beyond the scope of this study.

SI is widely accepted as is. And "designations of multiples and sub-divisions of any unit may be arrived at by combining with the name of the unit the prefixes deka, hecto, and kilo meaning, respectively, 10, 100, and 1000, and deci, centi, and milli, meaning, respectively, one-tenth, one-hundredth, and one-thousandth" (NIST, 2011). "Multiples and fractions … are normally restricted to steps of 1,000 indicated by prefixes" for numbers 10^6 or larger and 10^{-6} or smaller (International System, 2006, p. 94).

"There is (unfortunately) a widespread misconception that (the symbols of the) prefixes for positive powers of ten are all capitalized, leading to the use of K- for kilo- (H- for hecto) and Da- for deca-. Although this does seem like a useful idea, it is not correct" (Rowlett, 2005). Only the symbols of the "prefixes representing 10^6 or greater are capitalized … (and notice that) the kilogram is the only base unit whose name … contains a prefix" (Nelson, 1993, BG-16). Notice also that deka- is the only prefix with a two-letter symbol (da) thus avoiding confusion with deci- (d). The most common prefixes are (in order of magnitude):

yotta,	(Y),	meaning 10^{24}	deci,	(d),	meaning 10^{-1}
zetta,	(Z),	meaning 10^{21}	centi,	(c),	meaning 10^{-2}
exa,	(E),	meaning 10^{18}	milli,	(m),	meaning 10^{-3}
peta,	(P),	meaning 10^{15}	micro,	(u),	meaning 10^{-6}
tera,	(T),	meaning 10^{12}	nano,	(n),	meaning 10^{-9}
giga,	(G),	meaning 10^{9}	pico,	(p),	meaning 10^{-12}
mega,	(M),	meaning 10^{6}	femto,	(f),	meaning 10^{-15}
kilo,	(k),	meaning 10^{3}	atto,	(a),	meaning 10^{-18}
hecto,	(h),	meaning 10^{2}	zepto,	(z),	meaning 10^{-21}
deka,	(da),	meaning 10^{1}	yocto,	(y),	meaning 10^{-24}

This list was taken from Appendix C of the National Institute of Standards and Technology (NIST) Handbook 44; Specifications, Tolerances, and Other Technical Requirements of Weighing and Measuring Devices; General Tables of Units of Measurement; Tables of Metric Units of Measurement.

The etymology of these prefixes is somewhat confusing. Yotta and zetta are Latin whereas exa through deka are Greek. Deci, centi, and milli are Latin whereas micro and nano are Greek, pico is Spanish, femto and atto are Dano-Norwegian, and zepto and yocto are Latin (Bernklau, 2011). And there is some perplexity with regard to other matters as well.

"In computing, a custom arose of using the metric prefixes to specify powers of 2. For example, a kilobit is usually $2^{10} = 1024$ bits instead of 1000 bits. This practice leads to considerable confusion … (so) in 1998 the International Electrotechnical Commission approved new prefixes for the powers of 2" (Rowlett, 2005). But conversion from English units, Imperial units, or US customary units to metric units is generally a muddle. Specific discussions thus follow regarding common units for length, area, volume, mass, and temperature.

3. The Customary System

"The fundamental basis for the Statute System of England, and the measures of Wales and Scotland, is the Barleycorn. It is the Grain of an imported variety, not of an indigenous species … This new Barley was found to have a constancy, which when taken from the middle of the Ear, could be used to determine both measure and weight" (Ferrar, 2011, p.4). "In 1324, Edward II decreed that three barleycorns placed end to end would be the 'official' inch. After that, shoemakers began to use the barleycorn inch measurement. The largest foot was equivalent to 39 barleycorns (13 inches) and was designated as size 13. All other sizes were relative to this size 13 and differed by 1 barleycorn (or 1/3 inch) … With the rapid advancement in technology over the centuries, it is quite surprising that this same measurement system is still in use today" (Goonetilleke, 2003, p. 26). So, as in the distant past, a man's size 10 shoe equals 12 inches or 36 barleycorns never mind the corns on his feet!

Some other units are convertible to inches in multiples of 3. A palm is 3 inches, a span is 9, a foot is 12, a cubit is 18, a yard is 36, an ell is 45, and a fathom is 72 inches. But these multiples do not correspond to powers of 3, e.g. 9, 27, 81, 243, 729, etc.

