Secondary Magazine
Issue 71

National Centre for Excellence in the Teaching of Mathematics

Welcome to Issue 71 of the Secondary Magazine.

Contents

Contributors to this issue include: Alison Clark-Wilson, Marcus du Sautoy, Mary Pardoe, Richard Perring, and Peter Ransom.

From the editor

Welcome to this issue – in which we focus on some connections between mathematics and music.

The interview is with Marcus du Sautoy, the Simonyi Professor for the Public Understanding of Science, who is also professor of mathematics at the University of Oxford, and is well known for his popular mathematics books and his many TV and radio programmes about mathematics. You may have heard on Radio 4 recently his series A Brief History of Mathematics or watched his BBC documentary, The History of Mathematics. You may also have seen his Royal Institution Christmas Lectures and read his books Finding Moonshine, The Numb8r My5teries, and The Music of the Primes.

In 2004, in an article with the same title as his book, *The Music of the Primes*, Professor du Sautoy wrote:

> "It is one of the failings of our mathematical education that few even realise that there is such wonderful mathematical music out there for them to experience beyond schoolroom arithmetic."

This is related to Richard Skemp's message to mathematics educators that he expressed in 1983 in Mathematics Teaching, 102, in The Silent Music of Mathematics.

Professor Skemp thought about the sad fact that "all the mathematics they (his great-niece and her class mates) did at school was pages of sums" in the context of his observation that "most of us… need to hear music performed, better still to sing or play it ourselves, alone or with others, before we can appreciate it."

He reminded readers that:

> "We would not think it sensible to teach music as a pencil and paper exercise, in which children are taught to put marks on paper according to certain rules of musical notation, without ever performing music, or interacting with others in making music together. If we were to teach children music the way we teach mathematics, we would only succeed in putting most of them off for life."

Richard Skemp believed, as do most mathematic educators today, that:

> "For most of us mathematics, like music, needs to be expressed in physical actions and human interactions before its symbols can evoke the silent patterns of mathematical ideas (like musical notes), simultaneous relationships (like harmonies) and expositions or proofs (like melodies)."

In 1983 he asked:

"So why are children still taught mathematics as a pencil and paper exercise which is usually somewhat solitary?"

Do we still need to ask this question today?

It is ironic that Professor Skemp held "Mathematicians (with a capital M) largely to blame for this"!

In this issue of the Secondary Magazine we have ideas for classroom activities that are definitely not solitary exercises – you will find them in An idea for using ICT in the classroom, An idea for the classroom, Focus on… and the Subject leadership diary.

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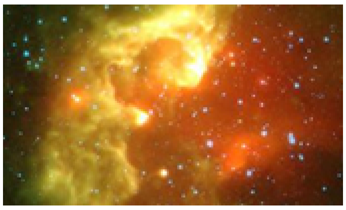

National Centre
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It’s in the News!
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The fortnightly *It’s in the News!* resources explore a range of mathematical themes in a topical context. The resource is not intended to be a set of instructions but a framework which you can personalise to fit your classroom and your learners.

Astronomers using the Keck Observatory in Hawaii have found what they consider to be the most suitable planet to support life so far.

Scientists believe that the planet, called Gliese 581g (named after its star, Gliese 581) is made of rock, like the Earth, and sits in the ‘Goldilocks Zone’ of its sun, where it is neither too hot nor too cold for water to exist in liquid form – widely believed to be an essential precondition for life to evolve.

This resource features space travel, mathematical modelling and estimation skills, as well as offering the opportunity of working with very large numbers.

Download this *It's in the News!* resource - in PowerPoint format

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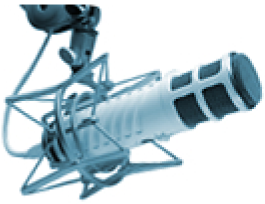


National Centre for Excellence in the Teaching of Mathematics

The Interview

Professor Marcus du Sautoy, photograph used with permission

Name: Marcus du Sautoy

About you: I am professor of mathematics at the University of Oxford and the Simonyi Professor for the Public Understanding of Science, a post previously held by Richard Dawkins.

The most recent use of mathematics in your job was…
I am writing a paper with a colleague in Oxford that requires analysing how many solutions an equation has modulo each prime p. The strange behaviour of this equation might help answer a 50-year-old conjecture about how many symmetrical objects there are with a prime power number of symmetries.

Some mathematics that amazed you is…the solution to the Poincaré Conjecture by the Russian Grigori Perelman. This is the first of the Millennium Prizes to be solved. It is a conjecture about the different topological shapes that 3-dimensional space can be wrapped up into. So it tells what shape our universe might be. Perelman didn't collect his $1 million dollar prize this summer. He prefers proving theorems to prizes.

Why mathematics?
I love the certainty that mathematics provides. A proof tells you with 100% certainty that your theorem is true. It can never be overturned. This is what makes it different to the sciences – scientists can hypothesise and provide convincing experimental evidence for a theory but ultimately can never know with certainty that their model is correct.

A significant mathematics-related incident in your life was…
The buzz of discovering something new in mathematics is amazing. I still remember the moment I created a new symmetrical object with strange new properties that had never been seen before. I am so proud of the discovery that I'd like it carved on my gravestone. Unfortunately the object lives in hyperspace so it will have to be described using the language of group theory.

