centimetres or millimetres

Which will you choose?

Pat Naughtin

In recent times, as they upgrade to the metric system, the people of each nation re-open a discussion about the most suitable small metric units for everyday use. The discussion always seems to focus on the questions:

Which is best: centimetres or millimetres?

and

Which will you choose: centimetres or millimetres?

Only occasionally does this discussion expand to include all of the small metric prefixes — centi, deci, hecto and deca, — thereby extending the discussion to centigrams, centilitres, centiseconds and all of their deca, deci, and hecto equivalents.

This debate, which Australia had when it upgraded to the metric system, is currently emerging in the UK and the USA as those nations make their inevitable progress toward complete metrication. And generally the same arguments – those for and those against centimetres or millimetres – are used repeatedly in each nation.

Over several years, I have collected many examples of the arguments both for and against centimetres, and for and against millimetres. There are lots of them, so I have decided to break this article into three parts.

Following this introductory page, there is a summary of the main arguments for the use of centimetres or millimetres. After this, I share the main lines of argument that I have collected; this is the long part (46 pages). Finally, there is a 3 page conclusion. If you are pressed for time, I suggest that you read the first 4 pages and the last 4 pages and only skim read the bits in the middle that interest you.

These main lines of argument are arranged in the form of a **Discussion** under a series of headings:

To make these arguments more approachable, I have arranged the various discussion points as if they were a discussion between three people: **John the engineer** from the UK, **Sarah the teacher-librarian** from the USA (both fictitious), and me.

John the engineer and **Sarah the teacher-librarian** are actually composite characters who are made up from the many people who wrote to me expressing their support for, or opposition to, either the centimetre or the millimetre. I really Thank you for your email. I really appreciate the support that I have received and the opportunity it has given me to reconsider the issues involved as I responded to the many points that contributors made.

The format that I use here — interspersing my remarks within the context of the original emails — was chosen to make sure that I reacted to them all fairly and reasonably. Many of these shared their ideas through the United States Metric Association discussion list that you can find at: http://lamar.colostate.edu/~hillger/listserv.htm

Imagine **John the engineer** as a scientifically trained engineer, who also has a home workshop where he designs and makes household items such as furniture and wooden toys, as well as doing general home repairs and renovations. **Sarah the teacher-librarian** works in a school as a librarian after having spent some years as a classroom teacher in several countries. She likes to cycle, to sew, and to cook, and she uses recipes from the countries that she has visited.

I have used the Australian, French, and UK spelling of metre and litre to avoid hassles with my spell checker!

Summary of centimetre vs millimetre arguments

Arguments for centimetres

Generally, professionally trained people provided the arguments for centimetres; mathematicians, medical practitioners, and teachers are good examples. These people are often quite proud of their numeracy. Their arguments include:

- ◊ The centimetre is widely used.
- ◊ The numbers are smaller with centimetres
- ◊ People can handle multiples of 10 and 100 better than they can handle multiples of 1000.
- ◊ The centimetre is more natural. The 'natural' conversion is: kilometres for miles, metres for yards and feet, centimetres for inches, and millimetres for fractions of inches.
- ◊ The millimetre is too small, too accurate, and too precise.
- ◊ Complete use of SI would include both millimetres and centimetres (and decimetres and hectometres).
- ◊ Children should be taught the full metric system and not just a part of it.
- ◊ Let market forces decide which units will be used in each type of human activity.
- ◊ My ruler is marked in centimetres not millimetres.
- ◊ Because it takes a lot longer to train people to use the metric system using centimetres, people learn it more thoroughly.

Arguments for millimetres

Practical people usually provide the arguments for millimetres; builders, engineers, and many trades people are good examples. Often the people who prefer millimetres either have low numeracy skills or they regularly work with people who have low numeracy skills. Their arguments generally include:

- ◊ You don't need any fractions – no vulgar fractions and no decimal fractions.

- You don't need decimal points.
- You can easily develop a mindset for assessing distances and lengths using millimetres; it quickly becomes second nature, and big numbers have never been a problem.
- You can be as accurate and precise as necessary for the job you are doing. For example in the building trade you rarely require accuracy greater than 'to the nearest millimetre'.
- Aiming at 'millimetre accuracy' automatically produces a better job than aiming at 'centimetre accuracy'.
- If you use milli as the preferred prefix, there are a smaller number of prefixes.
- The whole idea of avoiding the centimetre, decimetre, decametre, and hectometre in favor of the millimetre is to eliminate clutter and achieve simplicity.
- By preferring the millimetre, people have to work with only three length units: millimetres, metres, and kilometres and anyone who uses those three length units simply doesn't bother with any of the others. This matches our already established practices of having only three units for mass: grams, kilograms, and tonnes; and only three units for capacity: millilitres, litres, and cubic metres.
- Look at the way people so readily adopted the use of grams and millilitres without the need for centigrams and centilitres.
- It takes a lot less time to train people to use SI using millimetres so people learn it more thoroughly.
- For most people there will only be one 'conversion factor' – 1000 – in the whole system if they choose millimetres instead of centimetres.

1000 millimetres	= 1 metre
1000 grams	= 1 kilogram
1000 millilitres	= 1 litre

1000 metres	= 1 kilometre
1000 kilograms	= 1 tonne
1000 litres	= 1 cubic metre

Discussion

General remarks

Pat Naughtin: I would like to begin this discussion by sharing the conclusions that I have made after having closely observed the metrication process in Australia and compared this with metrication processes in many other nations. These observations have been made over 40 years, from the mid-1960s to now.

Let me be blunt. I recommend that you choose millimetres.

My preference for the use of the millimetre is almost solely based on an observation that I made in the 1970s after I had worked in the building trades as a technical writer and then moved to the textile trades doing similar work. I wrote something along these lines in about 1980 after studying metrication for about 15 years:

> *If you choose millimetres as your small unit for a metrication upgrade then the metric transition is smooth, rapid, and so economical that the companies involved save so much money that their net profits increase dramatically. Typically, metrication upgrades in all Australian building trades were completed in under a year and definitely in under two years — the best transition that I directly observed was a group of plumbers and gas fitters who, with good planning, made their metric transition in less than a day.*
>
> *On the other hand, if you choose centimetres as your small unit (as chosen by Australian textile industries), then you should expect your metric transition to be painfully slow,*

bitterly fought and enormously expensive, not only in financial terms but also in terms of ongoing human conflict. It's hard to know how long a metric transition using centimetres will take as no one has completed one yet. Suffice to say that 38 years is too short (1970 till 2008) in Australia and a better estimate might be 100 to 200 years with ongoing annual expenses of (say 10% of gross turnover per year see http://www.metricationmatters.com/docs/CostOfNonMetrication.pdf). For the latter estimate, I choose the nation of France as an example where they are still struggling with the confusion and expense (in both training and practice) of having two decimal points in building drawing numbers; an example is a building dimension of 1200 millimetres as 1.20.0 meaning 1 metre 20 centimetres and 0 millimetres.

The purpose of my writing on this issue is to encourage people to make a quick, clean, and economical upgrade to the metric system as soon as they can and as easily as possible.

My overall conclusions are:

- ◊ In Australia metrication has been hugely successful in the areas where we used millimetres. Metrication programs using millimetres have been fast, smooth, and so economical that many individuals and companies have profited greatly from their upgrade to the use of the metric system.
- ◊ Metric conversion has been least successful where centimetres were chosen as the small unit for everyday use. Metric programs using centimetres have been painfully slow, characterised by bitter internal squabbling, and expensive. Failed attempts at metric conversion all have this one thing in common — they tried to introduce the metric system using centimetres.

Please note that I'm not saying anything about the theoretical structure of the original metric system developed in France in the 1790s and I'm not passing judgement on the metric system, revised in 1960, that we now know as 'The International System of Units (SI)'. I am simply recording my observations about the metrication process that people choose to use when they upgrade to the metric system or to SI.

Sarah the teacher-librarian: I use centimetres frequently and millimetres occasionally, so I'm having a hard time accepting the general message that millimetres are in any way preferable to centimetres.

Pat Naughtin: That's understandable and you're not alone. Many others have trouble with this, and so did I for many years. I simply couldn't understand why metrication programs using millimetres worked so well and so quickly, while metric conversion programs using centimetres hardly worked at all. However, the evidence before me was irrefutable.

My conclusions are based on many years of personal observation in many different activities. For example, as a trainer of trade teachers I directly observed the ease of the metric transition for these trades: boilermakers, bricklayers, carpenters, fitters and machinists, furniture builders, piano makers, plumbers, and welders. I also observed the difficulties faced by textile workers such as scourers, carders, combers, spinners, tanners, weavers, and knitters when they tried the same metrication process using centimetres.

Simply put, if a group decided to 'Go metric' using millimetres, the process was quick and relatively easy. It didn't matter whether the people concerned were scientists, technicians, or bricklayer's labourers, nor did their mathematical skills (or lack of same) play a part. Generally, the metrication process took about a year for most people, with only a few laggards delaying their metric transition for up to two years.

On the other hand, if a group decided to 'Go metric' using centimetres, the process was slow, difficult, accompanied by moaning, groaning, threats of mutiny, and continual demands to 'go back to the old ways'. Using centimetres, the metrication process for these groups has taken at least 40 years – so far – and there is no clear end in sight. As a modern example, this is the path of upgrading to the metric system apparently chosen by the world's computer industry — I wish them well — but I won't hold my breath.

John the engineer: Let me go back to Sarah's initial remark: 'I still have a hard time accepting the general message that millimetres are always preferable to centimetres'. Is this what you're saying?

Pat Naughtin: No, I don't think that and I don't think that I have ever made that assertion. However, I firmly believe that if you're beginning a metric transition program for any organisation (school, workplace, company, hospital, industry, or nation) your metric transition will be easier, quicker, and cheaper if you choose millimetres rather than centimetres for measuring small lengths.

Sarah the teacher-librarian: That's all very well for engineers, carpenters, mechanics and the like, but the children I teach will have to use centimetres in their adult life. I have to teach centimetres, millimetres, and all the rest of the metric system because I don't know what my students will do with their lives.

Pat Naughtin: I've made an analysis of the various occupations in Australia, and the length units they prefer to use. From the 117 occupations listed by the Australian Bureau of Statistics, the results are as follows:

millimetre users – 96 occupations

Aircraft maintenance engineer (avionics), aircraft maintenance engineer (mechanical), aircraft maintenance engineer (structures), automotive electrician, binder and finisher, blacksmith, boat builder and repairer, bricklayer, broadcast transmitter operator, business machine mechanic, cabinetmaker, cable jointer, carpenter, carpenter and joiner, communications linesperson, computing support technician, dental technician, draftsperson, drainer, electrical engineering technician, electrical power line tradesperson, electrician (special class), electronic engineering technician, electronic equipment tradesperson, electronic instrument tradesperson (special class), electroplater, engraver, farrier, fibrous plasterer, fitter, flat glass tradesperson, floor finisher, furniture finisher, furniture upholsterer, gasfitter, gem cuter and polisher, general communications tradesperson, general electrician, general electronic instrument tradesperson, general fabrication engineering tradesperson, general gardener, general mechanical engineering tradesperson, general plumber, glass blower, graphic pre-press tradesperson, greenkeeper, gunsmith, jeweller, joiner, landscape gardener, leather goods maker, lift mechanic, locksmith, mechanical engineering technician, mechanical services and air conditioning plumber, medical grade shoemaker, metal casting tradesperson, metal fabricator (boilermaker), metal machinist (first class), metal polisher, motor mechanic, optical mechanic, painter and decorator, panel beater, patternmaker-grader (clothing), piano maker, piano tuner, precision instrument maker and repairer, pressure welder, printing machinist, refrigeration and air conditioning mechanic, roof plumber, roof slater and tiler, saw maker and repairer, screen printer, sheet metal worker (first class), shipwright, shoemaker, sign writer, small offset printer, solid plasterer, stonemason, surveyor, textile, clothing or footwear mechanic, toolmaker, upholsterers and bedding tradespersons, tree surgeon, vehicle body maker, vehicle painter, vehicle trimmer, wall and floor tiler, watch and clock maker and repairer, welder (first class), wood tradesperson, and wood turner.

centimetre and inch users – 12 occupations

Apparel cutter, baker, canvas goods maker, chef, cook, dressmaker, general clothing tradesperson, nurseryperson, pastry cook, picture framer, sail maker, and tailor.

7 occupations where length measures are relatively unimportant

Butcher, buttermaker or cheesemaker, confectioner, ladies hairdresser, smallgoods maker, men's hairdresser, and meat tradespersons.

Summary of occupations

Prefix and unit choice	Number of occupations	Percentage of occupations
millimetres	96	83.5 %
centimetres, feet, and inches	12	10.4 %
length measures relatively unimportant	7	6.1 %
Total	**115**	**100.0 %**

It seems to me that there is a very high probability that your students will use millimetres predominantly during their working lives. You might also notice that nobody regularly uses decimetres, decametres or hectometres at all.

Except for the non-preferred centimetre, the prefixes centi, deci, deca, and hecto are essentially never used in daily activities and maybe they shouldn't be taught in any detail – simply make mention of their existence. In the rare cases where these prefixes are used, and these are rapidly becoming rarer, these odd prefixes can soon be learnt. Certainly students shouldn't bother with converting to or from them.

I consider that it’s best to keep it simple, and to only teach the four prefixes: micro, milli, kilo, and mega.

Sarah the teacher-librarian: Why did you carry out this analysis?

Pat Naughtin: I did this because I had had the opportunity to work on the metrication programs of several building trades where the metrication program was quick, smooth, and relatively cheap (mostly completed in less than a year). This was before I moved to the textile and clothing industries where the metric transition is still muddled, bitter, and enormously expensive (nowhere near completion after more than 40 years — and counting). In comparing these metric transitions, I was immediately struck by one significant difference: the building industries had all chosen the millimetre as their small length unit, and the textile industries had all chosen the centimetre as their small length unit.

I was simply curious to see whether these same conditions applied in other industries. I found that it is generally true that industries that choose millimetres make their metric transition much faster than those that choose centimetres.

Sarah the teacher-librarian: Why do you think it works this way?

Pat Naughtin: Despite the clarity of the observation it took me years — I must be a slow learner — to reach any conclusions as to the reasons for this profound difference. Here are some of my thoughts.

If you choose millimetres as your small length unit you have immediate advantages:

- ◊ All measurements are whole numbers, so there are no fractions at all.
  - You remove all references to vulgar fractions (such as halves, and 1/16ths).
  - You remove all references to mixed numbers (such as 4 2/3 and 6 7/8).

- You remove all references to decimal fractions (such as 2.34 and 3.456).

◊ All measurements can be entered into a calculator without any conversion.

◊ There are no occasions when you have to slide decimal points backwards and forwards.

On the other hand, the choice of centimetres in the textile industry gave no such clear advantage to textile and clothing workers. The halves and quarters formerly applied to inches were simply transferred to half centimetres, quarter centimetres, half metres and quarter metres. And, even worse, textile and clothing workers had the added disadvantages of decimal fractions of centimetres — that they had rarely met in their trade before — and all the problems of converting between decimal centimetres and fractions of inches to suit their large stock of old patterns. It's no wonder that they have almost universally chosen to revert to inches and fractions of inches; they believe they understand them better than this 'new metric muck' (to quote a shirt maker).

John the engineer: I can see Pat's point. I first thought that using such a small submultiple of the metre as the millimetre would create cumbersomely large numbers, but I can see that the opportunity to use whole numbers is a very powerful advantage. In effect, the barrier of dealing with subdivisions of the unit of measure is avoided, calculations are simplified, and it helps break the old habits of using ordinary fractions to describe length (like one and a half centimetres). I suspect that Pat's correct in observing that the textile and clothing workers would have become fully metric ages ago if they had gone over to millimetres.

Pat Naughtin: I cannot stress strongly enough how important the choice of millimetres has been in the Australian building industry. Those of us that used the metric system during the metrication upgrade found it most helpful to use millimetres, because you always end up with a whole number, there are no fractions and there are no decimals, and no decimal points to move about. For many folk in the building industry, many of whom have limited numeracy, avoiding fractions proved to be a considerable advantage in adopting the metric system for all their length measurements, and the issue of larger numbers proved, in practice, to be quite insignificant. This benefit then carried over to their other measurements such as grams, kilograms, millilitres, litres, watts, and kilowatts. Without the prefix centi, fractions simply are never needed or used on building sites.

You are right about the ease of use of whole numbers. I recommend that whole numbers are almost always preferable to fractional numbers or mixed numbers with both whole and fractional components (I believe that Simon Stevin got it right on this issue in 1585 Go to: http://www.metricationmatters.com/docs/MetricationTimeline.pdf and search for Stevin). With hindsight, we have probably have had little need for fractions since Simon Stevin's book was published in English in 1608.

Sarah the teacher-librarian: Is Australia the best example of a successful metrication transition? If not, who would you recommend as a national model?

Pat Naughtin: I can answer this by giving examples of the way three different countries set about metric conversion. The most successful was, I think, South Africa.

South Africa

◊ South Africa made a conscious decision to 'prefer' millimetres in all industries except the textile industry, and their metric conversion was completed within the ten years they had set for the task in all industries except the textile industry. They also encouraged the teaching of millimetres in schools as the preferred small metric unit.

Australia

◊ Australia decided on the market forces approach where each industry made their own decisions as to which unit they would use for their small length unit — centimetres or millimetres. Schools were more or less left to their own devices to decide on which small unit to use. The transition has had two startlingly contrasting results.

