Optimal School and the metric system 2020

Report on a metric system survey at the Optimal School.

As I approached the front entrance to the Optimal School the first thing I noticed was the path from the gate to the front door. Several marked squares were set in the concrete, some with the title, **One square metre**, and several with the marking, **1 m²**. The markings were highlighted in different colours.

At the front door there was a large thermometer marked in degrees Celsius and inside the glass door an identical thermometer to give the internal temperature. Next to the inside thermometer I could see a poem that read:

Minus is ice – but often not nice.

Zero is freezing, but tens are not.

Twenties are pleasing, and thirties are hot.

Forties frying – fifties dying!

Later I was to discover that there were pairs of thermometers (and a poem) at each entrance door to the Optimal School. Students soon learned what clothing to wear inside and what to wear outside.

Just then the principal arrived to greet me and take me for a tour. As we walked from the junior school to the senior school I noticed that the path had its expansion cracks placed at one metre intervals. We soon tried to stretch out our paces to step in metres, laughing a little at our juvenile behaviour. I could step out metres reasonably accurately as I had trained myself to do this previously on building sites; the principal was more used to using a normal pace of about 750 millimetres so she found the stretched pace harder to do. The principal then told me that several paths like this were often used by classes to experience stepping behaviour such as we had just tried; rather than being silly it was a serious practical learning experience.

We passed a vegetable garden that was part of many school programs such as agriculture, cooking, design, health, sports nutrition, and science, as well as the actual gardening.

The garden beds were laid out in square metres and the principal said that it was a rule in the garden not to walk on productive soil. The one square metre garden beds allowed all the students, even little ones, to reach to the centre of each bed to plant, weed, or water. Also when weeding had to be done, one square metre was not too daunting to complete. She then added that the paths were 700 millimetres wide so that relatively large students could kneel on the straw in the path and the school's two-wheel garden carts could easily be wheeled along them.

The principal proudly told me that produce from the garden was collected daily by students and delivered to the home economics department and to the canteen. Students were also encouraged to add salad leaves and herbs to the sandwiches or bread rolls they brought from home for their lunch.

To provide water for the garden, there were two large rainwater tanks with signs on them; one read:

> *This tank holds 14 000 litres of water from 200 square metres of roof area. Every millimetre of rainfall provides 200 litres of water. It takes 70 mm of rain to fill this tank.*

The other tank had:

> *This tank hold 14 000 litres of water from 350 square metres of roof area. Every millimetre of rainfall provides 350 litres of water. It takes 40 mm of rain to fill this tank.*

On the second tank there was also a laminated sheet that gave the average rainfall for Optimal (840 mm) and showed a graph with the average rainfall for each month. The principal said that the student gardeners studied this closely every summer as they worked out the water allotments for the gardens.

The rainfall graph was redrawn each year from data collected in the school garden's weather station, connected electronically to a science room computer and placed so all students could read it. The weather station recorded: rainfall (millimetres), wind speed (metres per second), wind direction (N-S-E-W), air temperature (degrees Celsius), soil temperature (degrees Celsius), relative humidity (%), solar radiation (watts per square metre), and software in the unit calculated an approximate evaporation rate (millimetres per day).

We continued toward the senior school and met the school's extraordinarily tall physical education teacher (he was the basketball coach for the town team – the *Optima Optimists*). As I was introduced, the principal told me that the kids referred to him, behind his back, as '*two-meter-Peter*'; the teacher laughed and said that he knew about his nick-name but amused the students by pretending to grump when he caught them using it.

As we walked the principal informed me that the Optimal School was a combined primary or elementary school with a middle school and a high school on the same land. There were also some shared buildings, such as the music room.

It was hardly a room. It was much larger than an ordinary schoolroom as it provided for several large school bands and for the school orchestra. This room was also the home of the Optimal Community Orchestra that gathered here for rehearsal after school each week. Some school students, who played well enough to be in the Optimal Community Orchestra, had a short break after their normal school day while the adults from the town arrived for orchestra practice.

I was impressed by the amount of technology required by modern music. There was an electronically linked synthesizer laboratory coupled to a large screen. A student using a synthesizer keyboard was able to see the shape of the sound waves (sine, square, or sawtooth) and also the frequency, in hertz, of each note. When I was there he was playing with sub-aural notes below 20 hertz (20 Hz) and ultrasonic notes above 20 000 hertz (20 kHz).

There was also computer software available for composing music that was able to print out the 'dots' on paper that musicians use. I asked were there many would be composers at Optimal School and the music teacher replied that the software was mostly used to transpose music from (say) a bass clarinet to a French Horn because this is such hard work to do by hand.

There were also safety signs in several places that informed students about loudness, measured in decibels (dBA) that could do permanent damage to their ears. This listed an average quiet home at 50 dBA, a noisy restaurant at 80 dBA, and a rock group at 120 dBA. The charts clearly showed how long students could safely be exposed to loud sounds – for example a rock group at a concert – or listening to an iPod. The music teacher insisted that I take copies of three of these charts – I have attached these to this report.

At one end of the music room there was a large veranda that was also served as an outdoor stage. In front of the stage was a covered area protected from rain but exposed to weather from the sides. The principal explained that this area was used for students to eat their lunch and it had the added attraction for students that student music groups could book the stage to give a lunchtime concert. On the stage there was a sign that said that today's concert would be provided by a woodwind quintet of two clarinets, two saxophones, and an oboe. Tomorrow there was to be a brass trio with two trumpets and a euphonium and next Monday a sixth grade rock band.

The concrete floor of the covered area had squares of outdoor carpet, each of one square metre. Children could sit on the carpet to eat their lunch and to listen to the lunchtime concerts. Apparently this space was also popular with mathematics teachers as a place for students to experience full size area problems such as the areas of squares, rectangles, rhombuses, triangles, and parallelograms, and to measure the sides of right angle triangles.

I also noticed a large locker placed near the stage. When I asked about it, the principal told me that it contained chess pieces, as some students liked to book the floor space to play chess on the carpet squares – a piece for a Queen was one metre high. She told me that – once – some ambitious students decided to play a game with '*live*' chess pieces; the Queens were well behaved and contentedly got all dressed up and stood on their squares chatting to the Kings and the knights until they had to move. The problem was the pawns from the third grade – got bored and then started to wander away – one was found later, still dressed as a pawn, playing basketball behind the gym.