A mathematics joke that makes you laugh is...
How can you spot an extrovert mathematician? They look at your shoes when they talk to you.

The best book you have ever read is…
The Glass Bead Game by Hermann Hesse is about a futuristic game that aims to fuse mathematics, music, art, science and philosophy. When I read this I thought, 'Yes, this is the game I want to play.' That's what I try to do in my outreach work: to show how mathematics is everywhere in what we do. My ultimate aim is to become a master of the glass bead game.

Who inspired you?
Mr Bailson, my teacher at Gillotts Comprehensive School. He showed me that mathematics is so much more than just long division. Also Sir Christopher Zeeman. I went to one of his Royal Institution Christmas Lectures in 1978, the first ever to be given on mathematics. I came away that Christmas knowing that I wanted to be a mathematician like him when I grew up.

If you weren't doing this job you would…

Run away to the theatre. Apart from mathematics my other passion is theatre. I was very lucky to help Complicite with A Disappearing Number, their play about mathematics. I did workshops with the company for a couple of years exploring the maths of Ramanujan. I am currently devising a play with a group of artists about the Poincaré Conjecture.

What is your new book about?

The Num8er My5teries is based on the material I devised for the Christmas Lectures I gave in 2006. The book is very playful, full of games, experiments and curious stories of how mathematics can help answer some of life's mysteries. It also introduces five of the Millennium Prize problems, including the Poincaré Conjecture.

Tell us about mangahigh.com...

My 14-year-old spends hours playing games online. Wouldn't it be great, I thought, if we could create games that were brilliant fun to play but that required knowing your maths to advance through the levels. Mangahigh.com is the internet maths school that came out of this idea and uses curriculum compliant games to teach GCSE maths. Schools and pupils who've played the games love them.

The Num8er My5teries is published by Fourth Estate who also publish Marcus's other books: *The Music of the Primes* and *Finding Moonshine: a mathematician's journey through symmetry*.

Focus on…connecting mathematics and music

Many connections between mathematics and music are interesting to explore. Some have led mathematicians to very significant insights.

It is possible to see similarities in what mathematicians and musicians do. For example, both mathematicians and composers of music reason, discover, create and communicate. Mathematicians do and create mathematics – and 'bodies' of knowledge known as branches of mathematics exist at any particular time. Musicians create and play music – and 'bodies' of music, such as classical music or rock music, exist at any particular time.

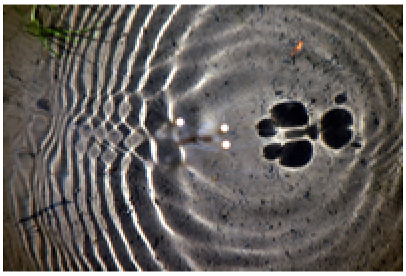
And there is a distinction, shared in both mathematics and music, between the practice of 'exercises' and the real activity or creation. As Marcus du Sautoy wrote in The Music of the Primes in Issue 28 of *Plus*:

> "It is one of the failings of our mathematical education that few even realise that there is such wonderful mathematical music out there for them to experience beyond schoolroom arithmetic. In school we spend our time learning the scales and time signatures of this music, without knowing what joys await us if we can master these technical exercises. Very few would have the patience to learn the piano if they were denied the pleasure of hearing Rachmaninov."

But, as Professor du Sautoy continued:

> "It isn't just aesthetic similarities that are shared by mathematics and music. Riemann discovered that the physics of music was the key to unlocking the secrets of the primes. He discovered a mysterious harmonic structure that would explain how Gauss's prime number dice actually landed when Nature chose the primes."

The significance of the Riemann Hypothesis, the role played in its formulation by Riemann's discovery of a link between a mathematical graph and a musical note, and how mathematicians have tried to verify or falsify the hypothesis, are entertainingly sketched for students in the whole article and in Marcus du Sautoy's book The Music of the Primes.



Ripples, photograph by Mila Zinkova

Students may enjoy exploring for themselves some of the simpler mathematical ideas and relationships that underlie, or are revealed when they investigate, music and its history.

Vibrating air creates sound. An initial vibration creates air-waves – or sound waves – just as a stone thrown into a still pond creates ripples.

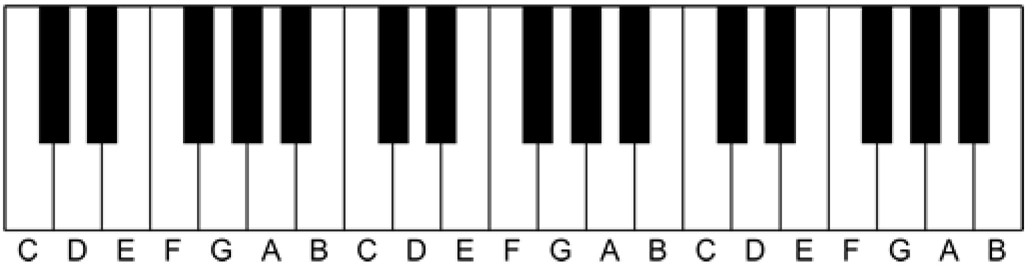
The pitch of a note is how high or low it sounds. It is determined by the frequency of the vibration that is producing the sound and is measured in hertz (*hz*) – a unit giving the number of vibrations, or wave cycles passing a point, per second. The lower the frequency of the sound waves the lower is the pitch of the sound. Listen to sounds with different frequencies.