- Metrication in industries where they chose millimetres as their small unit (such as the Australian building industry) was essentially completed in about a year.
- Metric conversion in the industries where they chose to use centimetres, such as the textile, clothing, and footwear industries, and in schools, they are still struggling with metric conversion more than 35 years on.

Canada

◊ The Canadian building industry is still struggling with their conversion process after more than 35 years – using centimetres.

John the engineer: I know I said that with millimetres the opportunity to use whole numbers is a very powerful advantage because you avoid fractions, but surely people who have few mathematical skills would have difficulty with large numbers, which can be inconveniently long and difficult to read. And I often see conversions with unwarranted precision, so we end up with 4 inches becoming 101.6 millimetres, regardless of the initial accuracy.

Pat Naughtin: Think about bricklayer's assistants and note that we are not talking about intellectual giants here. These folk had little trouble adjusting to house plans that contained numbers like 22 800 millimetres for the length of a wall. One of the reasons for this, I think, is that the big numbers have given their users four distinct advantages on a building site:

1. You don't have to remember the unit of measurement – it's always a millimetre.
2. There are never any fractions.
3. There are never any decimal points.
4. Calculations are mostly simple, but if they're not, they can — without any conversions — be fed directly into a calculator.

Compare this with the issues confronted by a textile worker (say a weaver) who still has to:

5. Remember which unit, or units, of measurement they are currently using.
6. Negotiate halves and maybe quarters and eighths of metres and centimetres.
7. Negotiate thirds of yard for feet; and 36ths of yards for inches.
8. Almost always have decimal points with varying numbers of digits to the right of them.
9. Perform calculations that might involve vulgar or common fractions, mixed numbers, decimal fractions or a combination of all of these.
10. Perform calculations by pen and paper methods, as electronic calculators are not good with fractions.

For example, compare:

How many 7 1/2 centimetre *strips can I cut from* 3/4 metre *of fabric?*

with

How many 75 millimetre *strips can I cut from* 750 millimetres *of fabric?*

I know which I'd prefer to do.

By the way, an Australian builder's labourer doesn't have to convert 4 inches to 101.6 millimetres – and hasn't needed to since 1975. People who follow the metrication path — using millimetres — don't use the word 'inch'. They only work in millimetres.

Sarah the teacher-librarian: Is this a peculiarly Australian and South African thing about choosing millimetres? Have other nations chosen a similar course?

No, this is not uniquely Australian; many other nations have also chosen the millimetre path for their metric transition. Apart from Australia, I can think immediately of Bangladesh, Botswana, Cameroon, India, Kenya, Mauritius, New Zealand, Pakistan, South Africa, and Zimbabwe. Of course countries, such as France, where the metric system has evolved over time, has become accustomed over the last two hundred years to the centi prefix — but it took them a long time — and it incorporates many inefficiencies such as additional mathematics classes in schools and additional errors in areas such as building and manufacturing.

But in the countries that chose the millimetre path, numbers on building drawings are usually written with a space every 3 digits, as in (say) 12 000 mm, so it's very easy to see that this is 12.000 metres or simply 12 metres. This gets rid of the decimal point so common with centimetres. Anyone looking at a plan for an office building or a home can quite easily convert between millimetres for cutting and fixing and metres for comprehending the whole job.

Here is an extract from the July/August 1978 edition of the South African Metrication News.

1. *One of the most important aims of the SI is the simplification and rationalisation of units, both for measurement and for use in calculations. The number of multiples and sub-multiples is accordingly restricted by giving preference to the use of prefixes that represent steps of 1 000 (x 10^3)*

2. *If this preferred range of prefixes is combined with the division of numerals into groups of three then this makes for extreme ease of conversion from, say, mm to m by simply moving the decimal indicator to the next available space viz: 1 725 352 mm = 1 725,352 m = 1,725 352 km*

3. *If the centimetre is interposed between the millimetre and the metre it has several disadvantages:*

   (i) It destroys the simplicity of the system,

   (ii) It makes it impossible to use the 'groups of three' method to change from centimetres, say, as the gap is in the wrong place viz: 76 322 cm = 763,22 m But there will be a tendency - using the 'gap' theory - to make the answer 76,322 m (a tenfold error).

   (iii) It is universal practice in technical drawings to use millimetres only. If this practice is employed all that has to be done is to write 'all dimensions in millimetres' at the top of the drawing and then leave all symbols off each dimension - a tremendous saving of time and ensuring that errors in transcription are avoided. If centimetres are permitted as well as millimetres then it would be necessary to use symbols again after every dimension and the risk of error in transcription is very great indeed.

4. *It should be noted that the objection to centimetre is confined to its use as a linear measure. When raised to the second and third powers, as in areas and volumes respectively, it is necessary to employ square centimetres and cubic centimetres to render the steps between successive multiples of area and volume, practical ones.*

5. In South Africa the centimetre is used in the clothing and textile industries and therefore also for related dimensions of the human body. It should, preferably, not be introduced elsewhere.

6. If the centimetre were given equal status with the millimetre we would have the situation where some people would specify the dimensions of, say, a piece of paper in centimetres and others would specify its dimensions in millimetres. This would be very confusing and would defeat one of the main objects of introducing a universal language of measurement.

7. There is no doubt that the preference that many people have for the centimetre is merely another throw-back to the Imperial system - it is the sub-multiple of the metre that is most closely related to the inch - and such people naturally tend to use it in all applications where the inch was previously used. This 'cross-section' of people is, however, diminishing.

8. The SI, if it is to retain its simplicity and its coherency, must employ as few sub-multiples and multiples as possible. Nobody wishes to interpose centigram between milligram and gram, for example, nor centinewton between millinewton and newton, nor centivolt between millivolt and volt, etc., and basically there is no reason why the measurement of length should require special treatment when it has been proven to be unnecessary for mass, force, electrical potential, etc.

9. One of the objections raised against the millimetre is that it is said to be difficult to visualize a dimension such as 250 mm. Yet nobody has any difficulty in thinking of 250 mL as a quarter of a litre and 250 g as a quarter of a kilogram. Perhaps the answer lies in the fact that we automatically relate 250 mL to the litre, the 250 g to the kilogram, yet when it comes 250 mm, we try to visualize 250 tiny divisions on a ruler instead of relating it to the metre.

It is suggested that once one cultivates this habit of relating millimetre dimensions to the SI unit, the metre, much of the 'antipathy' towards the millimetre will disappear.

John the engineer: Do you really think that it's not possible to succeed in converting people to typically use centimetres rather than millimetres? Suppose that we chose an industrial sector where everyone agrees that using centimetres makes sense; that the proper kind of training is provided; that dual-marked instruments are forbidden; that suitable M-days are chosen and enforced; and other ways were found to foster a clean break with Imperial thinking, would it be possible then?

Pat Naughtin: No, I don't think so. Even with all of these positive steps I don't think that you will be able to run a successful metrication transition, using centimetres, in under fifty years. If you choose this path, I wish you well, but I'm not confident of your success. I've never observed any metric conversion program using centimetres that has been quick, smooth, or cheap — if you succeed you'll be the first!

On the issue of banning dual sided tapes and rulers, I would like to remark that this is a great idea. As Australia made its successful transition to using metric units, we often referred to the saying, Don't duel with dual. We did this based on the knowledge that metric conversion (calculating metric values into feet and inches for instance) was essentially a stupid idea as it delays metrication indefinitely (see the computer screen example below that has delayed metrication of UK computer screens from 1965 till now — 43 years so far and counting).

Sarah the teacher-librarian: In most parts of the world 'centi' is officially regarded as a legal prefix. It's part of the metric system in every country that I visited.

Pat Naughtin: And in all of those places that actively encouraged the use of 'centi' as part of the introduction to the metric system the adoption of the new units was slowed dramatically. Here are some examples:

- ◊ In France it took almost 50 years to introduce the first metric system; centimetres were a key component of the original metric system.
- ◊ The USA has been trying to launch a metric system, or a decimal system, since at least 1785. In many activities they have used and are still encouraging the use of centimetres.
- ◊ England is still battling to introduce a metric system with centimetres as a key component.
- ◊ Kodak made a quick clean transition to film sizes using millimetres in 1910; they are still trying to make the transition to centimetres for paper sizes after a further 98 years.
- ◊ In Australia we have been clearly successful in upgrading to the metric system in those areas where we used millimetres and we have, just as clearly, failed so far in those activities where we are still trying to introduce centimetres.

Those attempts at metric conversion that have been painfully slow have one thing in common — they tried to introduce the metric system using centimetres.

Building

Pat Naughtin: We've probably spent enough time on general discussion, so could we now focus on the issue of centimetres vs millimetres on a topic-by-topic basis. I would like to start with building because John and I both have experience in this area.

I chose the buildings trades as an example of the success of millimetres for several reasons. Firstly, the recommendations in the building trades as to which units to use were quite definite and the various building trades took them up widely. Secondly, I had considerable experience in the building trades during the time that Australia converted to the metric system.

John the engineer: But surely in doing a big job like building a house, the amount of large numbers must be confusing to all the people on the building site.

Pat Naughtin: This didn't prove to be the case in Australia or in South Africa where the recommended small unit for buildings is the millimetre. In Australia, the building trades were very clear about this. The Australian Building and Construction Advisory Committee policy was:

> *The metric units for linear measurement in building and construction will be the metre (m) and the millimetre (mm), with the kilometre (km) being used where required. This will apply to all sectors of the industry, and the centimetre (cm) shall not be used.* *

With these words the Australian Building and Construction Advisory Committee effectively banished centimetres from the building trades in Australia, with the result that metric conversion in these trades was smooth, rapid, and complete. They made it clear that the centimetre should generally not be used, and in particular:

> *... the centimetre should not be used in any calculation and it should never be written down.* *

*Standards Association of Australia 'Metric Handbook, Metric Conversion in Building and Construction 1972

Most other trades followed their example, and subsequently followed their successful metrication program.

Where metrication has been successful, rapid, and economical, the centimetre has not been recommended, not in Australia and not anywhere else in the world. The Australian Building and

Construction Advisory Committee seemed to be well aware that centimetres are not only unnecessary but also a major impediment to learning and using the metric system. Their position has been proved by subsequent practice over almost two generations. It's just as easy to estimate distances in millimetres or metres as it is using centimetres; in fact, if you already have a mindset that includes centimetres in your measuring vocabulary then you have already (perhaps inadvertently) chosen the most difficult measuring path, and that path will be strewn with many conversion errors.

Using centimetres unnecessarily complicates a system that was chosen for its simplicity. Look at the recommended units for building in Australia. This is the complete set:

1000 millimetres	= 1 metre	1000 metres	= 1 kilometre
1000 millilitres	= 1 litre	1000 litres	= 1 cubic metre
1000 grams	= 1 kilogram	1000 kilograms	= 1 tonne

1 metre x 1 metre = 1 square metre

The only – rarely needed – 'conversion factor' is 1000

The 2 units for calculated values are square metres (m^2) and cubic metres (m^3).

There are only three units, metre, litre, and gram.

There are only two prefixes, milli and kilo.

Note that since there is only one rarely used 'conversion factor' of 1000, all you have to remember is that the decimal point moves three places, and the only complication is to know whether this is from left to right or from right to left.

There are even reports about the success of the millimetre in the building trades coming from the UK. As an example see: http://www.telegraph.co.uk/property/main.jhtml?xml=%2Fproperty%2F2004%2F04%2F05%2Fplevel07.xml&secureRefresh=true&_requestid=65356

Sarah the teacher-librarian: But what about countries that use centimetres in their building trades every day. When I was in Brasil recently, advertisements for new kitchens had all the cupboards listed in centimetres.

Pat Naughtin: I don't doubt that centimetres work well enough in (say) a country like Brasil who began their metric conversion in 1862. However, based on my own experience I have to wonder how long it took the Brasilians to make their metric transition. Did it take 100 weeks or did it take more than 100 years? I suspect it might have been closer to the latter.

John the engineer: At home on my numerous DIY projects, I'll often measure something as, say, 1490 mm and write it down as 149 cm. This is why I find the metric system easy to work with. I can use metres, centimetres, or millimetres as necessary, converting back and forth when necessary for simplicity or calculation.

Pat Naughtin: You clearly have the skills and the numeracy to do this — many others don't share your skills. It isn’t wise to make the assumption that all others on a building site are able to do the arithmetical gymnastics as well as you. All Australian architects, bricklayers, carpenters, engineers, and plumbers now happily use millimetres to measure the whole job because they share a common language — millimetres. As an example, I have seen drawings for a house set on land that was 151 340 x 20 160 and the only reference to any measurement units was the statement in the information block on the drawing that read, 'All dimensions in mm'.

John the engineer: Yes, without the decimal point those numbers can be read in any unit the viewer feels comfortable in. A decimetre-ist can feel just as happy reading those numbers as 1513.4 decimetres x 201.6 decimetres. All you have to do is move the decimal point two places to the left. It's so simple a child could grasp it.

Pat Naughtin: Well most children would have to waste an awful lot of time – years – learning where the decimal point goes, how many places to move it, and whether to move it to the left or to the right. Look, let's forget this hogwash about introducing centimetres and decimetres or what ever else and remember the KISS principle (Keep It Simple Stupid). To stick with one unit, the millimetre, all the way is to follow the KISS principle 100 %.

John the engineer: But I can't think of any building trades that need to work to millimetre precision on the job site. (OK, cabinet makers work to millimetre precision in the factory, but not on the job site.) You can't pour concrete, or hang plaster walls, or lay concrete blocks, or frame buildings, or even hang doors, to millimetre precision. The smallest division on an old pre-metric tape is 1/16th inch, and that was rarely used. So isn't the millimetre ridiculously precise?

Pat Naughtin: Well, in the first place it's the simplicity of the common language between (say) an architect and a carpenter that makes the use of millimetres worthwhile, rather than the issue of precision. But to answer your question, you're absolutely right in that a carpenter does 't hope to achieve millimetre precision, but he'll produce a much better job if he aims for it. If you use millimetres the units themselves ask – or should that be the units themselves insist – that you aim for greater precision both in your measuring and your cutting. You're not continually making rounding decisions as you measure and cut, as you need to do when you use centimetres; centimetres ask you to make guesses and estimates continually, for example is this division between the centimetre marks nearer to a half or nearer to a quarter of a centimetre? This also encourages non-decimal thinking — halves, quarters, eighths, and sixteenths are still part of your mindset.

One of the main issues here is that you are aiming for millimetre precision, and you've got it there whenever you need it; it can be surprising on a large building site how handy millimetre precision can be. For example, when you lay out a room (say 3600 mm by 4200 mm) you will need to measure a diagonal of 5532 millimetres to check if it's square. In the old (pre-metric) days you never knew how long the diagonal should be - it was too hard to calculate - so you simply measured both diagonals to see if they were the same. I suspect that there are a lot of old (ever so slightly) trapezoidal buildings.

If you are aiming to fit a door using centimetre precision you won't get as good a job as if you aim for millimetre precision. It's a funny thing, but as you move from the place of the measurement to the place of cutting you often decide to 'leave the line' or 'take the line'; these are small refinements but, I believe, they ultimately lead to a better job. Aiming to mark and to cut within a centimetre is not the same as aiming to mark and to cut within a millimetre.

John the engineer: What concerns me is the matter of precision and significant figures.

Pat Naughtin: I have to say that, although I am aware of this issue, I don't consider that it will ever take precedence in my mind over the probability of a quick, clean, and cheap metric upgrade using millimetres. In saying this, I am not ignoring the need to consider accuracy and precision issues when these are used in appropriate contexts. I suppose that, to me, it is a matter of priority in that I consider it more important to get people to use SI metric units first, and then to get them to use the SI metric units properly is a secondary issue.

John the engineer: Sure, there are a few manufactured parts, like small screws and pipe that have millimetre names. But you don't actually measure them on a building site.

Pat Naughtin: Surprisingly you often do. For example you might need to choose a drill bit to fit a bolt. Carpentry is not brain surgery but it's amazing how often a carpenter has to use quite fine measurements.

John the engineer: What about decimetres Pat? I've read that the Australian timber industry uses decimetres, stamping them on the butt of logs to indicate diameter and length. Is this true?

Pat Naughtin: Yes and no. If you have a log 1.6 metres in diameter you hit it with the '1' stamp and the '6' stamp; they're a bit like hammers. But as you do this you think '1 point 6 metres'. If the log is 700 mm you just hit it with a seven and you think 'zero point seven. In a little while (after you've measured the length of the log in metres) you will want to find the volume in cubic metres, so it's best to keep all the numbers in your head as metres then you won't have any conversions to do.

The reason for marking the logs with numerals only is to avoid the use of a decimal point or a decimal comma – which wouldn't be seen on the rough texture of the log – and not because decimetres were specifically chosen as the unit.

John the engineer: How do Australian workers, speaking casually on the job, pronounce dimensions of (say) 1.2 metres by 2.4 metres?

Pat Naughtin: I'll respond to this with a typical on-the-job dialogue.

> Joe: When you go down to the ground can you get me a bit of ply – standard sheet – twelve hundred by twenty-four hundred?
>
> Andy: Is that the exact size you want? If it's not yell out the sizes and I'll cut it for you on the ground.
>
> Andy climbs down the ladder
>
> Andy: What size is it?
>
> Joe: It's twenty-three hundred and eighty five long.
>
> Andy: Right. Wait while I cut it.
>
> Bzzzzzz — then silence.
>
> Joe: I've measured both ends now. Can you cut it eleven hundred and ninety at one end and taper it to eleven hundred and seventy-five at the other?
>
> Andy: Right ho.
>
> Bzzzzzz then more silence.
>
> Andy: Eh mate! Are you gunna come down and help me up with this or are you gunna sit there all day catching up on your sun tan? Etc.