Our next visit was to the craft room where they did woodwork and metal work. Outside the door was a postcard size (on A6 paper) notice that read:

Measurement policy for all crafts

Modified from the 'Metric Handbook for Building and Construction'

The metric units for linear measurement in construction are the metre (m) and the millimetre (mm), with the kilometre (km) being used where required. This will apply to all of our activities, and the centimetre (cm) shall not be used. Do not use the centimetre in any calculation and do not write it down.

This craft room from wall to wall is:

7286 millimetre long

5463 millimetres wide and

4221 millimetres high.

This craft room has: a floor area of about 40 square metres and
a volume of about 168 cubic metres.

P.S. We are not afraid of centimetres and we do not hate centimetres; we choose not to use them because people make less mistakes with whole numbers. Less mistakes means less loss of time and less waste of materials.

A permanent poster inside the craft room complemented this policy statement:

We use these metric system units for woodwork, metalwork, and for all other crafts

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

1 metre x 1 metre = 1 square metre

1 metre x 1 metre x 1 metre = 1 cubic metre

I asked the craft teacher what he did when students needed better accuracy than a whole millimetre. He replied that this didn't happen very often, and then only with senior students, so he treated this on a case-by-case basis using decimal fractions but –never – common or vulgar fractions. He remembered that a student had run into this problem a few years ago when her project involved a wooden frame with wires of varying thickness. The student had got into trouble with "gauge numbers" so, at first, she decided to put all the wire diameters into decimal fractions of millimetres. The craft teacher explained to her the principle of, "*Let the prefix do the work*" and told her about micrometres, so she converted all of the wire thicknesses into micrometres and she was back working in whole numbers again.

Next-door was the home economics room. It too had a postcard policy outside the door that read:

For cooking we use:

1000 grams = 1 kilogram

1000 millilitres = 1 litre

1 litre of water has a mass of 1 kilogram

1 millilitre of water has a mass of 1 gram

We do not use centilitres, decilitres, decalitres, or hectolitres.

For sewing we use:

1000 millimetres = 1 metre **or** 100 centimetres = 1 metre

We do not use fractions such as half or quarter centimetres.

For fine work use millimetres BUT don't mix centimetres and millimetres.
Choose one or the other and stick to it.

I asked one of the cooking teachers about the post card policy statement outside the door. He told me that the school curriculum committee had presented the policy to a staff meeting where it was accepted, but not all of the teaching departments had done it yet. He thought that some of them were finding the A6 paper size requirement a bit limiting and added, "*They're used to writing bulk amounts of stuff about their subjects –so an A6 postcard size of 148 mm by 105 mm is a bit daunting*."

The cooking teacher told me that one of the mathematics teachers was also the careers advisory teacher; students went to him when they wanted to find out about jobs and careers. When we arrived in the mathematics department I asked the mathematics/careers teacher how students from Optimal School were accepted in the broader community as potential employees. He replied:

No trouble at all. The feedback we get from employers is that our students, even the dropouts, are preferred to kids from other schools that don't focus on metric system measurement. As a result of our industry consultation we have devised a simplified set of metric system units that we know are successful in many companies and in many industries. We list these in a careers post card policy like this:

Careers and the metric system

Many successful companies in many successful industries restrict their use of the metric system to these units. Most (about 85 %) crafts, trades, and professions also choose these as they mostly give whole numbers with no fractions so there are fewer calculation errors that cost time and money.

1000 1000

millimetres metres kilometres

grams kilograms tonnes

millilitres litres cubic metres

— — — — —

1 metre x 1 metre = 1 square metre

1 metre x 1 metre x 1 metre = 1 cubic metre

Employers tell us that kids from so-called traditional schools have to be untrained from old measuring words before they can be taught to use the metric system and even then they don't quickly, if ever, get over both their old inches and ounces mindset and the metric conversion factors that they spent hundreds of hours learning at their old school.

The employers also tell us that new employees from the Optimal School can work at any level in the company from the factory floor to managers-in-training because they have a sense of the metric system as a system that is used in all aspects of manufacturing and commercial life.

The employers say that the only problem with Optimal School employees is that they are eminently poachable by other companies – and from anywhere in the world – simply because they are competent users of metric system units.

The entire floor of each mathematics room had been marked with discreet lines dividing the floor area into square metres.

Outside the mathematics room door, the post card policy sign read:

> This school is on land **400 metres** long by **200 metres** wide.
>
> It has an area of **80 000 square metres**, which is **8 hectares**.
>
> The junior school playground on the northeast corner is approximately **100 metres** by **100 metres** so it has an area of **1 hectare**.
>
> The senior school sports ground on the southwest corner is approximately **100 metres** by **100 metres** so it also has an area of **1 hectare**.
>
> The corners of the **hectares** on these two areas are marked with purple markers.

Later I checked the purple markers of the two marked hectares; each had a worn track where students walked or ran in 100 metre lots along one side, or in 400 metre lots right around the hectare. While I was looking at the senior school sports ground I noticed that its athletics track and field markings were all laid out to Olympic Games standards. Two metre Peter told me that, after some research, they decided that the Olympic standard markings could be applied just as cheaply as making up markings of their own. Then he added, "*The kids love the idea of being on a real Olympic track.*"

When I went to the junior hectare I noticed that much of the playground equipment was designed using the metric system as a default. There is a reference to this idea in the librarians reference list (attached to this report). There were also playground items for "children with all abilities" that included such things as a swing that could be used if you were in a wheelchair.