This can be simply demonstrated. Hold a ruler on a table so that it juts out beyond the edge of the table, and twang the ruler. Then if you make it jut out further and twang it again you get a lower note. The longer the part of the ruler is that's vibrating, the slower is the vibration, and therefore the lower the note.

Students might enjoy Hearing Subtraction – an interactive sound activity about frequency and beats.

The ancient Greeks in the time of Pythagoras, who took for granted a link between mathematics and music, discovered that musical notes are related to simple **ratios of integers**. They found that if two strings with lengths in the ratio 1:2 are plucked, the notes sound the same but at different pitches – one is higher than the other. This difference in pitch is what we call an octave.

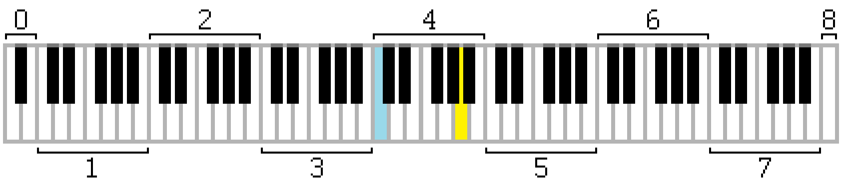
The note that we call middle C, which can be found more or less in the middle of a piano keyboard, has a frequency of around 256 *hz* – anything producing sound waves at this frequency will make a sound like that note. In the western scale of musical notes, C, D, E, F, G, A, B, (you can play those seven notes here), notes with a frequency ratio of 1:2 are given the same name.



Piano Keyboard by Jens Egholm

Doubling the frequency creates a note an octave higher. Reversely, halving the frequency creates a note an octave lower.

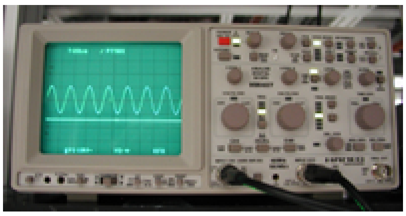
In this diagram middle C is coloured blue:



Piano Keyboard by Cyndaquazy

The note A that is nine white keys below middle C has a frequency of 440 *hz*. The 12th root of 2 (1.0594630943593...) is the ratio of the frequencies between half tones. So, the frequency of A# is 440 × 1.059... = 466.16376... *hz*, the frequency of B is 466.1637 × 1.0594 = 493.8833 *hz*, and so on. If you do this 12 times you end up with the A that is one octave higher and which has a frequency of 880 *hz*. By multiplying 12 times by the 12th root of two you have multiplied by $(2^{1/12})^{12}$. If you then multiply 880 by $2^{1/12}$ another 12 times you obtain the frequency of the note of the yellow key in the diagram.

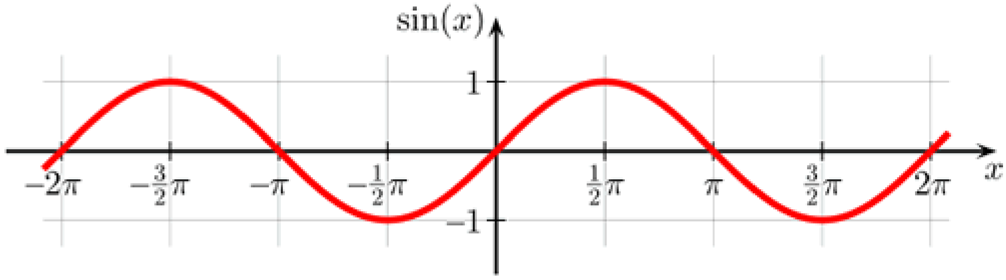
The pattern of a sound wave can be displayed using an oscilloscope:


Oscilloscope, photograph by Ilja

If a tuning fork

Tuning Fork, photograph by John Walker

is struck, it produces a pure note, which on an oscilloscope traces a sine curve:

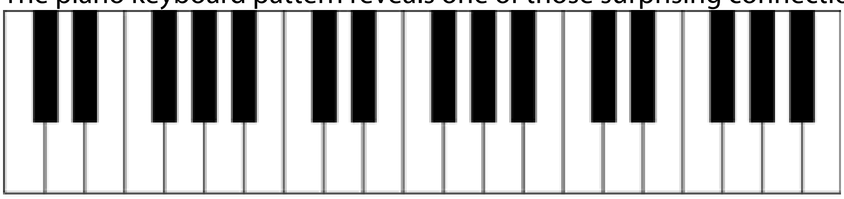


Sine Curve by Geek3

The tuning fork has two tines, which vibrate when the fork is struck. This vibration can be linked to the formation of a sine curve. As each tine vibrates, the distance of its end-point from the mid-point of the distance between the two tines in their starting position can be plotted against time. At first, the tine moves away from the mid-point until the displacement is at a maximum. And then, as the tines get closer together, the displacement decreases, until it reaches a minimum when the tines are closest together. This cycle is repeated many times per second, the exact number depending on the frequency of the tuning fork. A fork tuned to middle C and marked 256 hertz will vibrate 256 times per second, giving a continuous sequence of displacements and producing a sine curve.

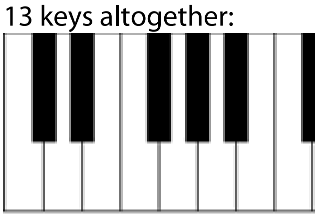
If the same note is played on a violin the curve will not fit a sine curve – it will be 'messy'. This is because when a violin string is stroked, secondary notes called harmonics are produced.