Sarah the teacher-librarian: Why don't engineers, scientists, and trades people use hecto, deca, deci, and centi?

John the engineer: Although the use of these would be perfectly valid SI metric system usage, engineers and scientists wouldn't think it appropriate because no one uses centigrams for measuring anything. Suppose something has a mass of 1.52 kg, which is also 1520 g. No engineer that I know would seriously think it would be a good idea to express this in centigrams: 152 centigrams. The centi simply isn’t used.

In science and technology, hecto, deca, and deci aren’t convenient to use, and they make calculations more complicated. Science and technology deal with a wide range of values requiring many prefixes, and the 'irregular' prefixes, hecto, deca, deci, and centi, add needless complexity without any advantage. These prefixes are called 'irregular' because they violate the normal pattern of the SI prefixes that places each prefix 1000 times smaller or larger than its nearest neighbour. They’re little used in science and technology, or in everyday life for quantities other than length.

Science and engineering professionals simply set their calculator to the ENG display and this automatically gives them answers in powers of 3 that is in 1000s; my calculator can't be set to automatically give answers in powers of 1 (10s) or powers of 2 (100s). Recording an answer with an 'irregular' prefix requires troublesome manual manipulation of the decimal point and the ever present possibility of a mistake. This is especially true for volume units like centilitre and decilitre that are not coherent. When you calculate the volume of an object from its coherent metric dimensions, you get an answer in cubic metres or one of its multiples. It's hard enough to remember that the prefix must be cubed along with the unit and that several multiples have old-metric 'nicknames' (litre, hectare, and tonne). But at least you don't have to move the decimal point. With regular prefixes, what you see on your calculator is what you get.

Sarah the teacher-librarian: I don't mean to get involved in the centimetre-millimetre debate in the building trades as I know little about them from a practical point of view. But I would like to argue for the importance of sensible rounding. The constant emphasis on exact conversions from inch-foot-pound sizes makes it impossible for people to visualise things as simple groupings of 10, 100, or 1000, and gives metric a reputation for dealing with large and unnecessarily complicated numbers.

Pat Naughtin: You can't get out of it that easily, because I know that you're a keen cook. If you're remodelling your kitchen you'll find that items such as sinks, stoves, and refrigerators are designed usually in 600 mm sizes. This is called a 600 millimetre module and it is more or less a universal standard. Even if you want to remodel a kitchen in the USA and (say) you want to use a French or an Italian stove you will soon meet the 600 mm module.

Sarah the teacher-librarian: Yes, I have met with this idea in the UK. The standard floor area to fit 'white goods' (oven, washing machine, dryer, dishwasher, fridge) is 600 mm wide by 600 mm deep. That usually means all cupboards along in a row are 600 mm deep, too.

Pat Naughtin: Yes, kitchen cupboards there usually come in the preferred 600 mm modules.

John the engineer: The word 'preferred' is my experience in the UK too. The sink unit is usually 1200 mm wide. Units of all other widths are easily available. I see 600 mm most often. Units of 300 mm seem to be for special things like shelves and wine racks. I have a cupboard that is 300 mm wide and 600 mm deep and I think it is far too narrow for good use as a cupboard. The 600 mm module seems to be the most common and the most popular.

Pat Naughtin: You could compare these modules with old pre-metric methods. For example, suppose that you have three pieces of heavy furniture that you are considering moving against a single wall, and you want to be sure there is enough space. You measure the three, add them, and compare to the length of the wall; it becomes a cumbersome calculation if the widths are 3' 4 3/8", 2' 1 1/4" & 4' 10 9/16".

Sarah the teacher-librarian: That's why using centimetres for 'everyday' usage is so appropriate. You can think in modules of 10 centimetres, which is more convenient than thinking in 100 millimetres (even though the distance is the same), and 10 is a more manageable number for most people.

Pat Naughtin: Yet people don't ask for 50 centigrams of meat because that is more convenient than 500 grams.

In the building trade millimetres work at all levels. If you are building a house frame, the tolerance and measures need not be anywhere near as refined as those needed for the finer details of a fireplace surround. But the use of millimetres means that you don't have to change your mindset as you move from outside carpentry jobs to inside joinery jobs.

And using both centimetres and millimetres can cause confusion as you try to keep the numbers in your head from the job to the saw bench. From experience, I know that a carpenter's work environment has many distractions such as swirling sawdust, flying wood chips, and perspiration running into your eyes. That's without the problems that you can create by jotting down numbers without units, or if the pencil-written units get smudged and you can't remember which units you used for a measurement you made ten minutes ago. And if you're using a piece of rough sawn hardwood as your 'writing pad', you can soon lose track of any decimal points.

Building and engineering drawings are simpler if all dimensions are in the same unit. In the first place you don't have to keep writing mm or cm beside each number. As I said earlier all you need is an information block in one corner of the drawing that reads, 'All dimensions in mm'. That's the main reason why design drawings are done in millimetres.

But also, with millimetres there is no need to go to 0.1 mm increments or smaller, so a decimal point need never be used, and as I said earlier, calculations are much easier with whole numbers and no decimal points. If centimetres were used many or most numbers would require a decimal point.

John the engineer: I use centimetres for carpentry because my tools are graduated that way, but I have no trouble changing between millimetres, centimetres, decimetres, and metres. For example, take a sheet of wall board with the dimensions 1200 mm x 2400 mm. I'd like that to be in decimetres, so that the sheet of plywood would then be 12 dm by 24 dm ('a 12 by 24 sheet, please').

Pat Naughtin: Yes, but not everyone is as numerate as you, and you're bringing in the curse of the decimal point again. Don't forget that you spent many years, first at school, and then at university, to be able to switch easily between units.

To save on materials, building systems are highly modular, and these modules rarely work in even numbers of whole metres; the usual modules are 600 mm, 1200 mm, and 2400 mm, because these numbers produce buildings on a practical human scale. Standard sheets of 1200 mm by 2400 mm can readily be divided, for cutting, without the trouble of worrying about inconvenient vulgar fractions or decimal points. Say you need to cut cover strips, and you need to know whether one module will supply enough strips. A simple division will give you the answer, and you can use even divisors of 2, 3, 4, 5, 6, 8, 10, 12, 16, 20, 24, 30, 32, 40, 50, 60, 80, 100, 120, 200, 300, and 600 without ever meeting any decimal or vulgar fractions.

John the engineer: In England, generally, engineering drawings are in millimetres and likewise stuff you'd buy at the hardware shop is usually marked in millimetres.

Pat Naughtin: Aren't metric drawings like that everywhere? If they're not they are heading in that direction. It's now becoming commonplace for workers to cross international borders for construction work and as the ease of using millimetres on jobs become apparent the shift that way is happening. As an example of this internationalisation of work, let me quote two experiences I had recently. At a new gold mine in the outback regions of Australia, the earth moving workers were from New Zealand, as were many of the construction engineers, and there were several builder's labourers from Tonga. And in Phoenix, Arizona, engineers that I met from the Airbus factory came from England and Germany.

John the engineer: I once put a cat flap in the door to the rear of my house. Initially I chose millimetres to do the task. I ended up switching to inches (the instructions showed both) as all I had to work with were single figures (plus a fraction), rather than 3 sets of 3 digit figures. It's not rocket science but with the inch version of instruction I kept all the figures in my head; with the millimetre version I had to refer to the instructions all the time. The result was a very fine working cat flap, although had I persevered I could have made it just as fine with millimetres.

Pat Naughtin: Methinks a little prejudice took over here. Let's look at what might be typical cut-out dimensions for a cat flap:

Inch dimensions: 6 3/8 x 7 5/8

Millimetre dimensions: 162 x 194

How many digits did you say? I count two lots of three in both cases.

On a broader scale you did the right thing in choosing to use inches only or to use millimetres only. The worst possible choice is to use both simultaneously. The best example of this, in the USA, was the Mars Orbiter fiasco. NASA considered that the metric system was more appropriate to use for an engineering project but unfortunately Lockheed Martin had other ideas, and provided data in inches and pounds instead of millimetres and kilograms. The result was the loss of a very expensive spacecraft when it reached Mars. When you ask, 'Why did this happen?' there are some who might say that 'it was all the fault of using Imperial measures' and others who could say 'it was all the fault of using metric units' but I say it is the result of using both — at the same time!

Sarah the teacher-librarian: In Europe mechanical engineers are solidly for millimetres, but many carpenters use centimetres. In France 1.5 metres is popularly referred to 'un mètre cinquante' by analogy with 1 franc and 50 centimes.

Pat Naughtin: Don't forget French carpenters have had since about 1790 to become comfortable with centimetres. Also remember that the French fought tooth and nail against the introduction of the metric system until strong legislation requiring metric units was introduced in 1837.

When Napoleon's armies were forced to retreat from Moscow, and Napoleon was banished to Elba, the new emperor, Louis Phillipe, declared the 'Mesures Usuelles' illegal in France and ordered that the only units to be used in France were to be decimal metric units. France changed to metric with a law that strictly banned all the non-metric measures (using old measures would become a penal offence) from 1840 onwards.

I'd hope we could now — with all the benefits of hindsight — bring about a metrication upgrade in something less than 200 years.

Think about the fact that the millimetre is a convenient way to express common everyday measurement, in whole numbers only, from something the size of a shirt button to the dimensions of a chair. The gram plays a similar role in expressing the mass of anything from a pinch of salt to a bag of flour, and so too the millilitre for capacity from a teaspoon to a large bucket and beyond. Numerically these quantitative measures are exactly the same. That's where the ease and simplicity of the metric system comes in.

And people find it easy to think decimally — they don't find it natural to count in lots of 14 or 16, as we had to do with stones and pounds.

John the engineer: I believe that the essence of what Pat has been telling us is that people try to use the centimetre as a replacement for the inch and by the same token try to carry over Imperial conventions (half centimetre etc). The result is that it doesn't work and people end up thinking there is something wrong with the metric system itself. I think this means we have to show people that metric is easier than traditional units provided you learn from the beginning to think of it, and to use it, in the right way. That is, don't try to remember the old system and convert to the new. Just use the new system.

Textiles

Pat Naughtin: Let's now turn to textiles because both Sarah and I have experience in this area.

Sarah the teacher-librarian: I am a non-scientist, non-engineer, and non-industry tycoon. I am just an average American who feels that everyone should use the metric system, as it is superior, easier to use, and it is universal. When I'm sewing, I've never measured to millimetre accuracy so I don't need decimal points with centimetres. I just oppose banishing the prefix centi to obscurity, especially as the centimetre is so useful for all types of clothing.

Pat Naughtin: An interesting artefact of using centimetres in Australian primary schools has been that, since this is a female dominated workplace, centimetres have become the basis for women's measurements; sewing requirements, baby lengths, body measurements, and curtains. This differentiation is obvious in catalogs that I receive from hardware suppliers. The front part is devoted to men's business and all dimensions are given in millimetres. The back, women's section, devoted to curtains, blinds etc., uses centimetres for all dimensions. Clearly the catalogue writers respect the ability of women to handle a more complex measuring system.

But in the clothing trade the use of centimetres has meant that there is now no meaningful numbering system in use in the industry at all. Recently, I visited a major department store and discovered that all of the women's clothing is calibrated in 'Size Numbers' that essentially have no meaning and that change from time to time.

Anyone who has any experience of these 'Size Numbers' knows that they not only change from manufacturer to manufacturer, but they also change through time. A leading retailer was quoted in the Australian daily press as saying 'of course Size 12 is a lot bigger than it used to be, say, 10 years ago'. It's hard to know how the industry copes with the irrationality. And what hope has a consumer got of receiving any sort of fair deal if this is the state of the industry. My wife tells me that if she is buying two blouses of the (ostensibly) same size, she always tries them both on because she has learnt not to trust size numbers.

Some dressmakers are still struggling to change to metric. I overheard a woman in a fabric store recently saying 'She's got a 26 inch waist and the skirt needs to be 45 centimetres long'.

Men's clothing sizes, in Australia, are still based on, and quoted in, inches, even after more than 35 years of metric conversion. One major reason for this is that the men’s industry chose what is called a 'soft conversion' to centimetres. That is, they simply renamed the inch measurement as a centimetre measurement. The length remained the same. Initially the women's clothing industry (in 1970) chose to use hard conversions to centimetres. That is, they actually converted the measurement to its centimetre equivalent and then rounded it to the nearest 5 or 0. This has proved to be slightly more efficient than the approach taken for men's wear.

Sarah the teacher-librarian: But this shouldn't be a problem anyhow. In continental Europe, everyone knows that clothing – and human height – is definitely in centimetres. And wine is in centilitres for retail and hectolitres for wholesale.

Pat Naughtin: Sadly, some textile scientists, engineers, and technicians will sometimes (often) use the opportunity of a metrication program to create their own special (jargon) units for this purpose and the prefix, centi, can be part of this. As an example, I was often puzzled by the inability of wool combers and wool spinners to communicate the idea of wool tenacity to each other, until I discovered that one lot were using a unit called 'newtons per kilotex' as their unit and the other lot were using 'centinewtons per tex' as theirs; one lot defined tex as grams per kilometre and the other lot defined it as milligrams per metre. However, to most of the textile mill workers, whose numerical skills are generally not well developed, terms like centinewtons and kilotex were just incomprehensible jargon.

Activities where little measurement is required such as, for example, butchers, bakers, cheese makers, and pastry cooks, usually choose centimetres. They are the people who have the least measuring skills because they don’t need to measure all day every day, as do bricklayers and carpenters. These are also the groups who received little or no training in the metric system when it was introduced into Australia. They included large groups of women such as nurses, schoolteachers (especially primary school teachers) but they also include other untrained groups such as doctors, police, lawyers and sports reporters.

Sarah the teacher-librarian: Are you saying that, in Australia, women tend to use centimetres and men seem to use millimetres? Why is there a difference between the way the metric system is used by women and by men?

Pat Naughtin: It isn't a neat divide between the women and the men. But when metric conversion was introduced into Australia, more men than women worked outside the home and many men worked for large industries or within large organisations.

These large industries and organisations gathered together to provide (government supported) training programs for their workers, so it was men who profited most from the training. This training supported the use of millimetres – centimetres were not mentioned — indeed their use was actively discouraged.

On the other hand, smaller organisations and people (mainly women) who worked at home were provided with very little training support, if any at all. These people had to devise their own approaches to the metric system, and this was often an uncoordinated grab bag of ideas gleaned from newspapers, magazines, radio, television and their children's schoolbooks. So while many men were trained to use millimetres, in general women were exposed to unsupported versions of the metric system involving lots of centimetres.

The sad part about all of this is that men got the easiest path.

Sarah the teacher-librarian: As we three know, it is only a matter of sliding decimal points backwards and forwards.

Pat Naughtin: Yes, I used to think like this too, and I think perhaps John still does. I kept saying things like, 'Can't they see that it's simple – can't they just move the decimal point'. Then I read some research that had been done on the mathematical skills of adult Australians. This showed that slightly less than half of their subjects could readily (within a fixed time limit) add three items (such as $7.80, $13.25, and $11.90) from a restaurant luncheon menu. When the complexity of calculating a 10 % discount or 10 % tip (just slide the decimal point remember!) was included, the number able to do this dropped to less than 10 %. I don't know what the situation is in the UK or the USA, but it could be that the situation is much the same as Australia's.

One of the thoughts that I had, in the 1970s, as to why the choice-of-millimetre industries were so successful, when compared to choice-of-centimetre industries, was that the introduction of millimetres was a positive help to workers in the building industries but centimetres did not help ordinary workers in any positive way.

When I thought of building workers they had gained millimetres — and the big numbers that go with them — but then as a trade-off, they no longer had to deal with any fractions — ever — at all. After a day or so, they did not regret the passing of calculations like 'What is 4 feet 5 3/4 added to 6 feet 9 5/16? and quickly added 1365 and 2065 and got on with their lives.

Textile workers on the other hand, now had to contend with centimetres that came with several ways to divide them. The metre could be, and still is, divided into halves, quarters, eighths and sixteenths by the simple expedient of repeated folding, and it could also be divided into 3 feet or into 36 inches. A metre could also be divided decimally into tenths, and I have seen Australian advertisements for decimetres of cloth within the last few days. Similarly, the centimetre could be divided into halves and quarters (and theoretically into eighths and sixteenths as demonstrated with metres). The centimetre could also be divided decimally into tenths.

The idea of decimal numbers was a completely new concept to most ordinary textile workers as they had been trained on the doubling and halving principle and on yards, feet, and inches. Textile workers reacted to the addition of these new-fangled decimal numbers by clinging tenaciously to yards and inches and adapting 'metric conversion' techniques to change any 'foreign' units back into old measures. By the way, I doubt that anyone in the Australian textile industry ever considered the issues of accuracy and precision as they struggled to cope in this new world of numbers and calculations. The choice of millimetres as the small unit of length for the Australian textile industry would, based on my observations of the building industries, have avoided almost all of this pain and commercial loss.

Sarah the teacher-librarian: But, in some cases, the use of millimetres just seems silly. For example, when I am making slacks I know that my trouser inside leg measurement is 73 cm. Two significant figures is all I need. It would be absurd to quote it as 827 mm (say), or give a 3-significant figure of 830 mm where to 0 has no significance!