I asked the mathematics teacher if he was as opposed to the use of centimetres as the craft teacher seemed to be. He replied:

> *Yes and no. We teach centimetres and decimetres to establish the definition of the litre as a cubic decimetre, and we use centimetres to establish the definition of a millilitre as a cubic centimetre but we don't use them much more than that.*
>
> *I am aware that one of the junior school teachers – fifth year, I think – argues that the teaching of multiplication by tens, hundreds, thousands and so on, by sliding decimal points back and forth, should be taught as part of pure number theory rather than using the metric system as a tool to teach this skill; we are beginning to think about that but we haven't made any decisions yet.*
>
> *Not that it matters much as the Optimal School policy and practice is to choose only one single metric system unit for each task and then sticking to it – so there's not much need for sliding decimal points. We are supported in this view by industry practice where they avoid decimals, and vulgar and common fractions by preferring to work in whole numbers.*
>
> *Actually I understand the craft teacher's position on whole numbers very well from my contacts in different careers. Industry generally chooses to use single prefixes to give whole number measurements wherever they can so it is simply good sense to make that the norm*

in our classrooms. If they need unusual measurements it will be easy for them to pick that up later if they have a thorough base of metric system knowledge.

The corridor outside the mathematics room, for the full length, was marked at one metre intervals. A science teacher told me that this was a particular nuisance when an entire class of ninth year students were using the corridor as a number line and each of them represented a positive or a negative number of metres; he said, "*They're a noisy lot of integers!*"

Our next call was to a science room where, just inside the door, was a set of scales to determine body mass, a height scale fixed to the wall, a calculator on a small shelf, and a small white board to record results. The associated notice on a piece of A6 paper read:

Your Body Mass Index (BMI)

◊ Step on the scale. Write down your body mass. Example 65 kilograms (65 kg).

◊ Measure your height. Write it down. Say 1.65 metres (1.65 m).

◊ BMI = mass ÷ height^2

◊ Use the calculator to work out your Body Mass Index (BMI) like this example:

◊ 65 kg ÷ 1.65 m ÷ 1.65 m = 23.875 kilograms per square metre (kg/m^2)

◊ Round this to one decimal place. In this example 23.9 kg/m^2

◊ Memorise your BMI number while you clean the white board for the next person.

Compare your Body Mass Index (BMI) with these values:

Underweight – less than 20 kg/m^2
Normal – 20 kg/m^2 to 25 kg/m^2
Overweight – 25 kg/m^2 to 30 kg/m^2
Obese – 30 kg/m^2 to 35 kg/m^2
Grossly obese – more than 35 kg/m^2

The principal told me that this 'BMI station' was so popular that there was a similar BMI setup inside the gymnasium, and the home economics department had purchased the equipment to place one in their room. There was also a thought about putting one inside the front door so that parents would have access to it as well – with guidance from their children.

Posters on the science department walls seemed to have themes based on measurement of astronomical events, of environmental effects on a worldwide scale, and of biological and sub-atomic events on a very small scale. Clearly here was a need for the full range of SI metric system prefixes. A science teacher gave me a list of prefixes that he had on each science room noticeboard – I have attached a copy to this report.

After visiting the science department, the principal introduced me to the teacher in charge of English, History, Languages, and Social Studies. She then left us to, as she put it, "*... go and do some real work*", adding that she would see me before I left.

In the Humanities Department I asked how they contributed to the metric system focus of the rest of the Optimal School. The teacher happily informed me that they were fully engaged with the school's overall metric system theme. She showed me stacks of written research assignments on the metric system and then took me to a classroom lined with student posters that resulted from a recent metric system assignment. She then added:

We set two assignments with a metric flavour each year at each grade level. These might be assignments for research, poster production, essays, or compositions. We change the themes for these each year to avoid repetition. Recent annual themes have been:

◊ The metric system and the future of planet Earth

- ◊ The metric system and society
- ◊ The religious basis of the metric system
- ◊ Honesty in measurement applied to shopping

And here are some of the actual questions we have set:

- ◊ Who invented the metric system?
- ◊ How did Benjamin Franklin, Thomas Jefferson, and George Washington influence the development of the metric system?
- ◊ What part did the British Association for the Advancement of Science (BAAS) play in the development of the metric system?
- ◊ Design and draw a poster showing a timeline of the modern metric system from 1780 till now.
- ◊ What is the legal basis for the International System of Units (SI)?
- ◊ What part did the Royal Society of London play in the origination of the metric system?
- ◊ What are the CGPM, the CIPM, and the BIPM?
- ◊ What is the "Treaty of the metre"?
- ◊ What is the National Institute of Standards and Technology (NIST)?
- ◊ How does NIST contribute to the use of the metric system in our society?
- ◊ What effect do you think that the use of the metric system has had on international trade?
- ◊ How does the metric system influence international relationships?
- ◊ How does having a common metric system influence medical research all over the world?

We don't worry too much about content; we are more concerned about the way the research is presented or in assessing how persuasively the student argues. However, that said, English, History, and Social Studies teachers have become quite knowledgeable about the metric system over the last few years.

In part we have been trained by the research of our students. One of the areas we now know more about is the scientific idea that some words have to have fixed and definite meanings; in science mass is not weight and energy is not power. We have to correct student work with these definitions in mind. Also we have to check the correct usage of metric system symbols in student writing. It took us a while to adjust to the idea that km/h is the correct symbol to use to write kilometres per hour; km/h is an internationally recognised symbol, not a randomly generated abbreviation like kph, kmh, KmH, KPH, and so on – I've seen them all.

It all started when we had a history teacher studying metrication as part of her advanced studies in history. Metrication, as she put it, "is the process that people use to upgrade to the metric system". *I can even tell you the date we started. The curriculum committee meetings were held in 2009 and early 2010 so we could begin our own metrication program on 2010 October 10. The whole school celebrated our decision to 'Go metric' on the only day this century that could be written as* ***10-10-10****. The progress we have made has taken 10 years since then. I suppose we could have started in any year: say, on the metric system's 'birthday' when the Royal Society published, "An Essay Toward a Real Character and a Philosophical Language" by Bishop John Wilkins that contained the original description of his invention of the metric system in 1668 on April 13.*

At this point, I mentioned that I thought that some Humanities teachers were not noted for their liking for mathematics, to which she replied,

You're right. We have at least one teacher like this.