The piano keyboard pattern reveals one of those surprising connections that pervade mathematics.



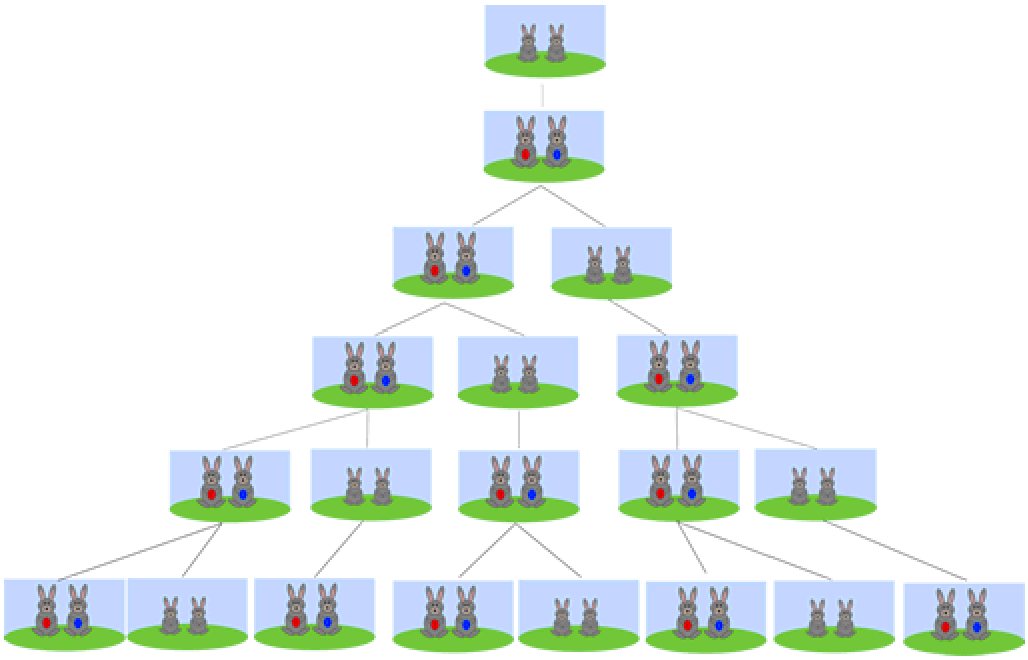
Piano keyboard by Lanttuloora

The black notes show the pattern 2, 3, 2, 3, 2, …
In any section of the keyboard showing an octave there are five white keys and eight black keys, making 13 keys altogether:



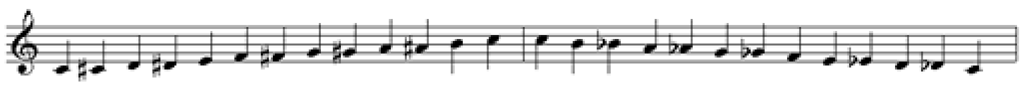
Piano keyboard by Lanttuloora

Where have you seen the sequence 2, 3, 5, 8, 13, … before? It's the Fibonacci sequence!



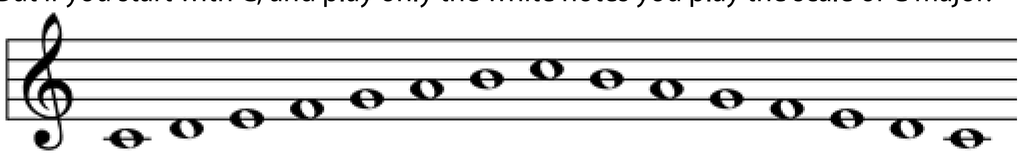
Fibonacci Rabbits by MichaelFrey & Sundance Raphael

When you play the notes on all 13 keys you play a chromatic scale:



Chromatic scale by Hyacinth

But if you start with C, and play only the white notes you play the scale of C major:



Diatonic scale by Benjamin D. Esham

If you do the same thing but play the second black key instead of the third white key, Eb (E-flat) instead of E, you play a minor scale.