Strangely, it would seem to me, that it is better to work with fabric in millimetres. Not because of the precision issue (which you quite rightly point out) but because of the accuracy issue; cutters who aim for millimetre accuracy do better work simply because they are aiming to cut to that level of accuracy. I am basing this idea on observations made in the Australian building industries where they estimate that material savings can be as high as 15 % by aiming for millimetre accuracy. And these savings arise before the further savings that arrive directly from having everyone on every building site working only in whole numbers. No fractions need be mentioned on any building site in Australia, and they haven't been needed since 1974 — there are no common or vulgar fractions and there are no decimal fractions either. These advantages could readily be transferred to the textile industries by adopting a policy of using millimetres — only.

Ease of use

Pat Naughtin: We have discussed the fact that in the various building and metal trades almost all people successfully, and quickly (in a few months in some cases), changed to the metric system in Australia if they use millimetres and avoided centimetres. We also know, again from experience such as measurement of men's clothing, that the use of centimetres has slowed down the conversion process remarkably (at least one human generation - from 1976 - so far).

And further, we know that whole national communities can change quite quickly to the metric system if the only conversion factor between adjacent units is 1 000. In Australia this was proven by our transition to SI units for mass and for volume. When did anyone last convert 500 grams of meat back into lbs and ozs?

People may initially have spent a little time converting back to pounds and ounces, but very soon they simply used the new units without conversion. There was no hint of a problem, and there are virtually no demands now to revert to the old pounds, stones, quarters, hundredweights, and tons. Given the simplicity of only three units, people rapidly accepted the fact of metrication and adopted it.

These two rules are all that an Australian needs to know about the measurement of mass.

1000 grams = 1 kilogram   1000 kilograms = 1 tonne

Australians also changed to millilitres, litres, and cubic metres quite comfortably. These two rules are all that an Australian needs to know about measuring capacity or volume.

1000 millilitres = 1 litre   1000 litres = 1 cubic metre

In both of these cases the only conversion factor is 1000, and so far no one has felt the need to protest about the urgent need for centigrams and centilitres in Australia.

Australians haven't baulked at expressing mass or capacity in hundreds, or occasionally a thousand or so, grams or millilitres — so why knock the millimetre? Builders, for example, say:

> *'Given that for practically everything else we are content with a 1000:1 ratio, why wouldn't it be better to stick to that throughout all of our measurements?'*

I'm convinced that the reason many Australians are still struggling with length measures is largely because of the difficulty of using centimetres.

In 1981, 'Metrication in Australia' by Kevin Wilks was published to summarise ten years of the activities of the Australian Metric Conversion Board. As I read this report it became very clear that

Australians were very successful in converting to SI in those trades and occupations where millimetres were chosen, and had just as clearly failed in those activities where centimetres were introduced.

Sarah the teacher-librarian: But the centimetre and centilitre are two of the most useful units of an everyday metric system in Europe. They might not fit in some 1000s pattern but that is no reason not to use them. Ordinary people don't care about 1000s patterns.

Some really nice and useful units that they use in Sweden (and in Europe generally) are:

- ◊ centimetres – always used.
- ◊ centilitres – perfect for soda cans etc. (eg. 33 cL or 50 cL) but not in millilitres (mL) that have so many unnecessary zeros.
- ◊ decilitres – used for cooking.
- ◊ millimetres – used only when a really small measurement is needed.
- ◊ decimetres – used widely in common language. (eg. "There were only a few decimetres between them.')
- ◊ hectograms – used widely. The Swedes would say 'three hectos' rather than 'three hundred grams'.

The metric system has been around for over 100 years over there and the units above are some of those that turned out to be useful. There is no reason for not accepting them in the USA.

Pat Naughtin: Exactly right! Sweden has been using the metric system for 'over 100 years'. In fact, they made their initial change to the metric system in 1875 — more than 130 years ago — but they'd been trading with their neighbours in metric units before that.

I’ve visited Sweden too, and observed how they use the prefixes milli, centi, deci, deca, and hecto. I was struck by the way that they were applied quite unevenly, and that, as you pointed out, they use jargon terms such terms as 'hectos'. I would like to ask two questions, but in doing so I am aware that I don't know the answers to either of them. They are:

- ◊ How long did the metrication process take in Sweden; we know that it was less than 130 years but how much less?
- ◊ What was the cost of metrication in Sweden; and was it smooth and economical?

I think that decilitres, centilitres, decalitres, decametres, decimetres, hectometres, decigrams, centigrams, and hectograms are needlessly complicated and confusing and that there is little, if any, advantage in using them.

Isn't this simpler?

1000 millimetres	= 1 metre	1000 metres	= 1 kilometre
1000 millilitres	= 1 litre	1000 litres	= 1 cubic metre
1000 grams	= 1 kilogram	1000 kilograms	= 1 tonne

John the engineer: Please pardon me for again splitting hairs – it's the engineer in me! In a sense what we have today has evolved from the original concepts of the designers of the metric system. In which case the current system was reached through evolution rather than careful design and, as we know from the natural world, evolution tends to produce results that mislead people into thinking that there must have been an intelligent design behind it.

Pat Naughtin: So you don't think that the current metric system is good design as such, but rather, if it is good at all, it was just dumb luck — an evolutionary or a historical accident!

Sarah the teacher-librarian: But if what John says is true, then those prefixes would have withered away under evolutionary pressures as well. The fact that they didn't suggests that they are useful — in particular they are worth the complexity of the additional units. I'd like to see greater use of these prefixes. For example decimetres seems particularly suitable for pool depths.

Let's not forget that one of the few positive features of Imperial/Colonial/Customary is that they have units that are suited to specific ranges (inches for measuring small distances, miles for big distances). The metric system achieves the same effect using prefixes, without the attendant conversion problems. Advocating anything that will make the metric system compare less favourably with Imperial/Colonial/Customary is not in our interest as promoters of the metric system.

John the engineer: I personally have become a millimetre-ist rather than a centimetre-ist at my work in recent years. That's because I like the absence of the last decimal point. But that's just my own work preference. I still use the centimetre for my height, 186 centimetres, and for my clothing, and I still use centimetres around the house for doing maintenance. I also use centimetres and even decimetres when I am working in my home workshop. It's no trouble for me to just change the units whenever I want to.

Pat Naughtin: And don't forget your innate ability with numbers, and the fact that it took years at school and university to reach that point.

John the engineer: Touché. But while I accept your observation that metrication in the Australian building industry was faster than the metric conversion in the Australian textile industry, I don't accept your conclusion that this was due to the former using millimetres and the latter using centimetres. This would be a more convincing argument if they could cite a successful migration of a clothing industry elsewhere using millimetres. I believe that centimetres are quite suitable for clothing, and the relative failure is due to other factors such as greater familiarity of the public with old pre-metric measures in the activities that deal with body dimensions.

Pat Naughtin: Sadly, no such comparison is available in the textile industry because, as far as I know, all nations when making their metric transition chose to use centimetres in their textile industry. By the way, also as far as I have been able to determine, they all experienced the same painfully slow metric conversion.

But a valid comparison is that Canada chose to use centimetres for building, and they're still struggling since their beginning in the 1970s. Australia, Botswana, Cameroon, Mauritius, New Zealand, South Africa, and Zimbabwe all chose millimetres and their building metrication process was done and dusted in a year or two.

If the USA adopts the use of the millimetre they will have only three common units of length. Their current common measures (say in the furniture and general building trades) are thirty-seconds, sixteenths, eighths, quarters, halves, inches, links, feet, yards, chains, and miles — eleven in all with many more conversion factors. The USA would replace eleven units with three units, all related by the single factor of one thousand.

1000 millimetres = 1 metre   and   1000 metres = 1 kilometre

John the engineer: I'm using millimetres at work because I'm generally working with parts less than 1000 millimetres long with tolerances ranging from 0.001 to 1 millimetre. This is good for me, because I never have more than 3 digits on either side of the decimal. Many dimension are 'hard metric' to the nearest millimetre, so I don't waste my time working with 6 digit numbers in these cases.

Pat Naughtin: This is what most people do within their workplace. They arrange for their units to provide convenient numerical values. At its best this process is also used to select units so that there are no fractions — at all — no common fractions such as 1/2, no mixed numbers such as 3 4/5, and no decimal fractions such as 6.789 either.

Sarah the teacher-librarian: I would argue that many people would have a problem if they were presented with clothing sizes or shoe sizes that had three digits.

Pat Naughtin: I have heard this statement on many occasions, but I've never been able to find any justification for it. I've seen ample evidence that people can and do accept three, or more, digit measurements. For example, in the USA, people readily accept 3 digit driving distances (in miles), 3 digit body mass (in pounds), 3 digit cooking temperatures (in degrees Fahrenheit), 4 and 5 digit prices for cars, 5 digit amounts for annual salaries (no problem at all there), and even 6 and 7 digit prices for homes. Based on these observations it is obvious that people regularly, and willingly, use 3 or more digit measures. As a matter of interest the international standard for shoe sizes (Mondopoint ISO 9407:1991) uses a three digit method to measure the length of your longest foot in millimetres. This is then rounded to end in 5 or 0 and shoes are selected to suit the size of your foot. I suppose that in this case your would be asked for your foot size rather than your shoe size.

Sarah the teacher-librarian: Oh yes, you're probably right now that I think about it. We do regularly use larger numbers than we have to. We prefer to go from feet to miles and skip yards in many applications and we don't make use of the stone, we simply use pounds. Larger numbers would be no issue for people, just something to get used to. The only reason a 46 inch waist sounds huge is because we're used to what a 26 inch waist means. I don't suppose that it would take long to learn what a 650 millimetre waist is. We soon get a 'feel' for units by using them.

Pat Naughtin: Or as my wife pointed out, 'How would you like to be told that you have a 0.65 waist instead? How small is that?'

John the engineer: We seem to understand our English measurement methods by each application but not in general. How many Americans would comprehend petrol sold by the pint or quart? If someone were to state their weight in stones and pounds, no one would understand. How many butchers in the USA would understand a request in pounds and ounces rather than in fractional pounds?

Sarah the teacher-librarian: I know what you mean; **t**he butchers at our local farmer's market become confused if I throw them a curve and ask for (say) 12 ounces, as stated in a recipe from the UK, instead of quarter-pound increments.

Pat Naughtin: This is an interesting problem because when you use the old pre-metric measures you always have a choice of, at least, three ways of saying the same thing; for example 20 ozs is the same as 1 pound 4 oz, and both of these are the same as a pound and a quarter.

I don't see this happening when you use the metric system. If your recipe calls for 1200 grams, the butcher would have no problems in serving you 1.2 kilograms. Because the metric system is based on decimals fractions and mixed numbers are rarely used.

John the engineer: If we wish to express a length of 1.62 metres, we now have three choices: 1.62 metres, 162 centimetres, or 1620 millimetres. What you are saying is that you want to restrict us to using 1620 millimetres.

Pat Naughtin: No – not at all. I think you've assumed that I am arguing in favor of only using millimetres, but I'm not. I'm arguing for the use of either millimetres or metres whichever is more suitable. If 1620 mm is not suitable then use 1.62 m.

Sarah the teacher-librarian: That's a coincidence! The example you chose is the same as my height — 162 centimetres. And that's how I think of it – in centimetres. It seems to me that there is a very natural tendency for folks to think of a millimetre as 'very tiny' at the scale humans usually operate at day-to-day. So it seems natural to measure 'normal' lengths (such as height) in centimetres.

Pat Naughtin: This could be because height wasn't expressed in yards. If a person was six feet that's what you said – not two yards. So there could be an unstated resistance to using metres for height. But why not just say 1.6 metres or 1.65 metres? In most instances that is quite accurate enough, and it's easier to visualise.

I don't recommend the use of centimetres or millimetres for human height. My recommendation to the police force in our state was to use metres as the unit for height, and to recommend that guesses be made so that they end with a five or a zero.

When I worked with our local state police force, training sergeants, and it was (and still is) their policy to use centimetres for measuring and guessing height. I was able to observe their reaction to this and to how they went about adjusting to this method.

Basically using centimetres has not been a success, and many of our police are still struggling to adapt to this policy. With hindsight it was probably unwise to leave police, nurses, doctors, lawyers, and others to their own devices to choose centimetres when describing human height. Even after more than 35 years, most police officers in our state have not yet changed their mind-set from feet and inches, and they tend to guess heights that way (usually using 2 inch intervals) and then convert their guesses into centimetres by memorising some conversion factors. For example, many police simply remember that 6 foot is 183 centimetres or that 5 foot 2 is 157 centimetres. It would be much simpler for us all if they changed directly to metres; for the above examples 1.8 m or 1.6 m would be just as useful approximations, keeping in mind that each estimate was probably made 'on the trot' so to speak.

I find it hard to believe that a police officer running at full speed in pursuit of a fugitive, also running as fast as they can, can tell me later that the fugitive was 163 centimetres. It's nonsense! I suspect that nobody can guess within an accuracy of a single centimetre. Clearly the officer has guessed the person's height at 5'4", changed this to 64", multiplied by 2.54 and rounded 162.56 to 163 centimetres. Surely it is much simpler and easier to guess that the fugitive was 1.6 metres or 1.65 metres and leave it at that.

If police were trained to use their own height (in metres), a standard two metre door, and the size of a fist (close to 0.1 metres) as convenient mobile references, they would have ready made measures in most places they visit and they could use these for estimation of height to the nearest 0.1 metres or even to 0.05 metres.

Similarly, it's amusing to hear a sports announcer describe someone as 187 centimetres. You know immediately that the announcer has yet to change their mind to metric. They have clearly done a complex conversion from old measurements. If they understood the metric system they'd probably round 187 cm to 1.9 metres. And that's probably the best level of accuracy (0.1 m) that we can hope for in guessing someone's height on the far side of a 200 metre wide playing field!

However, having said all of that, I am now noticing that there is a shift from centimetres to metres among Australian sports reporters. For example, some sports reporters have discovered that it's easier to think about a 2 metre basketball player or a 1.9 m football player, and they are beginning to use these terms, using metres as the unit. I think this is a positive step forward in changing the mindset of Australians.

And because height has never been described by using 'yards', there is no conversion taking place when these people now use metres, so the transition to a metric way of thinking will be rapid.

By the way, Sarah, I bet you quickly change your height to metres when you want to calculate your Body Mass Index — your BMI.

Sarah the teacher-librarian: Ha! Let's get back to the discussion about centimetres and millimetres. I think that where people have problems on this issue is when they have to describe a length that is less than a metre in hundreds of millimetres.

Pat Naughtin: I am mystified by the constant repetition of one of the 'reasons' why millimetres are too small for measuring many common things. The argument seems to be that because millimetres are so small, the numbers have to be inconveniently large. And 'inconveniently large' seems to mean numbers in the hundreds. My problem is with the question, 'Why are numbers in the hundreds considered inconvenient?' Remember I said earlier that I've seen ample evidence that people can and do accept three, or more, digit measurements. Think about this:

1 On most mornings I step onto a bathroom scale and confirm that my body mass in kilograms involves 3 digits!

2 My height is 1.85 metres and this is in the right form to calculate my Body Mass Index (BMI).

3 I measure out 350 mL of water to make a mug of coffee. Measuring this minimises the amount of electrical energy needed to boil the water. If my wife wants a cup of coffee, I add another 250 mL.

4 A road trip that we occasionally take to visit my sister-in-law is 195 kilometres from door to door.

5 My oven instructions tell me to cook various things at 220 °C.

6 Foods such as sandwich meats and cheeses may be sold in lots of 100 grams.

In all the examples above people routinely work with numbers in the hundreds with no difficulty at all.

However, if people in the USA really did object to three digit numbers, they could simply solve this issue by upgrading to the metric system. For most adults their 3 digit pound values would suddenly become 2 digit kilogram values!

Sarah the teacher-librarian: When I cook from some European recipes I have to deal with liquids in centilitres. I have to say that, personally, I avoid the use of centilitres in favor of (say) 250 millilitres on my coffee cup.

Pat Naughtin: Australia avoided centilitres (along with decilitres, decalitres, and hectolitres) in our metrication process, and as a result the conversion from all of the old pre-metric capacity or volume measures to millilitres and litres was relatively painless, reasonably rapid and it cost very little.

John the engineer: There are some building products that have micrometre names too.

Pat Naughtin: While builders don't generally use micrometres they are not fazed when they see them because they are part of the system. A builder simply knows that a micrometre is a thousand times smaller than a millimetre (perhaps because 1000 is the only conversion factor he knows).

On another line, I have recommended that a manufacturer use micrometres only, but this was in the specialist area of piano building.

The wires used in pianos can be described using various gauge numbers that differ between themselves and in reality have no specific meaning and depend largely on the part of the world where the piano wires originate. I recommended to Wayne Stuart, the proprietor of 'Stuart and Sons Pianos', that he order his wires by their diameter in micrometres and their lengths in metres and let the wire manufacturers work out what that meant in gauge numbers if they wanted to waste their time doing that. If you require a wire that is 1300 micrometres that is what you order. (See: http://www.stuartandsons.com/ for details of Stuart & Sons Pianos)

John the engineer: Clearly, prefixes are a great invention. So why don't we encourage the use of all of them?

Pat Naughtin: I absolutely agree. Prefixes were a great invention but this doesn't mean that they are uniformly useful. This is a case where less is definitely better.