Measurement in the US lumber industry is especially confusing. A 1 by 2 board is, for instance, ¾ by 1 ½ inches whereas a 2 by 8 board is 1 ½ by 7 ¼ inches. There are three general rules for converting from nominal to actual dimensions: (1) subtract ¼ inch from boards under 2 inches; (2) subtract ½ inch for boards under 8 inches; and, (3) subtract ¾ inch for larger dimensions (Engineering Toolbox, 2011).

With even less consistency, a rod (also known as a pole or perch) is 16 1/2 feet, a chain is 66 feet (4 rods), a furlong is 660 feet (10 chains), a mile is 5,280 feet (8 furlongs), and a league is 15,840 feet (3 miles). The title of Jules Verne's book, "Twenty-thousand Leagues under the Seas" published in 1870, refers to the horizontal distance traveled by the fictional submarine Nautilus. But some antiquated units are still used in both maritime and aeronautical navigation.

"Until the Second World War, most aviation outside America and the British Empire actually did use the kilometre for distances (and, consistently, metres for height), and indeed, for domestic aviation, Russia still does. It was only the post-war dominance of the USA in IATA (International Air Transport Association) and ICAO (International Civil Aviation Organization) that imposed nautical miles on an otherwise metric world" (Erithacus, 2010).

The knot is a unit of speed equal to one nautical mile per hour and the UK nautical mile is equal to 1.85318 kilometers (1.15151 miles). “Nautical miles measure distance. 1 nautical mile is the angular distance of 1 minute of arc on the earth's surface. As these differ slightly (6108' at pole and 6046' at equator) 6080' was adopted (this being its approximate value in the English Channel). The International nautical mile is (6076') 1852 metres (exactly), so is very slightly different from the UK nautical mile (1853.18 metres)” (Edkins, 2009).

With respect to length, width, and height, there is unfortunately much confusion. But matters are greatly simplified by the metric system with its single base unit for linear measure, the meter (3.28 feet).

With respect to area: a perch is a square rod, a rood is a rod times a furlong, and an acre is furlong times a chain. My home is for instance located on a five acre parcel, five chains by one furlong (330 by 660 feet). But in the metric system, the unit for area is the square meter (approximately 10.7639 square feet). And the hectare, although not technically part of the metric system, is defined as 10,000 square meters (approximately 107,639 square feet).

With respect to volume, the English system, the imperial system, and the US customary system are for the most part based on powers of 2. “Many cooking terms that you see in old recipes come from a medieval English 'doubling' method” (Pomroy and Naughtin, 2008, p. 1). They are literally a mouthful: 2 for a pony, 4 for a jack, 8 for a gill, 16 for a cup, 32 for a pint, 64 for a quart, 128 for a pottle, 256 for a gallon, 512 for a peck, 1,024 for a kenning, 2,048 for a bushel, 4,096 for a strike, 8,192 for a comb, 16,382 for a hogshead, and 32,768 for a butt/pipe.

It is important to remember that in the US liquid measure is one thing whereas dry measure is another, e.g. a fluid pint equals .4732 liters whereas a dry pint equals .5506 liters. In the UK it is an entirely different matter, e.g. both a fluid pint and a dry pint equal .5683 liters. An Imperial pint will therefore be the same size “whether it is beer or shrimps” (Edkins, 2009).

There is an old saying: “A pint’s a pound the world around.” And it is true in the US where 16 ounces are in a pound and 16 ounces are in a pint. But it is not necessarily true in the UK where 12 ounces are in a Troy pound and 20 ounces are in a pint in pubs and elsewhere.

It is also important to remember that an American gallon is only 3.7853 liters whereas an Imperial gallon is 4.546 liters. Thus the gas mileage listed on the window sticker of a new vehicle in Canada appears to be higher than in the United States!

The metric system is not perfect but it is simpler. “The metric unit for volume is the cubic meter, except for liquids, which are expressed in liters” even though liters are technically not part of the metric system (Robison, 1993, p. 68).

With respect to mass or weight, it is back to the barleycorn or “grain” which is the basis of three systems: Apothecary, Troy, and Avoirdupois. In each system, the grain equals 64.79891 mg. But other conversions are beyond the scope of this paper and probably the attention span of most readers. To confuse matters further, there is a long ton in the UK equal to 2,240 pounds and a short ton in the US equal to 2,000 pounds whereas the metric ton is 2,204.622 pounds (1,000 kg). And even though the metric unit for mass is the kilogram rather than the gram, the metric system is far simpler than any other.