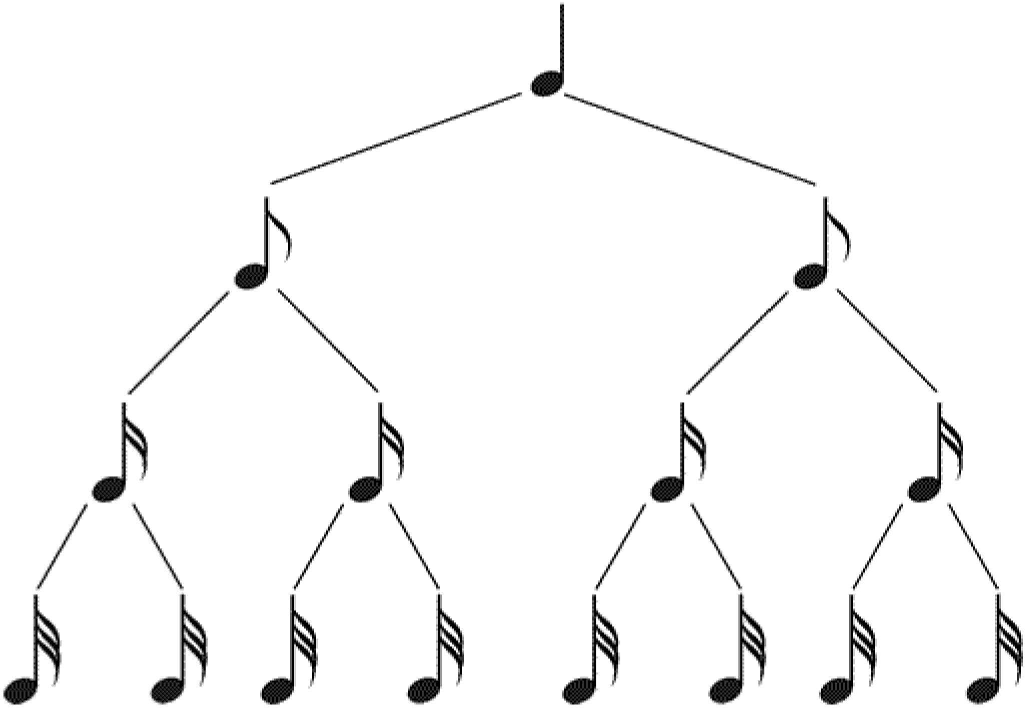
Some instruments are tuned to scales with numbers of notes other than 13. For example many folk songs use the pentatonic scale with only five notes. Interested students can investigate patterns in, and relationships between, the intervals between notes in different scales.

At Phil Tulga's Music through the curriculum site, students can play and hear intervals between notes on Virtual Panpipes, or on a Virtual Water Bottle Xylophone, on a Virtual Glockenspiel, or on Musical Fraction Tubes.

This JavaSound applet is a really great resource for students to use to explore the sounds of particular notes.

At the Exploratorium students can play listening memory games on the theme of the quality of sound.

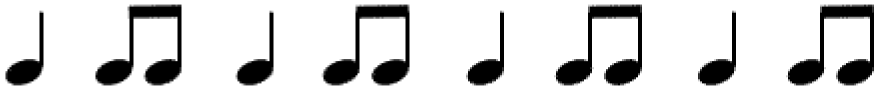
Musical **rhythm** helps students explore and develop some mathematical ideas. For example, beating half time, quarter time, and eighth time, can help students 'feel' fractions…



Solfege subdivision by Christophe Dang Ngoc Chan

…before exploring more complex patterns and their changes.

They can use objects, such as Cuisenaire rods, to represent specific beats.



The students lay out the rods to make a pattern – say, one red and two browns – and this pattern is repeated several times. Then they 'read' the pattern by clapping, or beating an instrument. They can be encouraged to create their own version of musical notation to record their patterns.

This is a simple, but very nice, interactive rhythm builder for students to explore.

A teacher describes how she uses rhythm to engage 10, 11 and 12-year old students in mathematical exploration.

By systematically allocating musical notes to represent numbers or digits students can listen to, rather than look at, number patterns and patterns within numbers – sometimes patterns that are overlooked when looking are discerned when listening!

And aesthetic properties of numbers may be revealed. For example on the website of the Mathematical Association of America (MAA) Ivars Peterson wrote:

> "The decimal digits of the mathematical constant pi, 3.14159265. . ., ring out an intricate melody that sounds vaguely medieval. Those of the constant *e*, 2.718281828. . ., progress at a relentless, suspenseful pace. Euler's prime-number-powered phi function bounces about with a semitropical

rhythm. Lorenz's butterfly meanders through a ragged soundscape. Pascal's triangle echoes with an eerie beat."

Professor Chris K. Caldwell of the department of Mathematics and Statistics at the University of Tennessee at Martin has developed a scheme for listening to sequences of primes, in which he represents one number by the musical note middle C, the next by C-sharp, the one after by D, and so on, for a total of 128 numbers. That correspondence is then used to 'play' primes. Because there are infinitely many primes, Caldwell's strategy is to divide each prime by a particular number, then play just the remainder – a novel application of modular arithmetic! For example, if the divisor, or modulus, is 7, then for the primes 2, 3, 5, 7, 11, 13, 17, 19, 23…, the numbers played are 2, 3, 5, 0, 4, 6, 3, 5, 2…. Students can explore these ideas at Chris Caldwell's Prime Number Listening Guide.

It's interesting that people agree that some particular musical chords are consonant (pleasing to hear) while other are dissonant (unpleasant). People agree that chords in which the frequencies of the two notes that are played together are in the ratios 1:2, 2:3, 3:4 and 4:5 all sound pleasing. Students could investigate for themselves the 'pleasantness' of chords created by notes with frequencies in various different ratios.

The jangly opening chord of The Beatles' hit A Hard Day's Night is one of the most recognisable chords in pop music.

The Beatles, photograph from the United States Library of Congress

A mathematician in Canada tried to find out how The Beatles produced that sound back in 1964, without using the synthesisers and studio electronics of today. Stanford University professor Keith Devlin said, "Sounds themselves are very mathematical things. And that was the key to unravelling this particular mystery."

Professor Jason Brown of the department of Mathematics and Statistics at Dalhousie University used sound-wave analysis based on the work of French scientist Joseph Fourier to deconstruct the opening chord. He found that it isn't created using only guitar and bass, as previously assumed. He concluded that that Beatles producer George Martin also played a five-note chord on the piano!