John the engineer: Centimetres are part of a whole decimal method of dividing units into smaller or larger parts. Centimetres, with decimetres, decametres, and hectometres, allow you to multiply and divide by the easy to use 'tens'.

Pat Naughtin: What you say is true. This was the original intention of the designers of the metric system in the 1780s and 1790s, but since then we have found multiples of 1000 to be far more practical and much easier to use.

John the engineer: My biggest complaint is that for longer lengths it makes numbers inconveniently long and difficult to read.

If you look through the list of occupations that you shared with us earlier, most of the professions that use millimetres are either technical, or involve small sizes or tolerances where millimetres are more appropriate. I suggest that your millimetres professions caught on more quickly because they are more technically minded and measure length more often than, say, a baker, cook, gardener, or tree surgeon. I would certainly not want to do landscape gardening in millimetres!

Pat Naughtin: A friend of mine is a landscape architect. I asked him what units he used and he replied that all of his drawings are done in metres or millimetres. When I asked why he replied, 'So all the tradesmen on the job can understand them and we never have to change from one lot of units to another. The large site layout drawings are done with the note 'All dimensions in metres', but anything that shows any detail has a note in the corner that says, 'All dimensions in millimetres' and I have never seen, or even heard of, anyone involved in landscape gardening using centimetres.'

John the engineer: You can mix and match millimetres, centimetres and metres to suit the particular job you're working on.

Pat Naughtin: You don't give up on this, do you? But this rarely, if ever, has any practical advantage. It is usually better to select one unit to work in a particular activity and then stick with it. For example, in a list of items it is best if only one prefix symbol should be used. Consider the lengths in these 2 lists:

One prefix	Several prefixes
4 mm	4 mm
12 mm	1.2 cm
6789 mm	6 m 78 cm 9 mm
30 mm	3 cm
1200 mm	1 m 20 cm

Which would you rather add, the first column or the second column?

John the engineer: The way you choose to measure is a tool — nothing more. Like any tool, it is quite possible to come to an objective decision that one tool is better than another. For example, a spanner and a socket perform the same task but they are different tools. The general criteria are:

◊ Which tool is more efficient at the task?

◊ Which tool is easier to use?

Pat Naughtin: When you're measuring all day long, you want the numbers to be easy to read, easy to say, and easy to remember.

Most people who use millimetres recognise that millimetres meet these requirements mostly because they don't need fractions. A millimetre is generally small enough for most woodwork, in fact lengths less than a millimetre are most uncommon. As you rarely need halves of millimetres or tenths of millimetres, all length measures can be expressed as whole numbers.

There is no need to discuss whether to use binary fractions (halves, quarters, and eighths, etc.), other fractions (thirds, sevenths, or twelfths), or decimal fractions as there is no necessity to use any fractions at all — ever. Calculations of all types are easier: additions are easier; subtractions are easier; multiplications are easier; and divisions are easier, and they can all be done on an ordinary calculator. And there is less clutter. For example the dimensions of A4 paper – 210 mm x 297 mm – looks a lot less cluttered, using millimetres, than 21.0 cm x 29.7 cm; and both are superior to the old 8 17/64 inches x 11 11/16 inches.

So let me comment on your criteria.

◊ Which tool is more efficient at the task? Answer: millimetres.

◊ Which tool is easier to use? Answer: millimetres.

Sarah the teacher-librarian: I can see that the metric system is clearly a 'better' tool at getting the job done, and people who change over get the hang of the new system very quickly.

Pat Naughtin: Yes, during the time I worked in the Australian building industry I met builders from all around the world and I got to know some of the metric methods used in other nations. Some of these had worked in centimetres in their home country. When they arrived in Australia, it was not long before they changed to working in millimetres. You could conjecture that they did this to fit in with the local builders, but I suspect that they changed also because it was less complicated. I particularly remember an Italian bricklayer who told me about one building company for whom he had worked using numbers like 2,34,5 to mean 2 metres, 34 centimetres, and 5 millimetres — every number had 2 commas as decimal markers.

Sarah the teacher-librarian: But I still say that numbers using millimetres get too big.

Pat Naughtin: Well, people are not frightened of large numbers for mountain or aircraft heights. We were traditionally given the heights of mountains in feet in the old days. No-one expressed the height of Mount Everest as 5 miles, 39 chains, 20 yards, and 1 foot: the estimate was 29035 feet (8850 metres). People aren't frightened of large numbers; they're simply not used to using them in some applications.

Sarah the teacher-librarian: And I also still say that with millimetres you have too many zeros.

Pat Naughtin: Anti-metric people have often pointed out how silly it is to name large, imprecisely measured objects in hundreds or even thousands of tiny millimetres with long rows of zeros. In isolation this is not a bad argument, but it ignores the enormous practical benefits completely removing fractions, both vulgar and decimal, from all measuring work. Measurement and calculations are much easier and there are few costly errors made, as can happen with calculations involving any sort of fractions.

And in arguing against millimetres people do tend to exaggerate a little to prove their point. For example, you don't need to express your height in millimetres — use metres. And as I have said before, no one baulks at asking for 500 grams of meat.

Experience in architecture and engineering, and in the bricklaying, carpentry, electrical trades, fitting and machining, gas-fitting, joinery, metal fabrication, plumbing, and saddlery trades has shown the benefits of using millimetres both in the initial learning of measurement skills, and in the use of them on a daily basis. The 'difficulty of too many zeros' is put into context when we consider that builder's laborers, in Australia, New Zealand, and South Africa, often with little secondary education, have no trouble with tens of thousands of millimetres, but rocket scientists at NASA in the USA had trouble landing a Mars Probe using a blend of old pre-metric and metric units. Ouch!

Sarah the teacher-librarian: With all this discussion of what is true SI and what is not, the average person really doesn't care. We'll leave that for the scientists and engineers to debate. We just want things to be easy to understand and easy to use, otherwise it will be difficult to promote change. Even with the term 'SI' I get the same blank stares as if I said ISO or NIST, but everyone in my circles knows what I mean by the term metric system.

Pat Naughtin: You're right that the scientists and engineers will continue to debate these issues but the sad part is that they will do so from their own perspectives, where their scholarly debates have little practical application for the rest of us. We expect leadership from our scientists and engineers, yet all we can see them doing is squabbling. One of the issues here is that many in our populations have limited numeracy skills, but our scientists and engineers seem to be innocently unaware of this, because they judge these issues from the perspective of their own highly developed numeracy. It is often difficult for a numerate person to see that the advantage of using millimetres (only) is that it reduces all measures to simple numbers – granted they may be large numbers – but they are simple, and can be successfully handled by a large range of workers.

And John, you know that professional engineers are used to handling the significant figures that ultimately produce the accuracy required for each job. If a newcomer to a technical industry reports something like 156 578 millimetres, implying accuracy to the nearest millimetre, their colleagues will soon set them straight. In technical work everyone who is involved with measuring soon learns about significant figures and where and how they are properly applied.

On anther issue, car drivers regularly add zeros to tachometer readings. Most cars have tachometers marked in single digits around the edge and a mark like '000 r/min' at the bottom of the dial. You have to add extra zeros to get the true speed of the engine; if the needle points to the number 3, you read it as 3000 revolutions per minute.

John the engineer: Let me take up your point about significant figures. This is one of the issues that grates with me when I see this issue poorly handled. For example, I regard the specification of a computer monitor screen as having a diagonal dimension of (say) 432 mm quite misleading. The latter dimension is given to 3 significant figures, which is:

(a) meaningless, and

(b) quite unnecessarily precise as a nominal screen size.

What would you do? Give the size as 430 mm? If you did, you would still be claiming 3 significant figures — the zero has a right to be just as significant as any other digit! Or maybe you would specify the screen size as 0.44 m, thereby (quite correctly) claiming only 2 (very sensible) significant figures.

Pat Naughtin: With respect, I think that you are stating the problem in reverse. It's a long time since computers have been designed or made using inches. Modern computers are designed and built using metric units with internal chip designs now down to nanometres, IC design now in micrometres, with the motherboard, case, and screen designed and built in millimetres — and then, finally, marketing to the public is done using inches. Conversationally, an order of events in this computer screen's history possibly went something like this:

> ***Designer 1:*** *'Can we make the screen about 350 wide, then it will fit neatly in the design of an old 350-millimetre case we already have?*

Designer 2: *'OK, I'll make it 340, then it will fit fine. Let me work out the height, If we use the 5 to 4 ratio of the old case, 340 means it will be 272 millimetres high exactly.*

Marketing manager: *'Hey you guys, what size will the new screen be?'*

Designers (in chorus): *340 by 272.*

Marketing manager: *What's that across the diagonal — I want the biggest number possible.*

Designer 2: *Hang on I'll work it out for you* ($\sqrt{(340^2 + 272^2)}$ = *435.4124481 millimetres.*

Marketing manager: *C'mon guys, what's that in real numbers?*

Designer 1: *A bit over 435 millimetres or a bit more than 43 and a half centimetres.*

Marketing manager: *No, I mean in inches.*

Designer 2 (after a calculation): *It'll be about 17.1422224 inches.*

Marketing manager: *OK, we'll call it the 17-inch model and we'll put a sticker on the screen showing that it's a 17" screen.*

By the way, I don't think that the concept of precision will occur to the marketing manager. However, if it does it will be thought of in the legal context of not having the company sued for false advertising. In the example given above, he would decide that 17 inches was slightly below the calculated 17.1422224 inches and therefore there was little chance of anyone suing the company based on false advertising.

By the way, Australia still has to confront this inches for screens stupidity on a daily basis because we allowed the television and computer screen makers from the UK and the USA talk us into allowing a loophole for inches in to the metrication process in 1970.

John the engineer: But people can get used to anything eventually — witness the number of people who are quite adept at Unix command line hieroglyphics.

Pat Naughtin: Yes, they can get used to it, but which system will reduce costly mistakes? A system that is easily learned will be learned more quickly, and is less likely to cause confusion later, and the metric system is a good example of this. In the Imperial system you have to learn about inches, feet and yards as separate units, and you are unprepared for ounces, pounds, stones, hundredweights and tons; or fluid ounces, pints, gallons, and barrels. With metric, you learn how the millimetre and the metre work together, and you automatically know how the millilitre and the litre work. And with not much more effort, you can understand how the gram and the kilogram work together.

Sarah the teacher-librarian: I've observed that the so-called irregular prefixes, hecto, deca, deci, and centi, along with kilo and milli, have long been taught to every American student whereas the other prefixes (eg. mega, giga, micro, and nano) are not routinely taught.

Pat Naughtin: And that's a real shame, because the prefixes mega, giga, micro, and nano are far more commonly used in American industry than deci, deca, and hecto. Teaching hecto, deca, deci, and centi, makes no practical sense. At the end of the day we all lose if there are too many prefixes. An old example was when two separate standards were introduced for video recording tapes (VHS v Betamax). Even though Betamax was regarded as the better technical choice, VHS won out commercially. In a way it didn't really matter which won out, it was simply important that one did, as maintaining both would have ultimately resulted in higher prices for consumers. This is why we have standards organisations such as the International Organization for Standardization (ISO).

Sarah the teacher-librarian: And no one seems to use decagram, even though I teach it because I think it would be convenient for the range of small masses encountered in everyday life.

Pat Naughtin: These irregular prefixes are often used in science and technology as a subterfuge to avoid giving up obsolete, non-SI, and non-coherent metric units. Here are some examples of this:

1. decanewton (daN) is sometimes used for forces because it is close to the obsolete kilogramforce (kgf) or kilopond (kp), even though most values could be more easily expressed in kilonewtons (kN). This practice seems to be declining.
2. decapascal (daPa) is used by audiologists because it is close to the obsolete mm H_2O they formerly used, even though the values involved could be more simply expressed in kilopascals (kPa). This practice seems to be firmly entrenched.
3. hectopascal (hPa) is used for atmospheric pressure because it is the same as the obsolete millibar (mb), even though the values could be expressed as easily, or more easily, in kilopascals (kPa). This practice seems to be growing.

Those in charge of metrication in these technical activities were scientists and engineers with little or no practical experience or interest in using (or encouraging) the use of the metric system in everyday life. They only concerned themselves with what applied to their speciality. How else could we explain the persistence in astronomy of miles, nautical miles, and kilometres, astronomical units, light-minutes, light-years, parsecs, and even kiloparsecs and megaparsecs. The latter are particularly offensive as they consist of a non-metric length measure prefaced by a metric prefix!

Actually, if you examine these situations closely, you realise that what the perpetrators are preserving is not the old units but the set of numbers they are used to using; they are not preserving old units, they are preserving '*reference values*' and '*rules of thumb*' so that the numbers that they have traditionally used either don't change or change numerically by only small amounts.

And the use of jargon can create communication difficulties that ultimately may prove to be very expensive. As I said earlier, I was often puzzled by the inability to communicate the idea of wool tenacity between wool combers and wool spinners, until I discovered that one lot were using a unit called 'newtons per kilotex' as their unit and the other lot were using 'centinewtons per tex' as theirs; but worse — one lot defined tex as grams per kilometre and the other lot defined it as milligrams per metre. I have no doubt that wool science specialists should use whatever is the best SI metric unit for them to use but they also should have a responsibility to communicate their results to the public. However, I know from (sometimes bitter) experience that scientific specialists are not metrologists. In my experience, in the Australian wool industry, I am still appalled at the lack of communication between wool scientists and wool growing farmers because of the scientist's silliness in using words like micron, tex, and denier, that few wool growing farmers can understand.

Let me share with you a somewhat embarrassing example. Someone posted, on an internet forum, a remark concerning a drinks can that had been mistakenly referred to in a newspaper article as 330 cL. The writer of the message jokingly imagined a giant 33 litre can of coke and I missed the mistake — it should have been 3.3 L — until someone else pointed it out. That stopped me in my tracks. This was not the first time I have privately got things wrong when converting between cL or cm and their larger units. Why is it (I thought to myself) that I am so prone to this kind of error? Surely nothing could be easier than multiplying and dividing by 100!

Sarah the teacher-librarian: If hecto, deca, deci, and centi aren't convenient for your purposes, fine, don't use them, but they are just as valid as kilo and milli, and may be more appropriate for other people.

John the engineer: As an example, the hectometre (hm) would be convenient for flight altitudes, if aviation ever metricates.

Pat Naughtin: The prefixes 'centi', 'deci', 'deca', and 'hecto' are legitimately listed among the SI prefixes for historical reasons, so they are all legally allowed. The reason I think they should be swept under the carpet is because these prefixes violate the simple and readily learnt SI principle of prefixes being multiples and submultiples of 1000.

There is a vast difference between activities that are legally correct and activities that can be described as world's best practice.

And if and when the aviation system metricates, I profoundly hope they use mm, m, and km, as I'd hate to be on a plane that ended up like the Mars Explorer, and for the same reason.

In most industries all around the world 'centi' is regarded as a non-preferred prefix. Worldwide, the automotive and mechanical engineers generally decided in the 1970s that engineering drawings should use millimetres only for dimensions. This was a decision that helped remove a lot of confusion from engineering drawings and led to the highly successful metric transition in the automotive industry in the USA that began in the mid-1970s — and ended in the mid-1980s.

Many believe there is a need to reduce the numbers of prefixes, especially to reduce the number of derived units. Therefore constructions such as decagrams per hectolitre and centigrams per decilitre should be avoided.

And the international standards bodies, such as the CGPM and the ISO, have discouraged the use of an earlier set of metric units called the centimetre-gram-second (cgs) units, as a group. Specifically they discouraged the use of the derived cgs units such as the dyne, the erg, the gauss, and the poise.

In many fields it is simply considered good practice to avoid centimetres.

John the engineer: I suggested in the UK that decimetres might be a way of making SI more acceptable to workers because the numbers are smaller.

Pat Naughtin: Don't underestimate the workers. They can master most measuring systems because they use them so constantly. There was concern in Australia about the large size of the numbers, if you use millimetres, but it never worried the workers on building sites. As an example, I was on a building site a few weeks ago when I heard a plumber (referring to an inspection pit) say,

> *'If it's twelve thousand three hundred and fifty from the laundry, then its gotta be nine thousand four hundred from the fence.'*

With which his mate took out another tape and to check if he was right.

Sarah the teach-librarian: In Canada, they use millimetres for rainfall and they use centimetres for snowfall. In both these cases, the measures are conveniently precise and, coincidentally, they amount to very nearly equivalent amounts of precipitation.

Pat Naughtin: This is a very good example of what I was just saying about incorporating a rule of thumb into your choice of units. Weather people know that it takes about 11 or 12 times more depth of snow to be equivalent to the same amount of rain. Put another way, it takes 11 mm or 12 mm of snow to be equal to 1 mm of rain. So when the metric system was introduced into Canada, they measured rainfall and snowfall in millimetres and centimetres — 20 mm of rain or 20 cm of snow. This practice will probably continue and will most likely spread south to the USA.

Sarah the teacher-librarian: I love the centimetre! OK, it does not fit perfectly in the SI scheme of things, but it is extremely handy. For me it is simply a matter of preference. I have been using the centimetre since I was around 10 years old. I really didn't use the inch much until I was in my early twenties and was forced to use feet and inches as an adult due to my employment. Boy, do I hate fractions. All those 1/4, 1/8 and 1/16 fractions drove me crazy. And decimals inches are even worse. You have to constantly consult a chart to convert the decimals to fractions.

I do use millimetres for smaller, more precise measurements, but I express my height as 162 centimetres so that there's no need to worry about a decimal point. I don't ever consider that I am 1620 millimetres or 1.62 metres. And I secretly wish the centilitre was more common, but here in the USA it is relatively unknown. The centigram is a moot point since gram is already a very small unit for common everyday usage.