“The kelvin (K) is the unit of absolute temperature and is an SI base unit” (UK metric association, 2011). But the word degree and the degree symbol are omitted as a matter of convention. Although “the degree Celsius (C), commonly called centigrade, is a derivative unit consistent with SI; the degree Fahrenheit (F) is not” (International System, 2006, p. 94). Converting from kelvin to Celsius or vice versa is simply a matter of subtracting or adding 273.15 degrees. Converting from Celsius to Fahrenheit or vice versa necessitates multiplying by nine-fifths and adding 32 degrees or subtracting 32 degrees and multiplying by five-ninths. Absolute zero is 0 kelvin, negative 273.15 degrees Celsius, or negative 459.67 degrees Fahrenheit. Pure water freezes at 273.15 kelvin, 0 degrees Celsius, or 32 degrees Fahrenheit. It boils at 373.15 kelvin, 100 degrees Celsius, or 212 degrees Fahrenheit (at one atmosphere of pressure). So Celsius does seem simpler than either Fahrenheit or kelvin at least insofar as water is concerned.

4. The Decimal System

Some mention should be made of Roman numerals. They were once used alongside English units just as the Latin language was once used alongside the English language. Although the Roman system was essentially a decimal (base-10) system, the Romans relied on a duodecimal (base-12) system for fractions to more easily accommodate fourths and thirds. The Roman numeral system lacked a zero. And it was not directly positional. There were no place values for ones, tens, hundreds, etc. Instead, the Romans used different symbols for different orders of magnitude. M, D, C, L, X, V, and I formed linear strings that represented cardinal numbers. But they were "meaningless without definitions of the individual symbols and a set of rules for performing arithmetic operations" (e.g. DD=M, XXXXX=L, XX+XX=XL) (Tabachneck-Schijf and Simon, 1996, p. 28).

During the Renaissance, Roman numerals were gradually replaced by Hindu-Arabic numerals. Leonardo Fibonacci (Leonardo of Pisa) "was one of the first people to introduce the Hindu-Arabic number system into Europe - the positional system we use today - based on ten digits with its decimal point and a symbol for zero … His book on how to do arithmetic in the decimal system, called Liber abbaci (meaning Book of the Abacus or Book of Calculating) completed in 1202 persuaded many European mathematicians of his day to use this 'new' system" (Knott, 2009).

5. The Evolution of SI

Although there is no doubt that the metric system "was first adopted in revolutionary France, the underlying ideas also came from England … The key principles … were proposed by Dr. John Wilkins in 'An Essay Towards a Real Character, and a Philosophical Language'" (Wilkins, 1668). And the following British scientists were honored in the metric system: Sir Isaac Newton (1642-1727) with the newton (N), the unit of force; James Watt (1736-1819) with the watt (W), the unit of power; Michael Faraday (1791-1867) with the farad (F), the unit of capacitance; James Prescott Joule (1818-1889) with the joule (J), the unit of energy; Lord Kelvin (William Thomson) (1824-1907) with the kelvin (K), the unit of absolute temperature; and Louis Harold Gray (1905-1965) with the gray (Gy), the unit of absorbed dose of ionizing radiation (UK Metric Association, 2011).

There were however exceptions to the rule including two French scientists: Blaise Pascal (1623-1662) honored with the pascal (Pa), the unit of pressure and stress; and Andre-Marie Ampere (1775-1836) with the ampere (A), the unit of electric current. Other exceptions included: the Italian Alessandro Volta (1745-1827) honored with the volt (V), the unit of electrical potential; and the German Heinrich Hertz (1857-1894) with the hertz (Hz), the unit of frequency.

"Harvey Neville … showed … 'that the metric system is English and not French in origin, while the so-called English system is a German invention … (and that) James Watt … originated and first published the decimal system of measurement'" (Williams, 1999, p. 313). But the founding fathers of America also deserved some credit.

Without the influence of Benjamin Franklin, Thomas Jefferson, and George Washington, the metric system would not have developed in France in the 1780s and 1790s. Both Benjamin Franklin and Thomas Jefferson served as ambassadors to France. They were also both active in the scientific community of France during their ambassadorial service: Franklin served from 1776 to 1784 and Jefferson from 1784 to 1789. Both men were active in promoting the ideas of decimal currency and decimal measurements to the French Royal court and to the scientific 'philosophes', who would later develop the decimal metric system (Naughtin, 2009).

The French indeed became the strongest proponents of the metric system. "During the French Revolution (1789-1799), members of the Paris Academy of Sciences turned their attention to the seemingly apolitical task of developing a new system of measurement … From the beginning, however, the metric system became embroiled in politics and controversy" on both sides of the English Channel and on both sides of the Atlantic Ocean (Monroe and Nelson, 2000, p. 20).