But we also have a language teacher who is highly intelligent and speaks and writes seven or eight languages, including Biblical Hebrew, which I believe is very difficult, She is a whiz at editing and correcting metric system usage so all the senior students who enter their science projects for external competitions go to her to have their projects checked for correct

> *metric system use. She also explains in her English classes that in other places, for historical reasons, they use words like centilitres, decigrams, and hectolitres that might need to be translated into the simpler millilitres, grams, and litres.*
>
> *This happened because Napoleon Bonaparte decided to add old measuring words (that he had redefined) to the "decimal metric system" with his "mesures usuelles" he also brought back common or vulgar fractions such as halves and quarters. The French people then had a "non-decimal, non-metric, non-system" and remnants of this still exist. In Paris today, people might ask for une livre (500 grams) or une demi-livre (250 grams) of meat or vegetables, un quart de un litre (250 millilitres) or une demi-pinte (250 millilitres). This political decision by Napoleon Bonaparte to preserve some old words effectively condemned the French people to smearing old words and fractions over the top of the simplicity of the "decimal metric system". Our French teacher still has trouble with this. At Optimal School we believe that, with some hindsight, we can do much better.*

As we spoke the school chaplain joined us and added that the same thing had happened in the UK when Margaret Thatcher was trying for better poll results to impress her party room colleagues in 1989. He said that Thatcher had followed Napoleon's example by encouraging the use of two old pre-metric words:

> *To impress her party room she said that she would, "save the mile and the pint for Britain". This she did by passing laws that were only intended to apply to beer (but only in pubs), to milk (but only milk delivered in bottles), and to signs (but only to road signs). Even then she used the metric system definitions of metric pints, and metric miles.*
>
> *Everything else in the Thatcher government* was to remain fully metric. By trying to save two words (and her own political future) she condemned the whole of the UK to go into the metric muddle where they still are. If Napoleon's move is any guide, we might expect Margaret Thatcher's efforts to continue to cause measurement confusion for at least another 200 years.*

I somewhat jokingly asked if he, as school chaplain, was an active part of the Optimal School metric system program. I was surprised when he replied, "*Of course, as you know the Bible regards honesty in measurement as a running theme.*" He then quoted from the Christian Bible:

> **Leviticus 19:36** *Just balances, just weights ... shall ye have ...*
>
> **Ezekiel 45:10** *Ye shall have just balances, ...*
>
> **Deuteronomy 25:14 and 25:15** *Thou shalt not have in thine house divers measures, ... But thou shalt have a perfect and just weight, a perfect and just measure shalt thou have.*

And from the Koran:

> **Koran Sura 83** Woe to those who give short weight! Who when they measure against others take full measure; but when they measure to them or weigh to them, diminish!

The chaplain thought that it might have been reflections on these quotes that led Bishop John Wilkins to invent the idea for a "*universal measure*" in 1668. He reckoned that the metric system arose out of Bishop Wilkins seeking "honesty in measurement". He then added:

> *You know that Bishop Wilkins idea eventually became the "decimal metric system" in France in 1795. The "decimal" part came from the USA, the "metric" part came from Italy, and the "system" part came from Bishop John Wilkins in England. Then the French put it all together as the "decimal metric system" and made it legal for the French nation and its territories. It soon spread to the rest of the world.*

As it was now lunchtime the chaplain offered to take me to the school canteen on the way to the staffroom. In the canteen I was agreeably surprised to see that all items listed on the menu board had their food energy content listed in kilojoules. I began to scribble down a few items when the canteen manager noticed what I was doing so she handed me a detailed list (a copy of this list is attached to this report). When I asked about the bottom section headed – *Typical takeaway foods -- we don't serve these in our canteen – look at the food energy levels in kilojoules* – she said that students often came to her to find out about take-away foods, probably for an assignment, so she always had copies ready to hand out.

The chaplain then led the way to the staffroom where a regular monthly Curriculum Review Committee meeting was being held. I was invited to join the seven committee members already present and to sit in on the meeting. The Chair welcomed me and suggested that I could contribute to the meeting or ask questions.

One of the committee members had previously put forward, as a Curriculum Review Committee topic, the issue of whether it was preferable to use centimetres or millimetres for most activities. As pre-reading for the meeting the proponent had supplied a list of occupations and the predominant metric system unit that they used every day. Here is my copy of the proponents list:

millimetre users – 97 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 cutter 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, picture framer, 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 – 11 occupations

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

7 occupations where length measures are relatively unimportant

Butcher, butter maker or cheese maker, confectioner, ladies hairdresser, smallgoods maker, men's hairdresser, and meat tradespersons.

Summary of occupations

millimetre users – 97 occupations	**84.3 %**
centimetre and inch users – 11 occupations	**9.6 %**
where length measures are relatively unimportant – 7 occupations	**6.1 %**
Total – 115 occupations	**100 %**

The proponent then summarised his position as providing Optimal School students with a broad general education as well as preparing them for the world job market He stated that, it seemed to him, that there was a very high probability that students from the Optimal School would use millimetres predominantly during their working lives.

The proponent argued that except for the centimetre, the prefixes centi, deci, deca, and hecto are essentially not used in daily activities of commerce and industry, and that he could not think of any examples where any industry used centigrams, decilitres, decametres, or hectograms. The only exception he could think of was the hectare and this was a special case historically. He thought that probably these prefixes shouldn't be taught in any detail – making mention of their existence was enough. In the rare cases where these prefixes are used, and these are rapidly becoming rarer, they could soon be learnt. Certainly students shouldn't bother converting to them or from them. He concluded by saying:

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

The chair then asked for immediate responses to the question before the committee, which she phrased as:

Is it preferable at Optimal School to use centimetres or millimetres for most activities?

As she went around the table, the science teacher pointed out that they taught all the prefixes from yocto to yotta but didn't bother too much about centi, deci, deca, and hecto as they sort of used a "rule of 1000" that favoured prefixes that were multiples of 1000.

The domestic science teacher said that they used both centimetres and millimetres with a preference for centimetres for general sewing and millimetres for fine work such as quilting and tapestry designs. For cooking they used centimetres for pot and cake tin sizes and centimetres with fractions or decimal or millimetres for (say) scone diameters.

The woodwork teacher said that he and all the other craft teachers only used millimetres and deliberately avoided centimetres; the physical education teacher pointed out that all the BMI heights, track lengths and jump distances and heights were in metres and decimals of metres so they didn't use centimetres or millimetres at all.