Another point. European measuring tapes number every centimetre mark with its centimetre number so the tapes are not cluttered with lots of useless final zeroes.

Pat Naughtin: Forget about the extra zero – you don't worry about it when buying meat or soft drink.

Best practice in Australia is to use millimetre marked tapes when you are working with millimetre-dimensioned drawings and the final zeroes have never proved to be an issue.

John the engineer: Mechanical engineering practice in metric countries is to use millimetres for all dimensions, even for huge railway locomotives.

Pat Naughtin: And if all the dimensions are in millimetres each number is sufficient on its own; no indication of 'mm' is required on any dimension and '500' takes less ink than '50 cm'.

John the engineer: But a common objection against using expressions like 1730 millimetres instead of 173 centimetres or 1.73 metres is that the statement in millimetres is overly precise. Many people claim that 1730 millimetres would imply that the quantity is expressed with an accuracy of ± 0.5 mm and that this precision may not be warranted.

Pat Naughtin: People with common sense soon decide the degree of accuracy needed. And it wouldn't be wise for you to express your designs for your remodelled kitchen in centimetres, as either you or the builder will then have to convert your communication into something that the trades people can understand. The possibilities for error and confusion will be present in every single measurement.

I once saw a piece of glass intended for the front of a shop counter that would fit neatly within this page — the butcher measured in centimetres, the glazier cut in millimetres, and the glass fitter brought a tiny piece of glass to the shop. One prefix for all jobs removes the possibility for error, and I repeat – common sense will dictate the degree of accuracy needed.

Learning

Sarah the teacher-librarian: But surely the use of centimetres or millimetres is really a language issue. It's about which words we choose to use, and all of us will make our own choices based on what we learn about these measuring units. There's obviously a cognitive balancing act going on in the minds of most people. They are asking: how many different prefixes should I use, how big should the numbers in front of the units be, will there be there a decimal point, and which prefix is best in this situation?

In other words there is a metric language 'marketplace' out there, and we should let this language 'marketplace' decide on these issues.

Pat Naughtin: What you say is true, and it's especially so in a democratic nation. We also must allow for freedom of choice, and if someone decides to take a slow, difficult, and expensive approach to metric conversion then there is little we can do for them. There is a race for leadership on this issue. As experience has shown that metrication with millimetres is faster, smoother, and cheaper than metric conversion using centimetres. As metrication leaders it should be our responsibility to try to convince people that it's in their best long-term interests to choose millimetres rather than centimetres for most of their length measuring.

John the engineer: But learning the metric system is really complex. There are the base units to learn, then the names of the 20 prefixes, and the names and meanings of the 22 'SI derived units with special names and symbols', making 49 new things to learn.

Pat Naughtin: A commonly held belief, but it's a nonsense. Most people can get through their whole lives easily using just the basic ten units, as I mentioned earlier. And those who need certain prefixes and/or derived units for their work will easily learn them as required.

Sarah the teacher-librarian: Let me support your millimetres only approach — but in my own way. I've been using centimetres only around the library and around my and house for years, and I simply find it easier. So I can sort of see an advantage in choosing to have only one prefix; it's an 'acquired' skill, but works quite well once you acquire it. The difference between us is that I have chosen centi as my prefix while you have chose milli as yours.

Pat Naughtin: I absolutely agree with your observation that it is best to have only one prefix, but had you chosen the millimetre:

- ◊ Thinking in 'blocks' of 100 millimetres and 1000 millimetres would quickly become quite natural. And you would have the advantage of being able to do most fine work without fractions and/or decimals.
- ◊ You would always use the same unit, whether for:
    - measuring a cake tin for cooking a muffin,
    - measuring paper to make your own greeting cards,
    - cropping graphics for insertion in a word processing document, or
    - fixing your mother's picture frame.

Sarah the teacher-librarian: In English-speaking countries most people grew up thinking in terms of inches and pounds. When metric conversion came along, it was easier to convert back and forth between inches and centimetres than it was between inches and millimetres. It was fairly easy to divide the centimetre lengths by two and a half to change them to inches.

John the engineer: My take on the situation is that the centimetre is so close to the inch that people brought up on inch/pound have a tendency to convert centimetre measurements into inches, whereas millimetre measurements are so different from inch-measurements that they don't try to make a mental conversion back into inches.

Pat Naughtin: And John, you've just mentioned a huge advantage in going from inches to millimetres. You don't do conversions. Centimetres are close enough to inches to lead many to continue with rough mental conversions from centimetres to inches, and this conversion approach can last for years. Converting from millimetres back to inches involves a division by 25.4 to understand metric dimensions, which is just plain difficult and people soon give up converting.

And this actually is a real advantage. People who choose millimetres tend to move directly (and quickly) to the metric system where they soon develop some points of reference — rules of thumb — in the new measures and then move on.

And one of the best-kept secrets is to develop these points of reference, because once you have learnt these simple references you never convert back.

For example my wife was converted to millimetres the day I got her to measure the width of the tip of her little finger. It was exactly 10 mm. She delightedly said that she now knows how much rain has fallen without the laborious task of converting back to inches – she simply looks at her little finger. She also uses her little finger as a reference when she is rolling pastry that needs to be (say) five millimetres thick.

Sarah the teacher-librarian: I think the following are reasons why we shouldn't ignore the prefixes between milli and kilo.

1. One of the disadvantages of having a single unit (of length for example) is that a convenient size for measuring one set of objects is not suitable for another. The Imperial/Colonial/Customary systems get around this by having several different units (e.g. inch, foot, yard, mile) and using whichever one is appropriate.
2. Once things get too big or too small, you're talking in scientific notation. So units like deca, hecto, centi and deci are useful in that they give us the ability to use a size of measurement that is suitable for what we are measuring.
3. If you remove some prefixes, you put the metric system at a disadvantage because of the relatively inconvenient size of the resultant units. And also, if you don't teach the full range someone will eventually stumble over one of the unlearned ones, e.g. decibels, decanewtons, hectopascal etc., and conclude that the metric system has exceptions and contradictions of its own.
4. And I like to teach that one of the beauties of the metric system is that once you learn the prefixes for metre, you've already learned the prefixes for every other measurement, as opposed to learning that 12 inches make a foot, 3 feet make a yard etc, which gives you no inkling of how ounces, pounds & stones are put together).

Pat Naughtin: After 25 years teaching SI and metric systems in Australia, followed by 12 years in research organisations, I have formed the view that there are two main ways that people use to approach SI.

The simple approach

For measures other than time, most people could accomplish all the measuring they will ever need in their lives with a simple system of only ten SI units. These units are:

- ◊ For length: millimetres, metres, kilometres,
- ◊ For capacity: millilitres, litres, cubic metres,
- ◊ For mass: grams, kilograms, tonnes, and
- ◊ For area: square metres.

Using this approach, you can see this means that the average person only needs:

- ◊ 4 core units - metre, litre, gram, and tonne;
- ◊ 2 prefixes using the same conversion factor - milli meaning 1/1000th and kilo meaning 1000 X; and
- ◊ 2 concepts - square metres and cubic metres.

That means a total of 10 quantity measures that need only 8 words (4 units + 2 prefixes + 2 concepts).

Even if you are a specialist (say in metal machining) you will probably only ever use the four prefixes 'micro', 'milli', 'kilo', and 'mega' and the only 'conversion factor' is still 1000. If only those prefixes that are multiples of 1000 are used, common units are readily understood and are easy to use.

The 'complete' approach

Let's compare this with the complete approach currently used in schools. For the same four physical quantities (length, volume, mass, and area) there are 37 units taught; they are:

millimetre, centimetre, decimetre, metre, decametre, hectometre, kilometre,

milligram, centigram, decigram, gram, decagram, hectogram, kilogram, tonne,

millilitre, centilitre, decilitre, litre, decalitre, hectolitre, kilolitre, cubic metre,

square millimetre, square centimetre, square decimetre, square metre, square decametre, square hectometre (hectare), and square kilometre.

cubic millimetre, cubic centimetre, cubic decimetre, cubic metre, cubic decametre, cubic hectometre, and cubic kilometre.

This approach requires:

◊ the same 4 core units: metre, litre, gram, and tonne, but it uses,

◊ 6 prefixes - milli, centi, deci, deca, hecto, kilo; and,

◊ 14 concepts - square millimetre, square centimetre, square decimetre, square metre, square decametre, square hectometre (hectare), and square kilometre, cubic millimetre, cubic centimetre, cubic decimetre, cubic metre, cubic decametre, cubic hectometre, and cubic kilometre.

This requires 37 units that need 24 words (4 units + 6 prefixes + 14 concepts) – 51 ideas in total.

Comparison

These figures suggest that the simplified system suggested here can be learned in 27% (14/51 X 100) of the time that it takes to learn the complete set of prefixes and units.

Alternatively we can say that it is 3.6 times faster to learn the 'simple' rather than the 'complete' set.

Clearly the 'simple' approach has the potential to be the most effective.

(Note: I am indebted to Richard T. Phelps from the American Institutes for Research in Washington DC, for the idea of linguistic comparisons between unit systems.)

I suspect that this is one of the reasons centimetres are used in Australian schools - they take more time. It takes a lot longer to train people to use the metric system using centimetres. This is especially important to school teachers who have been used to spending at least a year of all their students' lives teaching vulgar and decimal fractions to be able to calculate with old pre-metric measures.

Sarah the teacher-librarian: I've always used the centimetre as a basis for teaching my family and friends the metric system by using something they all know — the US money system — with the metre as a dollar, and a centimetre as a cent. This analogy also works to help people understand degrees Celsius.

John the engineer: You mention money. Interestingly, thinking about the introduction of decimal currency in England may be a guide for us. No one complained about the pre-decimal pounds, shillings, and pence before the changeover and when decimal currency came in few complained after a year or so.

Pat Naughtin: Yes, the change to decimal currency is now a non-issue in the UK, although there certainly were some who grumbled loudly about it when they had to change. Yet metric units and Imperial measures have been mixed up for more than four decades in the UK. Clearly currency and length are two very different things.

John the engineer: Within my circle of friends and contacts in this non-metric (but slowly changing) culture, they have a better understanding of a metre and centimetre than was true in recent years, but I usually have to define millimetres. Thirty years ago if I mentioned the word metre, I was looked at as if I had just gotten off a space ship; so we are making headway.

Sarah the teacher-librarian: I found some interesting stuff on the web site at the National Institute of Standards and Technology (NIST). This is from one of their fact sheets.

> *Rule of 1000 -- The selected multiple or submultiple prefixes for SI units shall result in numerical values between 1 and 1000. This rule allows centimetres or millimetres to be used where a length declaration is less than 100 centimetres. For example: 500 g not 0.5 kg; 1.96 kg not 1960 g; or 750 mL, not 0.75 L, or 750 mm or 75 cm, not 0.75 m;*
>
> *Number of Digits -- SI declarations should be shown in three digits except where the quantity is below 100 grams, millilitres, centimetres, square centimetres, or cubic centimetres, where it can be shown in two digits. In either case, any final zero appearing to the right of the decimal point need not be shown.*

Clearly NIST is supporting the use of centimetres — would you care to comment?

Pat Naughtin: Governments and government agencies often find themselves in a bind when some citizens strongly support one point of view — in this case the use of centimetres. Governments under these circumstances often adopt a 'holding position' until more data becomes available or the public consensus crystallises through some other cause. In the meantime they tend to publish statements that take a bet on each of the possible outcomes. Whatever the outcome of the public debate the above statements will have been right. However, instead of taking a cheap shot at NIST, I believe that the so-called 'rule of 1000' is flawed and should be reconsidered, but this is not the place to do this.

By the way, this debate between centimetres and millimetres has often highlighted the tendency of various official government and international bodies to dither. First they support one side — then there is a change of membership of their board of directors, and they change sides for a while — before they change back. It is very clear that these groups have never understood the nature of the various elements that contribute to such a major change as 'Going Metric'. Overwhelmingly, they treat it as if it were solely a technical matter, and tend not to allow for political, social and cultural factors. There are probably too many scientists or engineers involved, in management positions, who are making assumptions about the numeracy skills of the population!

Sarah the teacher-librarian: In my family we like to ride bicycles, and we mostly do our own repairs, so recently I was reading a catalog from a bicycle company in the USA. This catalog contained lengths measures in: millimetres (eg. 50 mm), decimal centimetres (eg. 15.7 cm), fractional centimetres (eg. 8 3/4 cm), inches (eg. 2 in.), decimal inches (eg. 4.67 in.) and fractional inches as mixed numbers (eg. 3 1/2 in.) — it was a real mess.

Pat Naughtin: This often happens within a business if they change to metric units without having a metrication policy or a measurement policy – the individuals choose their own measurements. You'll end up with a hodge-podge of measurements, and most will choose to use a combination of two or more. It's hard to assess the cost of this for the business, but an estimate made in the UK in 1980 suggests that this might cost the company about 9 per cent of its turnover and reduce its net profit by about 14 per cent.

John the engineer: But because of the equal status of the prefixes centi and milli in the BIPM Brochure and in NIST policy documents, there is little justification for efforts to force universal preference for one or the other prefix.

Pat Naughtin: Specialists in the various sectors of industry or commerce are free to choose the prefixes of most convenience in their respective disciplines, but they are mistaken if they believe that particular prefixes are best for all applications within their own business or within their own industry.

John the engineer: I agree with how well millimetres have worked in Australia, and with the above comment too. I'm in favor of millimetres myself when I'm at work. But I still maintain that it might imply a level of precision that isn't there, especially for body measurements. For engineering and construction, of course, that level of precision in many cases is there.

Sarah the teacher-librarian: I'm thinking, of course, of the best way of teaching people what is to them the 'new' system, and I think that we could build an entire teaching method based on the 'centi' prefix. Given that we have a currency that uses 100 cents in a dollar, I think that we could develop the use of the centigram and the centilitre in the USA.

I have seen the centigram in Europe, tho' it's not used as widely as the centilitre. The centilitre is in common usage for countries in Europe, where it's used for selling liquids and in recipes. In the same way as the centimetre is used — it seems to me — to bridge the gap between the millimetre and the metre, the centilitre is used to bridge the gap between the millilitre and the litre.

This could be the best for all of the people who are still learning metric, and for people who are trying to encourage them. Then we could develop the roles of the decametre, the decalitre, and the decagram, although I have never seen these used in schools.

Pat Naughtin: Why would schools teach these prefixes when they'll never be used in any industries? All this does is complicate the communication of quite simple concepts. What will actually happen is that the use of the centimetre in schools will legitimise its use in the community generally and from that legitimacy we gain mindsets, practices, and even derivatives such as centigrams per square centimetre that have little or no use in a modern industrial community.

Most Australian schools are still dithering about the methods they will use to teach the metric system. Many are committed to poorly understood 19th century centimetre-gram-second system units with the centimetre as a key component. A few brave souls are timidly suggesting the use of units from the old late 19th century metric system (called mksA), but there is still little understanding or promotion of SI, the modern metric system that was established in 1960.

A curious outcome of the approach by Australian schools is that they prepare very few Australian children for working in Australian industry. In most Australian industry a key component is the ability to make reasonable estimates in millimetres and schools simply don't address this issue. And this leads to the extraordinary outcome that apprentices, and other trainee workers in Australia do not begin to make estimates in the units used in their trade until after they leave school and start work. Let's suppose you intend to become a carpenter; you will rarely be asked to estimate any length in millimetres at school, so the development of your measurement skills must be done on the job, when you start work — after you leave school. You will also need to un-remember a lot of the length measurement taught in the schools. I can only see the hours and hours devoted to teaching all those unwanted measurements as a complete waste of time and money.

Medical

Sarah the teacher-librarian: Hospitals measure babies in grams almost as soon as they're born. I believe that this serves two main purposes: to provide a reference point as the baby grows, and to know the mass of the baby if it becomes ill and needs any sort of pharmaceuticals.

Pat Naughtin: My wife has suggested that one reason could be that grandmothers, whose babies' mass was measured in Imperial/Colonial/Customary measures, want to know the mass of the new grandchild so that they can compare its birth mass with that of themselves and their own children.

Sarah the teacher-librarian: My blood boils when I hear new mothers converting from kilograms to pounds, as I know that this puts their babies at risk, especially from wrong conversions.

Pat Naughtin: Once you know some references for babies, where:

◊ the average baby is about 3500 grams,

◊ a small baby is less than 2500 grams, and

◊ a big baby is more than 4500 grams

You probably won't need to think about pounds and ounces ever again.

It might even help to know that:

◊ the smallest baby that survived was 260 grams, and

◊ the largest surviving baby was 8000 grams.

Thousands of babies die each year while their parents, grandparents, sisters, cousins, and aunts calculate and then discuss whether the mass (or is that weight?) of a sick baby should be converted into grams or kilograms. If your grandmother wants to make a comparison with her own babies that were born in the last century, the safest thing to do is to convert the mass of Grandma's babies from pounds and ounces into grams for comparison with her new grandchild's metric mass in grams. Then if the baby did get sick there would be no risk of giving the wrong amount of medication based on confusion about the mass of the baby.

By the way, there are some forces in England wanting to adopt the centigram for mass measurements. Given the option of centigrams, to parallel centimetres, I fear for many more babies lives in the UK.