In this Open University podcast, Alan Graham, who has worked in Mathematics Education at the Open University since 1977, explores and entertainingly illustrates relationships between mathematics and music.

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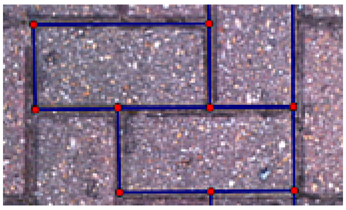


National Centre for Excellence in the Teaching of Mathematics

An idea for the classroom – using digital photos to explore transformations

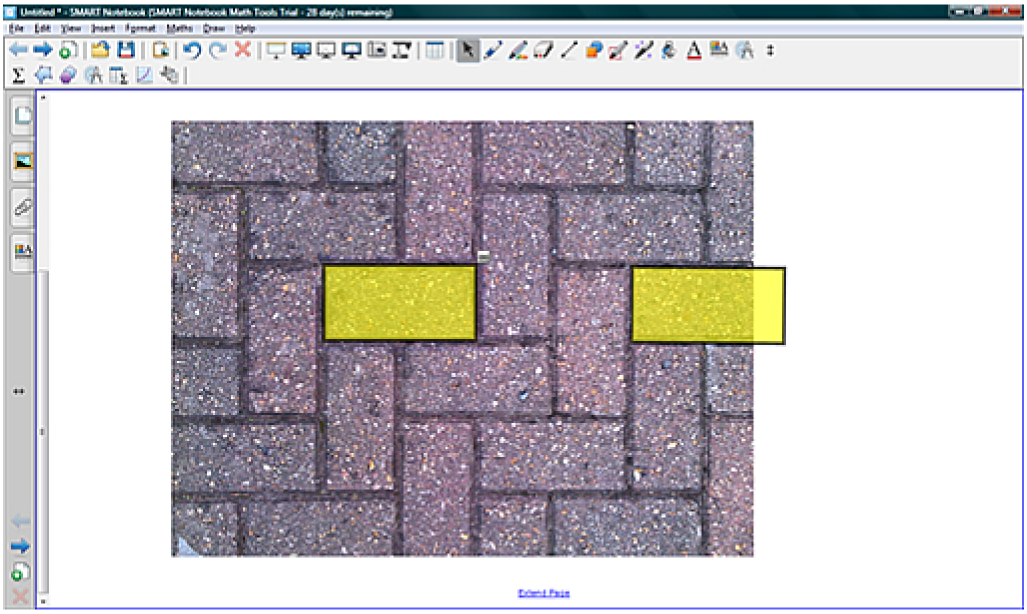
The ease with which we can all take digital photos offers a highly motivating opportunity to draw students' attention to the mathematics in their environment, and to provide some relevance and purpose to their learning.

By importing photographs into a range of different software, it is possible to highlight and transform by dragging or using the software's specific features in a way that develops students' understanding of mathematical transformations in an active way.

Begin by importing an appropriate photo by copying and pasting it into the software and 'locking' it to the background.

Within an interactive whiteboard package you can:

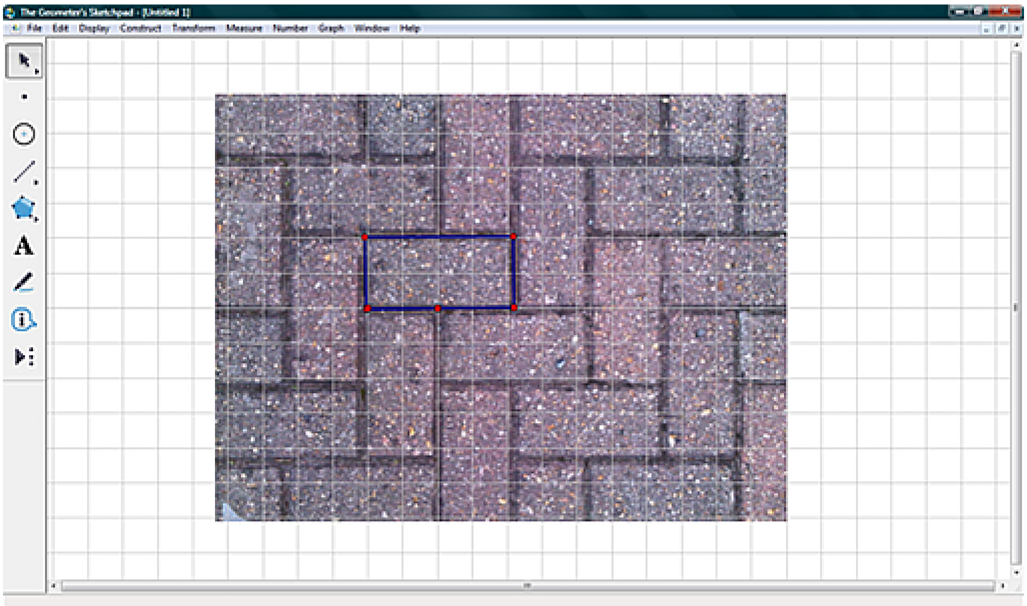
Highlight the unit of tessellation – in this case a single rectangle. Use a shape tool to recreate the rectangle over the top of the picture.