The craft teacher interrupted again to point out that using millimetres meant that they never had to use decimals or fractions on any of their student projects because every measurement was in whole numbers.

An art teacher supported this saying that the kids found it easier to layout their art projects in millimetres so they only had to work with whole numbers. This was especially useful for poster designs, page layouts, and for cover designs for their assignments.

Finally a third grade teacher told the committee that centimetres were used with the lower grades but that millimetres and metres were introduced into the higher grades. She also said that the little kids didn't measure much; they used rulers mostly as counting sticks and the centimetre cubes they used – from a Maria Montessori model – were used as counters rather than for measuring.

At this point all committee members thought that the issue needed more time for reflection and for consultation with other members of staff and perhaps with parents. The Chair agreed, and proposed writing an article about progress so far for the school newsletter and listing the subject on the agenda again in three months time to see if the committee could move closer to a decision.

Before the Chair closed the meeting she turned to me to see if I had any questions for the committee. I responded by asking did anyone do any "metric conversion" between old pre-metric measures and metric system units. They all agreed that this did not happen any more at the Optimal School. It had been tried years ago but it didn't work. One of the history teachers, as apart of her post graduate program, had investigated "metric conversion" throughout history and all around the world and found that "metric conversions" had not worked anywhere else either. The school then decided, as a matter of school curriculum policy, to go directly to using the metric system and not to use any "metric conversions" at all. This "direct metrication" approach, they told me, "*... works like a charm.*"

I then asked, "What about conversions within the metric system; say, changing grams into kilograms or vice versa?"

They gave this some thought before the woodwork teacher said that they deliberately avoided this by using only one metric system unit for each kind of task; he again gave the example of using millimetres ONLY for all woodwork and metal work. The home economics teacher added that they needed to teach students how to convert kilograms to grams as a lot of shopping is done in kilograms and most cooking is done in grams, and this is similar for litres and millilitres. She then paused before she added:

On the other hand, we are quite aggressive about "metric conversion" when we teach about the mass of newborn babies – we host a class meeting for young mothers on Wednesday afternoons. We firmly believe that rounding errors that can occur when changing from grams to kilograms endanger the life of the baby, because the rounding errors often don't let you see whether the mass of the baby has increased, or more importantly decreased, which could indicate the ill-health of the baby. As to so-called "metric conversion" from a baby mass in grams to pounds and ounces – this just fills us with horror – we don't support this at all.

After lunch I was taken to the art department where a group of senior students were designing a set for the drama group to use for a video production. There was much discussion about the lighting. When I arrived they were talking about candelas per square metre and lux.

When they moved on to colour temperatures expressed in kelvin, I admired the fact that they had been provided with some typical reference points; they knew that colours above 5000 kelvin were bluish-white and are called cool colours, that 6000 kelvin was close to day-light, and that colours below 3000 kelvin were yellowish white to red and were called warm colours.

When I asked a student why they were going to so much trouble with measurements he said, "My cousin, is a lighting man in a film and TV studio and he told me to get as much experience with lighting measurement as I could, because the best professionals at his studio "*used this measurement stuff nearly every day*".

Just then an art teacher joined us and as I introduced myself I commented on the practical approach to learning that the students were using. He replied that this was part of the culture at Optimal School and especially in the Art department. The art teacher then went on to say:

> *The curriculum committee wanted to provide our students with the opportunity to "do" the metric system in the playground and at home otherwise they will not understand the metric system from a practical point of view. You have probably seen plenty of evidence of the application of this policy all around the school. But what you won't see is evidence of the Optimal School campaign to "**Teach the metric system to your parents**" that the school also runs. Our students are expected not only learn the metric system for themselves, but also to teach it to the older generations. Needless to say, the tactic works! As I left he pointed to the postcard policy outside the door.*

Art policy:

If I hear, I will forget

If I see, I will remember

If I do, I will understand

Confucius 551-479 BCE

My final visit in the senior school was to the school library. The librarian was enthusiastic about the metric system documents she had been able to collect. Her goal was to provide documents for student research that were as near to the originals as she could get. In pride of place was the library's facsimile copy of Bishop John Wilkins' book, "*An Essay Toward a Real Character and a Philosophical Language*" that contained the original description of his invention of a "*universal measure*" that became the metric system. The librarian had a prepared a stack of reproductions of pages 190 to 194 from this book that she handed to students doing any assignments on the invention of the metric system. She said the kids liked reading 1600s English in its original form.

Another proud possession was a copy of Robert Norton's 1608 translation of Simon Stevin's 1585 book, "*Disme, The Arts of Tenths or Decimal Arithmetike*". She pointed out that Thomas Jefferson had been inspired by this book to develop decimal currency for the USA (he used the book's title for the tenth of a dollar – the dime – that Jefferson spelt as disme). Thomas Jefferson's decimal currency plan is now used in every country in the world.

Also, Thomas Jefferson used this book and probably Bishop Wilkins' book to help him to write his report to Congress on a decimal method for all measurements in the USA. The librarian thought that Jefferson was influenced by Simon Stevin's thought that decimal measurement would greatly help people in all works of life such as:

> *... stargazers, surveyors, carpet-makers, wine-gaugers, mint-masters and all kind of merchants.*

She had copies of the *"Magna Carta*", the "*Constitution of the USA*" and all the laws relevant to measurement passed in the USA since 1866 when the metric system became legal for the USA and copies of all the current NIST documents. She told me that the school students really appreciated being able to handle the "original" documents as this made them feel like real historians. She went on to say, "*However, that doesn't mean we don't keep up with modern trends. When a student comes looking for historical references, I ask if they've got a computer 'memory stick' and when they give me one of these I am able to download electronic copies of the main metric system references*". I immediately pretended to be a ninth year student wanting metric system references and handed her a memory stick that I routinely carry in my pocket. I have attached her references at the bottom of this report.