There were a number of objections. Lowis Jackson argued that "a binary subdivision is a far more civilized arrangement … while decimalization was favored by primitive races … no doubt, suggested to their uneducated minds by the possession of so many fingers" (Evans, 1904, p. 22). "Herbert Spencer … claimed that … the metric system is essentially imperfect … 'as 10 is divisible only by 5 and 2 (of which the remaining fifth is useless) … and halving only a makeshift fourth and no exact third'" (ibid, p. 19).

"The second report of the Standards Commission, presented to the House of Commons in 1869 … stated 'the natural inclination of the mind to halve and quarter continually exhibits itself in the subdivision of almost every base ... (and) the metric system does not afford the same facility'" (ibid, p. 20-21). Augustus De Morgan "recorded his opinion that 'the nomenclature would be found exceedingly inconvenient … (generally) ascending by Greek (prefixes) … and descending by Latin'" prefixes (ibid, p. 31).

In spite of such objections, "in 1866, Congress made the metric system legal in the United States" (Livingston, 1966, p. B-384). And in 1875 in France, seventeen countries including the United States signed the Convention du Mètre, also known as the Treaty of the Meter or the Metric Convention, which "established the metric system as an international system of measurement" (Shattuck, 2002, p. 466).

Almost a century later, "in 1960, the 11th General Conference on Weights and Measures changed the name of the metric system of units to 'le Systeme International d'Unites' or the International System of Units, commonly known as SI … (with) six basic units … the meter, kilogram, second, ampere, Kelvin, and candela. (And) in 1971, a seventh unit, the mole, was added" (ibid, p. 466).

"In 1975 the United States passed the Metric Conversion Act, which allows and supports voluntary conversion" (ibid, p. 466). It also "set a ten-year schedule for (complete) conversion" (Monroe and Nelson, 2000, p. 21). But "the Act of 1975 was amended by the Omnibus Trade and Competitiveness Act of 1988 that stated the metric system was (merely) 'the preferred system of measurements for trade and commerce'" (ibid, 2000, p. 22).

"In 1991 President Bush issued Executive Order 12770, which stated that the Commerce Department was responsible for directing and coordinating all federal agencies to convert to the metric system" (ibid, p. 22). And, now "the General Services Administration (GSA) … is leading the federal government's effort to shift the US gears from foot-pound-second to meter-kilogram-second" (Robison, 1993, p. 66). But even a gradual shift can lead to some grinding of the gears.

"Complicating conversion are the different ways to convert. Exact mathematical, or 'soft,' conversion merely changes the dimensions by use of multiplication and appropriate rounding (48 in. = 1,219 mm). Adaptive, or 'hard' conversion, changes mathematically and then adapts to a nearby round number (48 in. = 1,220 mm). Size substitution, another 'hard' conversion, changes to an existing standard size -- an easy-to-remember round number (48 in. = 1,200 mm)" (Silverberg, 1997, p. 43). "One of the biggest pitfalls in metric conversion is to rely on soft conversions and not hard conversions … (where) hard … refers to products manufactured to metric dimensions … (and) soft conversion(s) are metric in name only" (Robison, 1993, p. 69, 68).

Dealing with different systems of measurement can result in costly mistakes. One oft cited case involved a government contractor, Lockheed Martin, using English units and a government agency, NASA, using metric units. "Confusion between two measurement systems killed the mission of the Mars Climate Orbiter, a $125 million spacecraft, on September 23, 1999, during its entry into Mars' atmosphere" (Monroe and Nelson, 2000, p. 20).

This "mortifying … fiasco vividly demonstrates America's odd reluctance to fully embrace the metric system employed by every other industrial nation" (Petit, 1999, p. 63). Going metric all the way will not only eliminate much confusion, it will also "bring a welcome measure of relief to American exporters … (and) make it possible to sell our products directly abroad without further modifications" (Heller, 1989, p. 18-19).

"In 1790, George Washington (1732-1799), in his first message to Congress, reminded the legislators of their responsibility on weights and measures" (Naughtin, 2009):

> A uniformity of weights and measures is among the important objects submitted to you by the Constitution, and, if it can be derived from a standard at once invariable and universal, it must be no less honorable to the public council than conducive to the public convenience … Uniformity in the currency, weights, and measures of the United States is an object of great importance, and will, I am persuaded, be duly attended to.