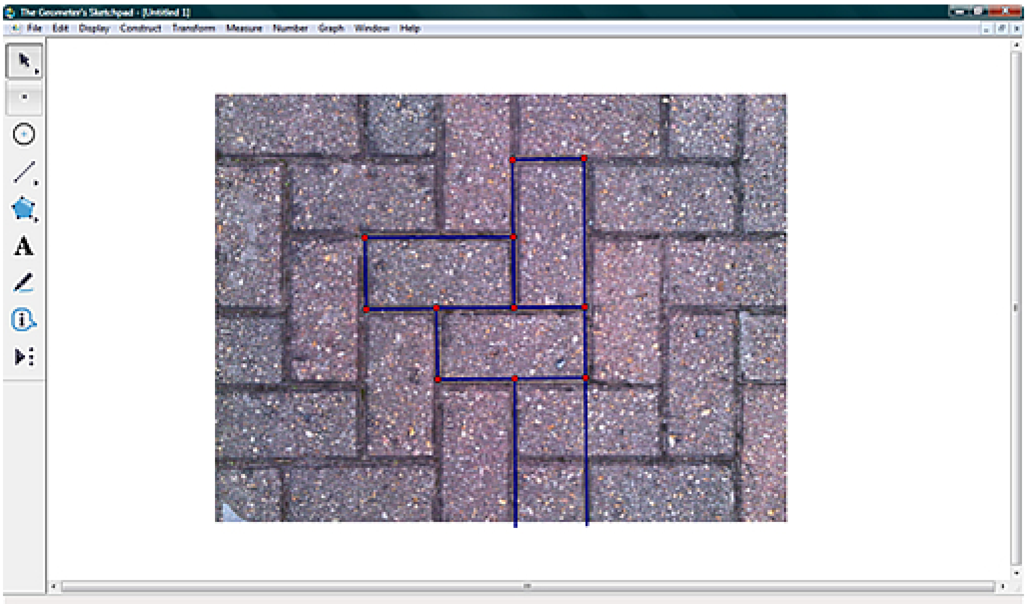
If you are focussing on translation, you can 'clone' the rectangle to create a pile and drag them individually to highlight the rectangles that are mathematical translations of the original rectangle.

If you are focussing on rotation, you can rotate the rectangle. However, it is useful to know that most Interactive Whiteboard Software does not let you specify the centre of rotation. This is where a different ICT tool might be better!

The same photograph within a dynamic geometry package would still allow you to identify a rectangular brick. But the software's features would also allow students to apply a grid underneath the picture to enable translations to be explored using a nominal scale.



Alternatively, both rotation and reflection can be explored using normal mathematical conventions. Students can be set the challenge to recreate the brick pattern using combinations of transformations.



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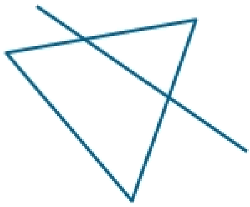
An idea for the classroom – regions created by reflections

This is a task in which students create their own examples, and that they could tackle in pairs on computers using dynamic geometry software.

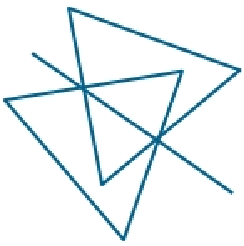
Introduce the task in the following way:

Using a large screen connected to one of the computers first draw a shape, such as an equilateral triangle, and a mirror line:

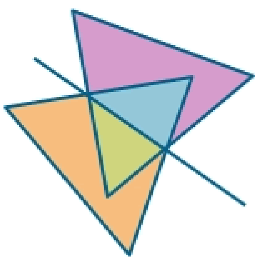


Challenge students to visualise the image of the triangle after reflection in the mirror line, allowing them plenty of time to establish images in their minds. Remind them that the whole diagram including the triangle, the mirror line and the image of the triangle will be composed of a number of regions. Ask: *How many regions will there be?*

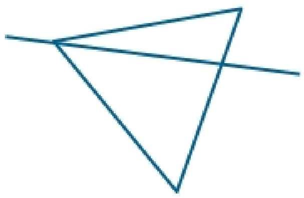
Students are likely to conjecture that there will be five, or four or three regions. To test their conjectures show the reflection:



They can see that total number of regions in the diagram consisting of the object, the mirror line and the image, is actually four:

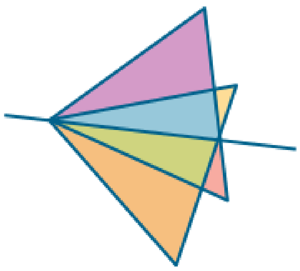


Now draw a diagram with the mirror line is in a different position in relation to the same shape. For example, like this:



Ask what will be the total number of regions in this case.

Students may conjecture correctly that in this example there will be six regions:



The students' task is to investigate the numbers of regions in their own diagrams created by reflections. Tell them to start with any regular polygon, perhaps a square or a regular pentagon, and a mirror line. Then draw the reflection of the polygon in the mirror line, and count the number of regions in the whole diagram (excluding the exterior region).