I next visited several classrooms in the junior and middle schools. On the way I passed the school caretaker's shed. In a small school like the Optimal School the caretaker was in charge of grounds, building maintenance, and cleaning. He was in his shed so I introduced myself and asked how the school's metric system policies affected him. I was surprised when he replied:

> *They affect us in every way. All new work is done in metric and, after the woodwork teacher advised me, we only use millimetres. All our cleaning contracts are now worked out in square metres of floor area.*
>
> *The only issue we have is with very old machinery. For instance we have an old engine for emergency electricity; it's got old nuts and bolts. Our solution was to put together a small set of old tools to fit that machine. We've also got a very old mower that has it's own set of tools. We make sure that these tools never get mixed up with metric tools by putting a red paint mark on them. Metric tools have a green paint mark so there's no danger of trying to use metric tools on the old machines or old tools on metric machines.*
>
> *It's easy once you get the hang of it and we don't damage the tools or the nuts and bolts by using the wrong tools.*

I thanked the caretaker, and then began to move back to the junior school. As I left the caretaker's shed I noticed that he had a postcard policy on the door. It read:

Optimal School energy policy

To save energy at Optimal School rooms are:

- ◊ heated to 18 °C in the winter, and
- ◊ cooled to 26 °C in the summer.

Back in the junior school there were scales for body mass and rulers fixed to walls in every room. Apparently, you used centimetres for your height until you grew to 1.1 metres; then you were allowed to use metres. The children seemed to regard this as a major highlight in their development. It was a bit like when they changed from printing letters one at a time to doing joined-up-writing – it was a major achievement.

At Optimal School they had another practice that I had not seen before. Up to the third grade students measured everything in whole numbers of centimetres (without decimal or vulgar fractions) but from fourth grade onwards they measured in whole numbers of millimetres. Again students regarded this as a major transition and a highlight in their development toward being "*grown-ups*".

It wasn't immediately obvious but apparently the metric system was not used at Optimal School as a convenient tool for teaching about fractions and decimals. As a fifth grade teacher put it:

> *We use physical things to teach about halves, quarters, and such. The metric system prefixes mean that you can select the right size prefix for each task so you can avoid decimals and fractions altogether; the metalwork teacher taught me this.*
>
> *Generally, when you're actually using the metric system, say when you are building a house or renovating a kitchen, there is no point in sliding decimal points back and forth at all – you choose to use millimetres only – and then you let the prefix, milli, do the work.*
>
> *I think that it is simply wrong to use the metric system as a sort of tool to teach numerical mathematics skills – it's damaging to student's perception of the metric system if they learn to regard it as just a tool for teaching decimal arithmetic by sliding decimal points. My fifth grade kids and I treat multiplication and division of decimal numbers as pure mathematics and we deal with the metric system separately.*

Another insight I gained from a seventh grade teacher is that she will not use the "*Pages*" program from the Apple computer company because they divide centimetres into quarters and not into decimal fractions or into millimetres. She says:

> *In fact, the Apple Company will not even let us choose millimetres to layout our pages. Children might be doing an assignment on the history of the metric system and, according to Apple, when they want to layout their pages they have to work either in inches and fractions of inches, or in centimetres divided into halves and quarters.*

Then she added:

> *... and the Microsoft Company is no better – all of their defaults in Microsoft Word are in inches and fractions of inches. To be fully metric, all students in all schools have to fight daily against these two major software companies and their backward looking attitude to modern measurement. Their attitude is pre Simon Stevin, so they are pre 1585!*

It was now late in the school day so I returned to the general office to find the principal. I had to wait in line as several junior school students wanted to swap rulers. Apparently, if you had a ruler with inches on it you could hand it in to the office and they would replace it for free with a brand new ruler marked in centimetres on one scale and in millimetres on the other three scales. These new rulers are 300 millimetres long, which is long enough to rule up an A4 page that is 297 mm high and 210 mm wide.

When the students had all got their new replacement rulers, I asked the woman in the office about the A4 paper size. She was delighted to tell me that she thought it was the best decision the school had made:

> *It's hard to say how much paper we've saved since we changed to the A series of paper sizes. We use A4 for general work and A3, A2, A1, and A0 for artwork such as student posters. We use the smaller sizes for various different things; you've probably seen the A6 postcard policies outside some of the rooms. When we cut those on the guillotine from A4 to A5 to A6 there is no waste – only a bit of paper dust. The A series of paper sizes must save thousands of trees in our forests.*

This is where the principal found me. I thanked her for her hospitality, asked her to pass on my thanks to all the staff and to stress to all how generous with their time and their ideas I had found all the staff and students at the Optimal School. The principal then invited me into her office to discuss the broad principles involved in the Optimal School metrication upgrade.

I asked how they had started the program and she said that it came from a realisation that metric conversion did not work and they needed another method. In the end they chose the idea of direct metrication where you change to the metric system immediately, learn a few reference measurements such as averages, normal ranges, and world records. She says that when she explains this to new staff she often uses newborn babies as an example:

Smallest ever surviving baby	**280 grams**
Small baby in the normal range	**2 500 grams**
Average baby	**3 500 grams**
Large baby in the normal range	**4 500 grams**
Largest baby recorded	**10 800 grams**

She says that she uses training like this for new teachers because, as she puts it:

> *"New teachers are a mixed lot. We have to convince some of them that the metric system is the way we do things around here at the Optimal School. The safety of babies is a good example of how the metric system, in whole numbers, saves lives."*

I then mentioned that I had been to a curriculum committee meeting where the discussion was about using millimetres or centimetres. She responded that this topic came up from time to time and that she expected it to continue until everyone changed to millimetres. She said that millimetres were quick and the whole transition to the metric system could be completed in a single day. However, some teachers had gone down the centimetre road and had developed a centimetre mind-set so nobody knew how long their metrication upgrade might take. She theorised that centimetres were more difficult to work with because they continued the use of fractions like halves and quarters, and decimals with all the sliding of decimal points. She reckoned that whole numbers worked better for the metrication transition and better for ordinary everyday use, especially for design and construction work in art, design, cooking, craft, metalwork, textiles, and woodwork.