John the engineer: I find it incredible the number of units that the medical community use. When you have a blood test, they seem to flood you with information. Recently, I had a sugar test and the report came back to me in millimoles per litre and also (in parentheses) in milligrams per decilitre. Why don't they make it simpler?

Pat Naughtin: Many believe there is a need to reduce the numbers of prefixes, especially to reduce the number of derived units. Therefore constructions such as decagrams per hectolitre and centigrams per decilitre should be avoided, especially in the medical community.

What I think actually happen is that the use of centimetres, decimetres, and hectolitres in schools legitimises their use in the community generally, and from that legitimacy we gain mindsets, practices, and even derivatives such as centigrams per square decimetres. This legitimacy appears most obviously in the medical community where such derivatives have proved to be particular popular. In fact, there is a real need to reduce not only the numbers of prefixes, but especially to reduce the number of derived units based on uncommon prefix choices.

Unit diversity in the medical community inevitably leads to increased risk.

John the engineer: On the issue of centi prefixes, the medical profession worldwide uses milligrams for prescriptions, even if a dose is more than a gram (say 1250 mg), rather than confusing the issue with centigrams.

Pat Naughtin: The medical community seems to have got this one right. Following this logic, if we don't need centi for centigrams, then we don't need centi for centimetres. The situations are the same. Notice that I wrote 'need', not 'want'. Some people may want the prefix centi (and deci and deca and hecto) but they don't need it.

Sarah the teacher-librarian: A friend had to get some x-rays recently but her confidence dropped when she noticed a bright yellow post-it note on the x-ray machine, with bold print stating that the measurements were in mm (millimetres) and not in cm (centimetres). She worried that, since the note was needed, she could assume that there had been problems. She just hoped the x-ray staff read the post-it note before they used the machine on her!

Pat Naughtin: This is another example of an organisation that has yet to develop a measurement policy. Without any measurement policy there is a policy vacuum that is soon filled by random choices of units made by individuals — often for their own selfish reasons.

Sarah the teacher-librarian: Another friend told me she had her ear checked for the resilience of her eardrum. This was reported in the form of a graph plotting millilitres against decapascals. Understanding that this was the mindset of the physician I wished my acquaintance well with the future of her hearing, as I quietly wondered how many people actually understood anything about their ear resilience tests.

Pat Naughtin: I think that the medical industry's decision to use the prefixes, centi, deci, deca, and hecto plays a key role in encouraging unit diversity within the medical community, and I believe that this inevitably leads to increased risk for all of their clients. I suspect that the number of people who die from 'measurement diseases' or from errors in measurement made by medical workers is higher than anyone cares to admit or to adequately investigate.

There is a real need to reduce the numbers of prefixes from SI that are used in the medical community, especially to reduce the number of derived units. Ornate unit constructions such as decagrams per hectolitre and centigrams per decilitre should, at worst, be avoided and at best be scrapped.

Education

Sarah the teacher-librarian: Another justification for the centimetre is in education, particularly in teaching young children to measure small distances and also to calculate with them. Imagine trying to introduce area with a piece of paper 216 mm by 278 mm. The child has to multiply 216 x 278. Even if you 'round' they are still faced with 220 mm by 280 mm and a multiplication of 220 x 280.

Pat Naughtin: As a example of the use of millimetres in schools, I suggest that you have a look at this short (two page) article on how to use the dimensions of writing paper in schools http://www.metricationmatters.com/docs/PageBordersInchesORmillimetres.pdf

Sarah the teacher-librarian: But wouldn't it be better to do these calculations in centimetres. You could think of them as 21 centimetres by 29.7 centimetres.

Pat Naughtin: True, but now you have to contend with the issues of decimal fractions at the same time as you are teaching a valuable lesson about saving paper in your classroom and at home. You could easily lose the main game — the paper saving issue — as your students get lost sliding decimal points around the place.

Sarah the teacher-librarian: I think that it's far more appropriate to give them the larger unit - the centimetre - leading to introductory measurements and calculations like 21 x 28.

Pat Naughtin: Leaving aside the inaccuracies that you have introduced with your rounded values, notice that, had I used centimetres, the pages of the article, *Page borders — inches or millimetres*, would be awash with decimal fractions and decimal points. Using only millimetres made the issues of paper use and paper saving understandable ideas even at a junior primary school level. And I don't believe that saving 20 % of the world's paper every year is an insignificant contribution to a world environment when the issue of global warming needs to be considered See: http://www.metricationmatters.com/docs/AWordAboutGlobalWarming.pdf for further details about the problem of using non-metric measures for environmental issues.

Sarah the teacher-librarian: The children have to learn about centimetres anyway as they will work with them when they grow up.

Pat Naughtin: This is probably not true — even in the USA. Companies that have already upgraded to the metric system do so by searching for *'world best practice*', then adopting that practice. This usually means the adopting of a millimetres policy for their small length unit. Examples are the motor industry when they build cars, trucks, tractors, and motorbikes, and the computer industry when they build computers and their peripheral components such as printers and screens.

Dumbing down numbers for teaching children is, in my opinion, simply silly, as it serves no useful purpose. One of the stated purposes for having schools is to prepare children for their future lives in the world of adults. In Australia, this means that children absolutely need to learn how to use millimetres for measurements of all kinds. In the analysis that I did in occupations in Australia about 85 % of all our occupations use millimetres as their small unit of measure and most of the other 15 % don't do much measuring of length at all (butchers and bakers are examples).

Sarah the teacher-librarian: When do you think that children should learn about centimetres?

Pat Naughtin: I would suggest that at about grade 4, when children are making the transition from block letters to 'joined up writing', might be a good time for children to learn to use the easier millimetres as part of the world of adults.

Mindset

Pat Naughtin: I suppose that it's all about a concept called mindset. Anyone who measures mostly in millimetres will adapt to millimetres, and develop a mindset that allows accurate estimates in millimetres. On the other hand if most measuring is in centimetres, centimetre skills will be developed. Acquiring a mindset using millimetres, or centimetres, has nothing to do with education or intelligence, but rather the amount of practice you have with a particular unit.

If you practice with millimetres your mindset will be in millimetres – it's a simple as that.

Everyone has easily adapted their meat and grocery shopping to grams and kilograms – they have that mindset. But no matter how simple the metric system is, and how easy it is to use, it still has to be learned. This involves a learning curve and some hardships initially, but adaptation and the benefits of simplicity come quickly.

And the hardships involved in teaching basic arithmetic to primary school children is nowhere near the hardship involved with the old Imperial system or the poorly taught metric system. Had all school teachers been put into the room with the builders (a very large room mind) and told that from now on all you will teach in schools is the millimetre/metre etc system, we wouldn't even be discussing the state of SI in Australia.

John the engineer: The most common quantities that people — who are not engineers or builders — measure are mass and volume as they go about their day to day activities of shopping and cooking. Length measures are used much less frequently. Length is used extensively in crafts such as sewing, trades such as carpentry, and professions such as engineering.

Pat Naughtin: Yes, mass and volume measurements have been, on the whole, readily accepted. It's the less-used length measurements that cause the angst.

John the engineer: The problem as I see it is that, in the UK at least, virtually every 'everyday' product — things that would traditionally be named in centimetres in continental Europe — are labelled in 'industrial' millimetres and this is definitely giving ammunition to the opponents of the metric system. How do you convince the public that it is simpler to refer to a 4 x 8 sheet of plywood as 1200 x 2400 mm? It is hard enough convincing them that 1.2 x 2.4 m is easier.

I get very irritated when I see descriptions of household goods in catalogs (clocks, radios, even computer components) with descriptions such as '187 x 273 mm'. No one except the original designer, who did the drawings to be passed to the mould maker or whatever, needs to work to that precision. 19 x 27 cm would be perfectly OK for a retail catalog.

Pat Naughtin: For a start, your last sentence demonstrates one of the favourite arguments used against millimetres. But all the catalogues I have seen simply don’t give that degree of precision. They are almost always rounded out to the nearest 0 or 5.

Also, It seems to me that you are trying to convince people with sound and rational arguments. Forget it. The point is that you don't need to convince these folk that the metric system is better than anything they have used in the past. Talking or arguing with people who have not done any measuring with the metric system is quite pointless. But as soon as they experience the simplicity of the metric system for themselves they will then convince themselves that it is the better way. The one truism of the metric system worldwide is that once someone uses the metric system for some time they never willingly go back to using old pre-metric measures. The only people who try to argue against the metric system are those who have not used it yet so their arguments are usually based on conjecture, and that’s why they very often use these unnecessarily precise measurements to try to make their point.

Simply decide that you will only use one of these: centimetres or millimetres — as your small unit and always change to this one. And of these as you know well and truly by now, I recommend millimetres so that your metrication process will be quicker.

Sarah the teacher-librarian: I can't visualize 10 000 millimetres, I have to convert this so that I can think of it as 1000 centimetres or as 10 metres.

Pat Naughtin: You don’t have to. In your everyday life I'm certain you would say 10 metres in the first place — and if you practise you will soon easily visualise a distance of ten metres.

John the engineer: I'm the same. If I see 2500 mm I visualize it by converting it automatically to centimetres or to metres. I do this because my brain interprets 2500 millimetres as 250 centimetres or as 2.5 metres. I'm relying on my experience with metres rather than millimetres for such a large quantity of millimetres.

My experience has shown that most people are quite comfortable with numbers into the hundreds ending in either '0' or '5' followed by centimetres for those lengths that can be expressed in that form. So I can easily see shoppers feeling natural about asking for a 120 x 240 piece of lumber (they would certainly drop the 'cm' as understood), whereas 1200 x 2400 (mm) won't roll off the tongue (or the mind) nearly as easily.

Pat Naughtin: If I were nit-picking here I would say – count the syllables. 120 x 240 (one hundred and twenty by two hundred and forty) has 13 syllables, 1200 x 2400 (twelve hundred by twenty-four hundred) has nine. The second rolls off the tongue much more easily.

Once you enjoy the other advantages of a millimetre only work site (with no fractions, conversions or unit identifier) you soon become comfortable with saying things like, 'A standard sheet is 1200 by 2400', and there is no need to mention the unit millimetre. If you choose centimetres and say '120 by 240', I have to ask, 'Is that centimetres or is that millimetres?'

Sarah the teacher-librarian: That's all very well, but to me centimetres are just the right size because they are close to the size of the traditional inch.

Pat Naughtin: I've observed that practically everyone who uses the centimetre as a core unit of length measurement has yet to gain an understanding of the simplicity of the metric system. My experience is that many people who use centimetres also use inches and feet – often in the same sentence. This tells me that they have (probably quite unconsciously) chosen to try to develop two parallel mindsets — one in centimetres and the other in feet and inches. That is, they have never really moved away from the Imperial system. This simply doesn't happen if you use millimetres.

The real issue of course is not about the number of digits but about an unwillingness to change. People generally hate change and they don't like to relinquish that which took them so much effort to learn – in this case they want to cling to an old way of measuring. People simply prefer things that are already familiar. They like 2 digit waist sizes (in inches) because they are familiar with 2 digit waist sizes. If they were accustomed to 3 digit waist sizes (in millimetres) they would be comfortable with 3 digit waist sizes just as much as they are comfortable with their 3 digit body mass (in pounds).

Sarah the teacher-librarian: So you're saying that people who change to centimetres can't leave inches, feet, and yards behind them

Pat Naughtin: Yes. And I've also noticed that people who use centimetres generally use binary fractions (half, quarter, eighth, sixteenth, thirty-seconds, etc.) to subdivide units. They have yet to change to decimals and for this reason centimetres are often taught non-decimally.

Teacher: *How wide is the palm of your hand?*

Student:In between 8 cm and 9 cm.

Teacher: *Let's call it eight and a half, or is it nearer eight and a quarter.*

Obviously, if the teaching environment were based on millimetres there would be no need for the use of binary fractions. The student should have answered something like *84 mm* — a much more accurate answer.

We know from experience that almost all people can successfully, and quickly (say two weeks), change to the metric system if they use millimetres and avoid centimetres. We also know that whole communities can change quite quickly to the metric system if the only conversion factor between adjacent units is 1000.

An example of this is the change made by the Australian community to grams, kilograms, and tonnes to measure mass without a hint of a problem. Also Australians changed to millilitres, litres, and cubic metres quite comfortably. In both of these cases the only conversion factor is 1000.

Perhaps here's another clue to the failure of centimetres. Everyone says that millimetres are too small – perhaps the fact is that centimetres are too big.

The millimetre, like the millilitre and the gram is small enough to be used as whole numbers.

John the engineer: Recently, I had a visit from a metrication supporter from New Zealand. His gift to me was a pure SI-metric tape measure that was 8 metres long. In New Zealand, people use the millimetre for handy measurement; for example 1434 or 324 or 2450, with millimetres assumed. The tape measure I received is scaled in millimetres only, with gradations of 10 mm (10,20,30, etc.) between 100 intervals, and even the metre marks are noted as 1000, 2000, 3000, etc. Is this the measurement practice in other countries besides New Zealand?

Pat Naughtin: This is also the practice in Australia, Botswana, Cameroon, Mauritius, South Africa, and Zimbabwe. The utter simplicity of this style has always captured my imagination. I feel that anyone can be taught this method quickly and smoothly without the jumble of other prefixes. In practice, the elegance of measuring in millimetres only is striking.

Sarah the teacher-librarian: The centimetre is used the most widely.

Pat Naughtin: Schoolteachers use this as the main argument for the use of centimetres; unfortunately it's probably not true. The use of centimetres is widespread in schools, particularly primary schools, and people learn about centimetres in schools. Then, depending on their work, many have to forget all that their schools taught them and begin to learn about millimetres after they leave school, because millimetres are the unit of choice for most trades and industries (> 83 %).

So it seems that Australian schools are teaching measurement methods that are simply not useful in much of Australian industry, and we need to ask why this is so in Australia. Other nations, such as the UK and the USA, might also profitably consider this question.

The centimetre is used for (usually non-commercial) activities or by people who don't regularly need to use commercially valid measurements, such as those needed for industrial standards.

On the whole it is probable that millimetres are the more widely used, and it is definitely true that they are used more regularly as they are used in activities where measurement is used hundreds of times each day.

And then there are many young people for whom this after-school learning never happens. If they don't learn about millimetres soon after leaving school, many simply forget the centimetres they were taught at school (because they meet few people who use them) and slip into a largely garbled set of Imperial measurements that they learned from their parents and grandparents.

Sarah the teacher-librarian: In the old days we had a full range of choices. We had 12 inches in a foot, 8 pints in a gallon and we are comfortable with 60 seconds in a minute, 24 hours in a day, and, in the UK, they use 14 pounds in a stone. So it’s obvious that we can handle quite a wide diversity of conversion factors.

Pat Naughtin: I know that schoolteachers like teaching conversion factors, but why waste time teaching conversions when there are so many more interesting skills to offer students? The old pre-metric ways you describe took ages to learn and they were almost never completely learned – who memorised the back of their exercise or copy book in its entirety? The old methods were error prone, and they provided us with little more than a warm and fuzzy feeling that we were sticking to the old ways. Enough of the metric system to build a house can be printed on the back of a business card and can easily be learnt by anyone at all, whatever their initial numeracy skills.

However, having said that, there are far more choices than you have revealed here. I will constrict myself by asking a few questions about the ones you mention (in reverse order):

- Are we truly comfortable with a 24 hour day that we have to adjust every so often with a leap second to keep it aligned with astronomical reality?
- How do you distinguish between 45 seconds and 45 seconds, when one is measuring the time and the other is measuring an angle, without checking the context of where these are written?
- Which pint and which gallon are you suggesting — the current UK gallon, the USA gallon, or one of the numerous historical pints and gallons?
- Which inch are you using — if pre-1959 are you using the Canadian, Cape, or one of the two UK or the two USA inches; if post-1959 are you using to the international metric inch or the statute inch of the USA?
- To which pound are you referring — avoirdupois or Troy?
- Have you considered the butcher's stone (of 8 pounds) as well as the fruiterer's stone (of 14 pounds)?

Sarah the teacher-librarian: Oh, fair enough! The old ways sure did contain a lot of complexity.

John the engineer: In Germany civil engineers historically used centimetres; mechanical engineers used millimetres generally and micrometres for special purposes. I couldn't agree with you more when you say that decametres (dam), decimetres (dm), and hectometres (hm) are unnecessary. Centimetres are understandable in some contexts, but 'dam', 'dm', and 'hm' are largely unknown in many metric countries, and should really be dropped out.

Pat Naughtin: Again, we are dealing with mindset issues. In Germany, we are dealing with mindsets that have had the luxury of development since Germany first began to use the metric system in 1870 — 135 years ago. Do you think that citizens in the UK and the USA will be happy with a metrication process that continues for another 135 years into the future — until 2140?

Although deci, deca, and hecto are a legitimate part of the International System of Units (SI), they are unnecessary and they lead to truly slow development of mindsets.

Official position

John the engineer: Some people who argue against centimetres say that they violate the official metric system principle of prefixes being multiples and submultiples of 1000. This is not true. It may be a style preference in some engineering disciplines, but it is emphatically not an SI principle as it is not a preference declared by the CGPM, the CIPM, the CCU, or the BIPM!

Pat Naughtin: What you say is true, but more practical organisations such as the National Institute of Building Sciences (now NIST), the American Institute of Architects (AIA), and the American Society of Testing Materials (ASTM) have all recommended that centimetres not be used in specifications or on plans.