6. Conclusion

"The United States is now the only industrialized country in the world that does not use the metric system as its predominant system of measurement" (NIST, 2011). "Complete conversion is probably unattainable; land titles in feet or acres might remain unchanged for generations" (Livingston, 1966, p. B-385). But waiting another century or two for the US to fully adopt SI simply will not do. This is the 21st century. And numerous programs are readily available online to facilitate conversion. Examples include:

http://www.metric-conversion-tables.com/
http://www.metric-conversions.org/
http://metricconversioncharts.org/

Outside the classroom, we as citizens should campaign for adoption of the metric system and support such organizations as:

http://gometric.us
http://metric.org
http://ukma.org.uk/

"Conversion in other countries has been successful only when there has been a mandated change overseen by the government" (Schmidt and Gwin, 1988, p. 9). "There is an inherent difficulty in changing something while it is being used. It takes planning and decisive action to avoid chaos … American conversion attempts relying on 'voluntary' – albeit funded – efforts by individual US government agencies, have twice been abandoned in midstream. All nations that have adopted the metric system have mandated its use. Nowhere has there been spontaneous or voluntary conversion" (Wunderlich and Bruschi, 2000, p. 96).

Britain adopted the metric system in 1971. But "no change in the use of weights and measures was made easily. Central government authorized changes by statute and also the appointment of inspectors; it defined standards by having a physical embodiment of each measurement in safe keeping. Industries decided whether to go fully metric or to convert existing imperial units into metric ones" (Lee, 2010, p. 20). Although conversion was not easy, it was nonetheless essential to accommodate not only the European common market but also the vast global market.

Like it or not, the metric system is now the preeminent system of weights and measures. Inside the classroom, we as teachers should require the use of SI in all of our courses and update our syllabi accordingly. But, in some quarters (or tenths), there is still an odd reluctance to embrace metrification. While advocates say it is the duty of schools to teach SI, detractors say: "This attitude is … only that of the propagandist for any particular 'cause'. The same claim is made by the advocates of total abstinence from alcoholic drinks, of the abolition of tobacco, of reformed spelling, of flag worship, etc. As with the advocates of other additions to the duties of the schools, the metric partisans have not yet put forth a convincing argument" (Rich, 1930, 606-607). It is however hard to argue against a clear mind, healthy lungs, phonetic English, sincere patriotism, and the metric system.

There are of course pros and cons with respect to any issue. The great merit of measurement reform is that it would no longer confuse generations of students year after year converting from one system to another. The main obstacle is that one generation would have to learn an entirely new system and that would require a tremendous effort. And if the metric system is adopted in the United States, within a generation or so, old English calculations would be unintelligible. But "the advantage of metric over the English system is roughly analogous to the advantages of the modern English language over Sanskrit for discussing and thinking about modern technological society" (Schiessler, 1971, p. 308).

"Math should emphasize the metric system. The United States is the only nation in the world that does not use that system" (Cushner, p. 169, 1990). And "the metric system will best be taught by constant use, not by sporadic reference and infrequent examination. The only effective way to insure the metric system's adoption and incorporation is to set aside the customary system and use the metric system exclusively" (Schmidt, 1988, p. 9). "Most people insist upon translating metric dimensions into U. S. customary dimensions before they make use of the information. For example, they translate 25.4 millimeters to 1 inch. The translation is a waste of time and somewhat difficult when using fractions of an inch, several feet or parts of a mile.

Not recognizing this, neophytes conclude that metric is difficult or that it is a waste of time. Yet, experience has proven … that persons who literally learn to 'think metric' and blot out all memory of customary units have no difficulty … In fact, they quickly learn to appreciate the convenience and efficiency of the Base-10 relationships and will not go back to customary measures unless forced" (Frasier, 1974, p. 43). "We need to assume responsibility for actively teaching our students the metric system … (since) to fail to do so may limit their participation in a global society" (Monroe and Nelson, 2000, p. 23).

In the meantime, the evolution of the metric system continues apace. "Presently, we are facing the next essential change in the international system of units, subject to the CGPM (Conference Generale des Poids et Mesures) approval. The expected redefinition of the kilogram in terms of the Planck constant *h* (beside redefinitions of other base units) will eliminate the last artefact (the international prototype of the kilogram) from the set of definitions of base units, so that the new system of units will refer exclusively to atomic properties and physical constants. Therefore, the new international system of units, often called the New SI or the Quantum SI, might also be named "the Artefact-Free SI" (AF SI for short) … The advantage … is that one should expect ever newer versions of the New SI (e.g. the unit of time can be redefined in terms of spectral lines of ever higher frequencies, and the new value of the second will affect values of other base units)" (Chyla, 2011, p. 1008). The clock is ticking.

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