I then asked about how she saw future progress of metrication at the Optima School. She thought for a moment before she said:

> *It'll be like the past. We will proceed bit by bit. A teacher will learn something new about metrication, investigate it further, then prepare a case for the curriculum committee who will um and ah for months before they either accept it or reject it. then we will make a small*

change. Our most recent was the idea for the A6 policy statements outside the doors of each department; these are still happening. Before that it was the BMI stations. These took off and have spread all around the school from their original proposed locations. I suppose the future will be much the same as the past — steady progress through small changes.

What about opposition from outside the school?

We did have a sort of opposition years ago when we put the thermometers on the doors. Some parents complained that they wanted conversion charts to change back to degrees Fahrenheit. Our history teacher took them on with data about the complete failure of "metric conversion" wherever it had been tried in the world. But, I think, her best selling point was when she told them about 'Mrs Fahrenheit's armpit' as the scientific basis of the Fahrenheit scale.

It had been a full and active visit and I was now filled with multiple new ideas for promoting the metric system in other schools. The new ideas arose directly from the generosity of the Optimal School teachers I had met and from the thoughts and ideas that so many of their very practical applications had sown in my mind.

Where to start? I have no idea.

To achieve success like the Optimal School is not the work of an idle moment.

Perhaps I will re-read these notes until an idea strikes me as do-able.

I will do this one thing. Then I will re-read these notes again.

Other than that the only advice I can suggest is:

Good luck with your own approach and your own ideas.

Geelong, Australia

Note: *The Optimal School does not exist, it never did exist, and it probably never will exist. However, many of its parts are real, and many other parts could apply without too much effort. The observer is clearly an Australian (as you can see from the spelling) but the school is not exactly located. It could be in the UK, in the USA, in Australia, in New Zealand, in South Africa, or in any other part of the world.*

Metric system references for library research

Origin of the metric system

http://www.metricationmatters.com/who-invented-the-metric-system.html

http://www.metricationmatters.com/docs/CommentaryOnWilkinsOfMeasure.pdf

http://avalon.law.yale.edu/18th_century/jeffplan.asp

http://en.wikipedia.org/wiki/Metric_system

http://metricationmatters.com/docs/USAMetricSystemHistory.pdf

http://www.metricationmatters.com/docs/MetricationTimeline.pdf

http://www.bl.uk/treasures/magnacarta/index.html

http://www.usconstitution.net

Arguments for the use of the metric system

http://www.youtube.com/watch?v=xXK-QJ_9SLs&NR=1&feature=fvwp

http://www.philforhumanity.com/Metric_System.html

http://www.metric4us.com/whynot.html

http://metricationmatters.com/why_metrication.html

Metric system laws and regulations

http://www.nist.gov/pml/wmd/metric/metric-policy.cfm

http://lamar.colostate.edu/~hillger/laws

http://physics.nist.gov/Pubs/SP811/sec09.html

http://lamar.colostate.edu/~hillger/laws/mendenhall.html

Bureau International de Poids et Mesures (BIPM) documents

http://www.bipm.org/en/si

http://www.bipm.org/en/si/si_brochure for SI Brochure on-line

http://www.bipm.org/utils/common/pdf/si_brochure_8_en.pdf to download SI Brochure

Other useful documents and resources

http://www.metricationmatters.com/docs/CostOfNonMetrication.pdf

http://www.metricationmatters.com/docs/ApproachesToMetrication.pdf

http://www.metricationmatters.com/docs/MetricPlayground.pdf

http://www.abc.net.au/am/content/2010/s3099936.htm

http://www.youtube.com/watch?v=U5802FBaMSI

And just for fun watch these guys try to work out:

"What is the difference between 180 mm at the front minus 140 mm at the back?"

http://www.youtube.com/watch?v=Omh8Ito-05M

Or search for armpit to find out about Mrs Fahrenheit's armpit at:

http://daretorant.com/?p=597

Metric system prefixes for science

prefix	Symbol		Example using metres
yotta	**Y**	10^{24}	**1 yottametre (1 Ym) ~ radius of the 'Local super cluster of stars ~ the diameter of the known visible Universe ~ 500 Ym**
zetta	**Z**	10^{21}	**1 zettametre (1 Zm) ~ diameter of the Milky Way galaxy**
exa	**E**	10^{18}	**1 exametre (1 Em) ~ the nearest star similar to the Sun is 1.9 Em away**
peta	**P**	10^{15}	**1 petametre (1 Pm) ~ light travels about 9.5 Pm in a year**
tera	**T**	10^{12}	**1 terametre (1 Tm) ~ a little more than the distance from the Sun to Jupiter (0.8 Tm)**
giga	**G**	10^{9}	**1 gigametre (1 Gm) ~ diameter of a small star (Sun = 2.4 Gm)**
mega	**M**	10^{6}	**1 megametre (1 Mm) ~ Distance: Geelong to Sydney; Nashville to Dallas; New York city to Detroit; Sydney to Brisbane**
kilo	**k**	10^{3}	**1 kilometre (1 km) ~ 10 minute brisk walk**
hecto	h		As the prefixes hecto, deca, deci, and centi in hectometres, decametres, decimetres, and centimetres are rarely used in science, commerce, industry, or trade, we mention these but we don't use them to measure any of our science projects.
deca	da		
deci	d		
centi	c		
milli	**m**	10^{-3}	**1 millimetre (1 mm) ~ diameter of a pin**
micro	**µ**	10^{-6}	**1 micrometre (1 µm) ~ small bacterial cell**
nano	**n**	10^{-9}	**1 nanometre (1 nm) ~ DNA helix diameter**
pico	**p**	10^{-12}	**1 picometre (1 pm) ~ atomic nucleus**
femto	**f**	10^{-15}	**1 femtometre (1 fm) ~ proton or neutron**
atto	**a**	10^{-18}	**1 attometre (1 am) ~ electron or quark**
zepto	**z**	10^{-21}	**1 zeptometre (1 zm) ~ diameter of a preon**
yocto	**y**	10^{-24}	**1 yoctometre (1 ym) ~ the diameter of a neutrino**

Food energy

Active junior school kids use about 7000 kilojoules of energy every day.

Active senior school students use about 10 000 kilojoules of energy every day.