As an example in the USA, the National Institute for Standards and Technology, the federal technology agency that works with industry to develop and apply technology, measurements, and standards says, in NIST Special Publication SP 811 (Section 7.9):

> *It is often recommended that, for ease of understanding, prefix symbols should be chosen in such a way that numerical values are between 0.1 and 1000, and that only prefix symbols that represent the number 10 raised to a power that is a multiple of 3 should be used.*

They then qualify this by saying:

> *However, the values of quantities do not always allow this recommendation to be followed, nor is it mandatory to try to do so.*

And then add:

> *In certain kinds of engineering drawings it is customary to express all dimensions in millimetres. This is an example of selecting a prefix based on the practice in a particular field of science or technology.*

It seems to me that the various professional associations, both international and national, want to constrict the range of prefixes in their own industry to multiples of 1000, but they don't want to publicly make it too obvious that they do not want to use centi, deci, deca, and hecto, because some folk seem to have developed an attachment to the centimetre.

For example, the various Australian authorities have been very coy about making this preference public.

The Australian National Standards Commission says:

> *... these multiples (hecto, deca, deci, and centi), their names and symbols are not preferred and their use should be limited as far as possible.*

and the Standards Association of Australia (SAA) statements in 'The International System of Units (SI) and its Application — AS 1000 —1979':

> *As far as possible, the multiples and sub-multiples . . . are limited to ternary powers of 10*

and

> *The use of prefixes representing 10 raised to a power which is a multiple of 3, is especially recommended.*

is hardly screeching the death of centimetres from the roof tops.

However, although I agree with your original statement that using millimetres in preference to using centimetres is not formally a part of the International System of Units (SI), (and I agree that CGPM, CIPM, CCU, and BIPM do not state it as a preference), I believe that all of these organisations have been quietly moving away from a strict decimal system toward one based on intervals of 1000.

As evidence, I suggest that you examine the partial list of SI prefixes below. These are all spaced at intervals of 1000 with the exception of the four initial prefixes from the 1790s.

All prefixes added to the metric system since 1799, have all been multiples of 1000. All of them.

Of the 20 SI prefixes currently available, 16 are multiples of 1000 and the four that are not are the historical remnants of the old metric system (hecto, deca, deci, and centi). I suspect that these four have been retained for historical reasons only.

0.01	deci	10	deca
0.01	centi	100	hecto
0.001	milli	1000	kilo
0.0001	**No prefix**	10 000	**No prefix**
0.000 01	**No prefix**	100 000	**No prefix**
0.000 001	micro	1 000 000	mega
0.000 0001	**No prefix**	10 000 000	**No prefix**
0.000 000 01	**No prefix**	100 000 000	**No prefix**
0.000 000 001	nano	1 000 000 000	giga
0.000 000 0001	**No prefix**	10 000 000 000	**No prefix**
0.000 000 000 01	**No prefix**	100 000 000 000	**No prefix**
etc.			

If the in-between prefixes are so mightily useful and so convenient, why don't we have prefixes for all the powers of ten? Why do so many have '**No prefix**' in the above list?

I believe the original metric system was intended to have a new prefix for every additional power of ten (both positive and negative powers). But it quickly became too cumbersome so the BIPM began using just the powers that were multiples of 3. That worked fine, but the other prefixes were never dropped. Perhaps CGPM, CIPM, CCU, and BIPM should reconsider this issue and make a much more definite statement since there is clearly a difference of opinion between the theoretical and the practical sides of this discussion.

Sarah the teacher-librarian: But, BIPM regards the centimetre is an SI unit.

Pat Naughtin: Please don't misunderstand me. I'm not suggesting that any official SI units (e.g. millilitres and millimetres) are technically inferior or superior to any other units. What I am saying – as strongly as I can — is that for any nation that is currently in the process of metrication, the choice of millimetres and millilitres will hasten the process remarkably. In some countries they do use units such as centimetres and centilitres. For example, in Switzerland they apparently have a law that open bottles of wine have to be served in centilitre glasses; this odd use of centilitre is just that – odd.

I used to say that you could teach a builder's labourer enough SI units to construct a house in 50 minutes - using millimetres; and it takes at least 50 years to teach a clothing worker enough SI units to construct a skirt – using centimetres, and I only had my tongue slightly in my cheek. If you choose centimetres as the small unit of length for metrication at your place of work, you should also settle down for (at least) a 50 year wait to complete your metric conversion process.

John the engineer: Regrettably, when Britain started to go metric in 1965, our own British Standards Institution and the UK Metric Commission made the mistake of trying to introduce the millimetre for all smallish dimensions. This gave the impression that the authorities were promoting the idea that the centimetre was not an approved unit. As a result, the millimetre has been used for many consumer products where the centimetre would have yielded a much more 'user friendly' figure.

Pat Naughtin: But the nature of 'user friendly' simply means 'I have used this unit for some time and I am now familiar with it'.

John the engineer: And one of the things that the Metrication Board did was to publish a picture of a fashion model with her dimensions in millimetres, which led to much laughter and derision.

Another attack came from Anne, Countess Attlee, who waged what she called, 'The Metric Sense Campaign'. Before her marriage she had spent several years in France as a journalist where she learned about the metric system and wanted to use the metric system as they did in France. One of her campaigns involved making fun of a bathtub being measured in what she considered the laughable measure of 1800 millimetres.

Pat Naughtin: If you prefer to visualize a 1800 x 900 x 600 bathtub (with all dimensions in millimetres) as 1.8 metres x 90 centimetres x 6 decimetres, then that's fine, you go right ahead. But if you own a hardware business that sells and fits bathtubs, you naturally use a standard way of describing them that is known to everyone in the bathtub selling, arranging, and fitting chain. Who wants expensive errors?

John the engineer: Of course, the anti-metric folks quickly seized on the fashion model and the bathtub as proof of the unsuitability of the metric system for everyday use in the UK.

Pat Naughtin: But those who supplied the 'laughter and derision' or promoted it have receded into their rightful place in history — they've been forgotten.

It's in the nature of anti–anything–progressive people to seize on any opportunity to prevent change. Ultimately they are not resisting the metric system; they are resisting change. The same or similar folk resisted the decimal currency change, and they will no doubt resist any progressive changes in the future. Count them — see that they are a small in number but a noisy lot — then get on with your life by ignoring them.

John the engineer: Just as market forces killed the Beta-format for video tapes, it is market forces that are keeping alive some Imperial measures in the UK. Betamax was far superior in quality, yet VHS won. Maybe market forces will allow the old Imperial measures to ultimately win over the metric system.

Pat Naughtin: I hope that you're wrong; it's a very bad option. And if it did happen we would not return to the old pre-metric measures alone; we would then have a hodge-podge of some pre-metric measures, some old metric units, and some SI metric units to contend with, together with all the possible conversion factors between them. However, given that world trade is always conducted using the metric system, it is highly unlikely to occur.

Pat Naughtin: I have to say that my discussions about why you should choose millimetres instead of centimetres are simply based on observations – observations made of the metrication process mainly in Australia, but also in several other countries both directly and indirectly. Countries that use the centi prefix have become accustomed to it over a very long time. But then there are the people changing from old pre-metric measures to the units of the metric system. If they use millimetres, the change is smooth, rapid, and orderly; if they choose centimetres, the change is rough (with much reverting backwards and converting to old measures), slow (perhaps 50 years with centimetres as opposed to 50 weeks with millimetres), and disorderly (characterised by bitter political infighting between individuals and between groups). In short, my preference for prefixes that are based on powers of 1000 is a preference for sheer practicality based on my own observations.

Conclusion

This is probably a good place to conclude this discussion. Let me end as I began, by again sharing the two observations that I have made over the last 40 years. They are:

◊ In Australia metrication has been most successful in the areas where we used millimetres. Metrication programs using millimetres have been fast, smooth, and so economical that many individuals and companies have profited from the change.

◊ Metric conversion has been least successful where centimetres were chosen as the small unit for everyday use. Metric programs using centimetres have been painfully slow, characterised by bitter internal squabbling, and expensive. Failed attempts at metric conversion all have this one thing in common — they tried to introduce the metric system using centimetres.

After almost two generations of using the centimetre in Australia in some trades and not others (almost a controlled experiment), I believe that we can make the following clear statements:

◊ I know that practically everyone who uses the centimetres as a core unit of their length measurement has yet to gain an understanding of the simplicity of the metric system.

◊ At a personal level individuals who use centimetres very often use a muddle of old and new measurements. This inevitably means that the metric conversion of these individuals will take at least one human generation and probably more, as they will share their attitudes with their children and grandchildren.

◊ The centimetre does not necessarily encourage users to use a decimal system as the old binary fractions are still used with centimetres.

◊ The centimetre has failed in legal and police circles to effectively communicate heights in such a way as to assist in the capture of criminals.

◊ The centimetre is too hard to use. Many trades and occupations that have tried to use them have failed in the attempt and have generally failed to move far away from the old feet and inches.

◊ The introduction of centimetres in the clothing trades has had little or no effect, especially for menswear. The difficulties of using centimetres mean that manufacturers use meaningless size numbers, or they use old inch sizes barely disguised as meaningless size numbers.

◊ The use of centimetres in sport has so far failed to describe sports people or sporting events. Further the difficulty of use of the centimetre has so angered some sports commentators that many still, as a point of pride (in the 21st century), refuse to use anything but Imperial measures to describe sporting events, and sports men and women.

◊ The use of centimetres in education has been a failure. Not only has this experiment failed, but also schools have yet to take up the opportunity to introduce SI generally into Australian schools. It is now true that nobody leaves school with the ability to estimate lengths using the unit that is used in the majority of Australian trades and industries – they have to learn to use millimetres after they leave school. There can be no greater indictment of the Australian school system's approach to the metric system.

I suppose that you could think of your choice as approaching a fork in the road where you have to make a decision as to which road you will take. Unfortunately you cannot stop and think about this — you have to make a quick decision as you drive.

On your left there is a well-made dual highway with three lanes each way. This is the most popular road and you notice that almost all the other drivers are choosing this road. You also notice that cars, as they enter this roadway, are slowing slightly because of the traffic. This road is old, slightly uneven, it is fully loaded with traffic and you see that an emergency vehicle is about to enter with its siren blaring. You guess that someone has made a driving error in all this traffic and that there has been an accident. This is the **centimetre** road.

On your right there is a brand new road that has just been completed. It hasn't been officially opened yet because the government officials can't agree on a date and time for the opening or who will take precedence in the speechifying. If you decide to take this road you will see two small temporary hurdle barriers. One of these says 'Lots of zeroes 000' and the other one says 'Big numbers 12 345'. With a quick zigzag you pass these signs to find yourself on a modern well-made highway with ten lanes in each direction. The surface is new and smooth. There are very few other cars. This road is much shorter and the bends are all carefully banked to accommodate speeds up to 200 km/h with safety and there are no speed limits. This is the **millimetre** road.

Please note that once you make this decision there is no turning back. You will have to remain on whichever road you choose. Whatever your choice, you will inevitably live in a metricated society. It's just that one road choice leads to a smooth, fast, and economical transition and the other will be painfully inefficient, slow, and enormously costly (See: http://www.metricationmatters.com/docs/CostOfNonMetrication.pdf for estimates of costs in the USA)

Pat Naughtin: Do either of you have any remarks that you would like to make in conclusion?

John the engineer: I'm still thinking about your highway analogy. As an engineer, I obviously use millimetres at work and I will use millimetres in my garage and workshop at home. But I'll probably still use centimetres inside my home for things like window and curtains, and for my clothing because I think that the textile industry in the UK will go the same way as the textile industry in Australia.

Sarah the teacher-librarian: The use of only millimetres is not for me. I'd have to fight all the way with my colleagues at school. I'd have to fight constantly about recipes and textile designs and patterns at my sewing group. My colleagues have already chosen to go down the centimetre road and I will either have to follow them — or I will have to constantly disagree with them.

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P.S. After I compiled the above notes and added my remarks, I asked my wife, Wendy Pomroy, to read and edit it for me. She did this extremely thoroughly, and as she went through the discussion she added some thoughts of her own.

Additional thoughts from Wendy Pomroy

I have watched this discussion about whether to use centimetres or millimetres with some interest.

I spent my working life both as a concert pianist and as a musician working in opera and ballet, so length measurement did not play a large part in my everyday life!

When Australia changed to decimal money in the 1960s, everybody had to go from pounds, shillings and pence to dollars and cents — from three different ways of counting money to two. For about a year everybody asked: 'How much is that in old money?' But after that people simply used dollars and cents without any thought of converting back to old pre-decimal ways.

I wondered about this and decided that as we were using money often — every day — the new values quickly became the only values, simply through regular use. I also noticed that no one ever mounted a campaign to have a 'decidollar', so that instead of pounds, shillings and pence we could have dollars, decidollars, and cents. No. You had so many cents, and when you got to a hundred you had a dollar — that was that.

A few years after the decimal currency conversion, Australia also converted from ounces and pounds to grams and kilograms. Same thing. When you got to a 1000 you converted to a kilogram and again — that was that — 300 grams, 750 grams, 1 kg or 1.2 kg. As most of us shopped frequently it wasn't long before we were happily saying 750 grams of meat, please, or I'll have a kilogram of bananas. No one found grams and kilograms difficult to cope with, and now, no one ever asks how much that is in pounds and ounces. Nor has anyone mounted a campaign to have grams, decagrams and kilograms. We just use grams up to a thousand and then use kilograms. And again I'm sure it's because we use these measurements so frequently. It was the same with millilitres and litres.

We also went from feet and inches to millimetres and metres — or some of us did. Everyone in the building trade received training in millimetres, often via Government grants, and changed to the new measurements quickly, with no back conversions. They didn't think 'I wonder what that is in feet and inches' for very long, and everyone in the trades measures easily and accurately with two measurements only — metres and millimetres. By the way, there was not a lot of free government–sponsored length measurement training for concert pianists, ballet dancers or opera singers!

But we inherited the centimetre, already well entrenched in some parts of the world. And any time someone said centimetre to me I tried immediately to convert back — 'how much is that in inches?' And I still hear that same question every day. I really continued to think in inches while trying to think in centimetres.

I now believe that if you only use millimetres you can have accuracy and precision when you need it, and an approximation when total accuracy is not necessary, and the numbers simply aren't a drawback, as has been proven with changes from grams to kilograms and millilitres to litres; and the biggest advantage is that you never — ever — convert back.

I think anti-millimetre people exaggerate to try to make their point by complaining that we don't need that level of accuracy, and that the numbers are too big. I don't hear this complaint about grams and kilograms or about millilitres and litres — only about length measurements.

How did I change and how long did it take?

To answer the second question first. Once I found the millimetre tape measure — about 30 seconds.

One morning Pat persuaded me to measure the width of my little finger (10 mm), the width across my knuckle (80 mm) and from elbow to tip of middle finger (450 mm). That's all I did. I have not thought about inches or centimetres since then — and I never try to convert.

I not only have never referred to any other form of length measurement, I even helped a friend buy all the furniture he needed for his new flat in London without the aid of a tape measure. I did it all with my three measurements — 10 mm, 80 mm and 450 mm. What a breakthrough. My friend now exclusively uses millimetres to furnish his apartments and as he is an internationally recognised opera singer, he moves fairly often.

I don't think that Pat realised back then what a powerful tool he had given me.

Recently, I had a new stove installed (oh joy). I discussed the diameter of the flue pipe with the plumber (in millimetres) and the distance from the floor to the ceiling (in metres). I discussed the dimensions of the space needed with the builder (in millimetres). I was comfortable saying that the stove was 600 mm wide and 900 mm high, the gap on one side 30 mm, and that the shelf he was to build should be 28 mm as I only wanted a 2 mm gap between it and the stove. There I had both broad measurements, and accuracy when necessary. If I hadn't been using millimetres I probably would have had to hold thumb and finger apart and inaccurately ask for the gap to be about 'this wide'.

And the key to my rapid conversion? In the same way that I'd learnt to visualise in feet and inches after years and years of schooling, I now visualise in millimetres. It's that simple. If I want pastry rolled out to 5 millimetres, I look at my little finger and roll the pastry to half its width. If the instructions say 'roll the pastry to 0.5 centimetres, or roll it out to 1/2 centimetre', I just think 5 mm and get on with it. If I need a 200 mm cake tin, I know that's a little bit more than the width of my two hands across the knuckles. And I also know that 200 mm is a bit less than the width of an A4 page. It doesn't matter that an A4 page is 210 mm. For this purpose, roughly 200 mm enough is quite good enough.

And just as, over time, I knew what an inch was because I used it regularly for so long, I can now visualise the new measurements in millimetres and because I can visualise I use no other.

To me millimetres are now second nature, and all I ever use are millimetres, metres and kilometres.

Wendy Pomroy

Metric system consultant, writer, and speaker, Pat Naughtin, has helped thousands of people and hundreds of companies upgrade to the modern metric system smoothly, quickly, and so economically that they now save thousands each year when buying, processing, or selling for their businesses. Pat provides services and resources for many different trades, crafts, and professions for commercial, industrial and government metrication leaders in Asia, Europe, and in the USA. Pat's clients include the Australian Government, Google, NASA, NIST, and the metric associations of Canada, the UK, and the USA.

Pat specialises in the modern metric system based on the International System of Units (SI), but he is mostly concerned with the processes that people use for themselves, their groups, their businesses, their industries, and their nations as they go about their inevitable metrication process. See http://www.metricationmatters.com/ for more metrication information, contact Pat at pat.naughtin@metricationmatters.com or subscribe to the free 'Metrication matters' newsletter at http://www.metricationmatters.com/newsletter/