Drinks

Water	lots from tap	0 kJ
Carrot juice	200 mL	270 kJ
Tomato juice	250 mL	290 kJ
Grapefruit juice	200 mL	305 kJ
Apple juice	200 mL	390 kJ
Orange juice	250 mL	400 kJ
Lo-fat milk	300 mL	450 kJ
Pineapple juice	250 mL	530 kJ
Cola soft drink	375 mL	660 kJ
Whole fat milk (whole)	300 mL	900 kJ
Milk shake chocolate	300 mL	1485 kJ

Fruit and vegetables

Mandarin	70 grams	145 kJ
Carrot	1 carrot	135 kJ
Apple	100 grams	270 kJ
Orange	100 grams	330 kJ
Grapes	medium bunch	525 kJ
Banana	1 medium	575 kJ

Sandwiches

Sandwich, salad	150 grams	600 kJ
Sandwich. peanut butter	200 grams	750 kJ
Sandwich, chicken and salad	200 grams	1000 kJ
Sandwich, ham and cheese	1 medium	1500 kJ

Snacks

Sultanas	25 grams	275 kJ
Cashews	25 grams	515 kJ
Chocolate bar with peanut	40 grams	805 kJ
Almonds, roasted	30 grams	640 kJ

Typical takeaway foods -- we don't serve these in our canteen

Pizza	1 thin slice	900 kJ
Fish, deep fried in batter	1 piece	1045 kJ
Roast chicken sub	1 small	1350 kJ
French fries	small serve (90g)	1089 kJ
Meat pie	175 grams	1880 kJ
Hamburger	Big	1965 kJ
Fried chicken	2 pieces	3010 kJ
Hamburger	Whopper with cheese	3100 kJ

Environmental Loudness Comparison Chart

Measured as decibels using the A scale – dBA

Here are some loudness measurements that might help you to understand the volume levels of various sound sources and how they can affect your hearing.

Sound source	
Weakest sound heard	0 dBA
Whisper Quiet Library	30 dBA
Normal conversation (at about 1 metre)	60-70 dBA
Telephone dial tone	80 dBA
City Traffic (inside car)	85 dBA
Train whistle (at about 100 metres)	90 dBA
Truck traffic (at about 50 metres)	90 dBA
Train in enclosed space (at about 50 metres)	95 dBA
Loudness level that can result in hearing loss after sustained exposure *Hearing protection is recommended at this level and above*	*95 dBA*
Motor mower (at 1 metre)	107 dBA
Snowmobile, Motorcycle	100 dBA
Power saw at (at 1 metre)	110 dBA
Loudness level that can result in temporary hearing loss after relatively short exposure and permanent hearing loss after sustained exposure *Hearing protection should be worn at this level*	*115 dBA*
Loud Rock Concert	115 dBA
Pain begins	*125 dBA*
Pneumatic riveter (at 1 metre)	125 dBA
Even short term exposure can cause permanent damage - Loudest recommended exposure WITH hearing protection	*140 dBA*
Jet engine at 30 metres, Gun Blast at 1 metre	140 dBA
Death of hearing tissue	180 dBA
Loudest sound possible	194 dBA

Music Loudness Comparison Chart

Measured as decibels using the A scale – dBA

Here are some loudness measurements of music that might help you to understand the volume levels of various sound sources and how they can affect your hearing.

Loudness levels of music	
Normal piano practice	60 -70 dBA
Fortissimo Singer (at 1 metre)	70 dBA
Chamber music, small auditorium	75 - 85 dBA
Violin	82 - 92 dBA
Piano Fortissimo	84 - 103 dBA
Cello	85 - 111 dBA
Clarinet	85 - 114 dBA
Trombone	85 - 114 dBA
Piccolo	90 -106 dBA
French horn	90 - 106 dBA
Flute	92 -103 dBA
Walkman on (set of 5 out of 10)	94 dBA
Loudness level that can result in hearing loss after sustained exposure *Hearing protection is recommended at this level and above*	*95 dBA*
Oboe	95-112 dBA
Tympani & bass drum	106 dBA
Earbuds can reach this level of loudness	110 dBA
Loudness level that can result in temporary hearing loss after relatively short exposure and permanent hearing loss after sustained exposure *Hearing protection should be worn at this level*	*115 dBA*
Amplifier rock (at 2 metres)	120 dBA
Full symphony orchestra (peak)	120 - 137 dBA
Even short term exposure can cause permanent damage - Loudest recommended exposure WITH hearing protection	*140 dBA*
Rock music (peak)	150 dBA

Sound Loudness Health and Safety Chart

Measured as decibels using the A scale – dBA

Here are some loudness measurements of music that might help you to understand the volume levels of various sound sources and how they can affect your hearing.

Occupational Health and Safety **Daily Permissible Loudness Level Exposure** ***Do not exceed this amount of time on any single day.***	
Time per day	***Sound level***
8 hours	90 dBA
6 hours	92 dBA
4 hours	95 dBA
3 hours	97 dBA
2 hours	100 dBA
1.5 hours	102 dBA
1 hour	105 dBA
30 minutes	110 dBA
15 minutes or less	115 dBA

NOTES:

Like any other sound, music can cause hearing loss if it's loud enough and exposure is long enough. You can damage your hearing at a live concert or by listening to recorded music. Here are some thoughts that might help you to keep your hearing for longer.

- Earbuds, such as those used with an iPod, pose a threat to long-term hearing. Audiologists say that it is the high sound level portable music players can reach. Many earbuds advertise specifications of 110 decibels.
- Exposure to loudness has been shown to increase high blood pressure and to increase several psychological difficulties.
- High frequency sounds – above 4000 hertz – are the most damaging. The highest octave of the piccolo is from about 2000 Hz to 4000 Hz.
- One-third of the total sound loudness of a 75-piece orchestra comes from the bass drum.
- Speech reception is not seriously impaired until there is about 30 dB loss so you don't notice the loss. By that time severe damage may have occurred.
- The incidence of hearing loss in both classical and rock musicians has been estimated at about 40 %. A Swedish study showed that 59 out of 139 musicians (42%) had hearing losses greater than that expected for their ages.
- We all experience gradual hearing loss as we get older. We lose the higher frequencies first.