Prompt students:

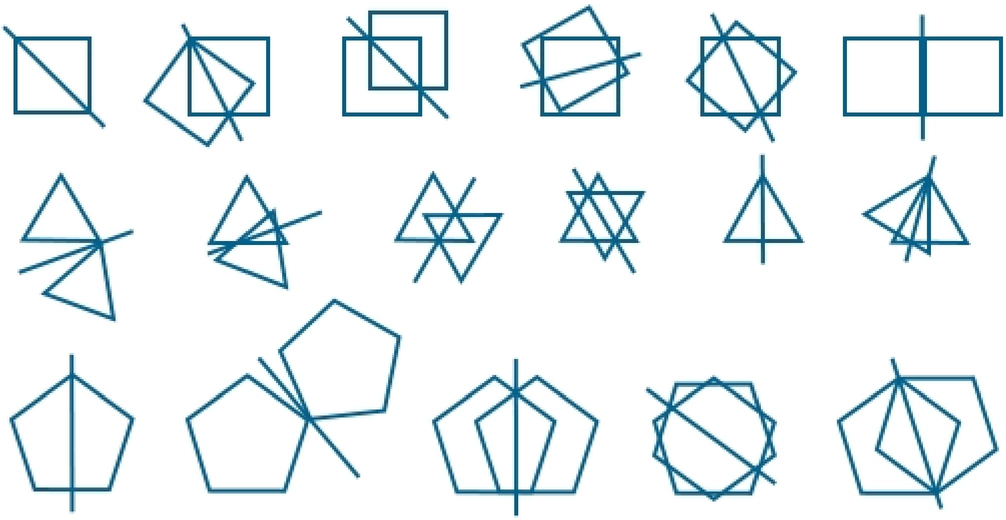
- *think about what you can change*
- *ask your own questions, and try to answer them.*

Encourage students to explore their own examples by changing aspects of the situations that they create. For example, they may change the position of the mirror line but keep the same polygon. Or they might change the number of sides of the polygon while retaining the regularity.

From time to time, invite particular students to link their computer to the large screen, show their diagrams to the whole class, and talk about what they are finding. These brief whole-class episodes should generate discussion and prompt students to ask their own questions, such as:

- *what are the maximum and minimum possible numbers of regions when the shape that is reflected is a square?*
- *what numbers of regions is it impossible to make?*
- *when you reflect a square, are there any numbers of regions that you can only make in one way?*
- *are the maximum and minimum possible numbers of regions the same for all regular polygons?*
- *is the maximum number of regions related to the number of sides of the polygon?*
- *how is the maximum number of regions related to the number of sides of the polygon?*

In one lesson, the diagrams that students created and printed out to support their findings included these:



Encourage students to generalise and make conjectures.

In one lesson students conjectured that:

- *when any regular polygon is reflected the minimum number of regions is always 2*
- *you cannot make three regions when you reflect a square*
- *when an equilateral triangle is reflected the number of regions is never more than 8*
- *you cannot make more than ten regions when you reflect a square*
- *you cannot make three regions with any regular polygon*
- *you cannot make an odd number of regions with any regular polygon*
- *whatever regular polygon is reflected the maximum number of regions is twice one more than the number of sides of the polygon.*

A few students were able to express this last generalisation algebraically:

- *the maximum number of regions is 2(*n + 1*), where* n *is the number of sides of the polygon that is reflected.*

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Secondary Magazine
Issue 71

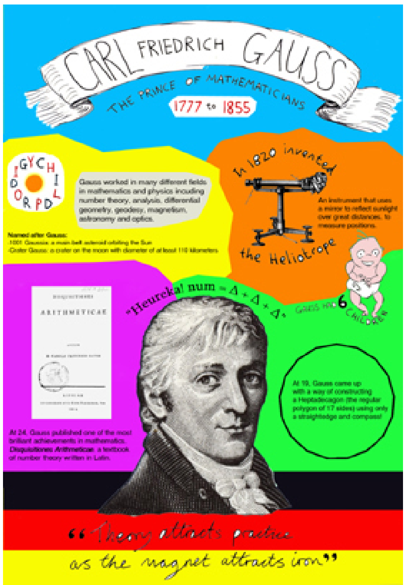
National Centre for Excellence in the Teaching of Mathematics

5 things to do this fortnight

- In memory of Benoît Mandelbrot who died on October 15, you could look at a short slideshow - In pictures: Mandelbrot's fractals, watch the video Mandelbrot Set Zoom, and explore the Mandelbrot Applet.

- Will one of your students be a winner in the Maths Careers website Poster Competition? Could your students design a poster as enchanting as this one?

  All the student has to do is pick a mathematician from history, do some ‘digging’ to find out about her or his life and work, and then design a beautiful A4 poster to convey what they find out.



- Would you like to help other teachers, and enhance your professional development, by joining a Mathematics in Education and Industry (MEI) Development Group? Why not go to the MEI Development Groups meeting on Saturday 27 November 2010, starting at noon at the London Mathematical Society?

- The British Society for Research into Learning Mathematics (BSRLM) is for people interested in research in mathematics education and provides a supportive environment for both new and experienced researchers to develop their ideas. BSRLM organises a day conference in each academic term. The next meeting is on 13 November 2010 at Newcastle University.

- On 16 November at 1pm in the Museum of London, Professor John Barrow will give a free public Gresham College lecture about Continued Fractions. How did Ramanujan make good use of their odd features to make striking discoveries?

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Maths Careers website Poster Competition image courtesy of Maths Careers

Subject Leadership Diary

Things never seem to go exactly to plan – but good planning helps things run as smoothly as possible, and minimises crisis management. Good communication helps all the time, for example when I'm receiving information about changes to personnel, or just letting people know when something will reach them.

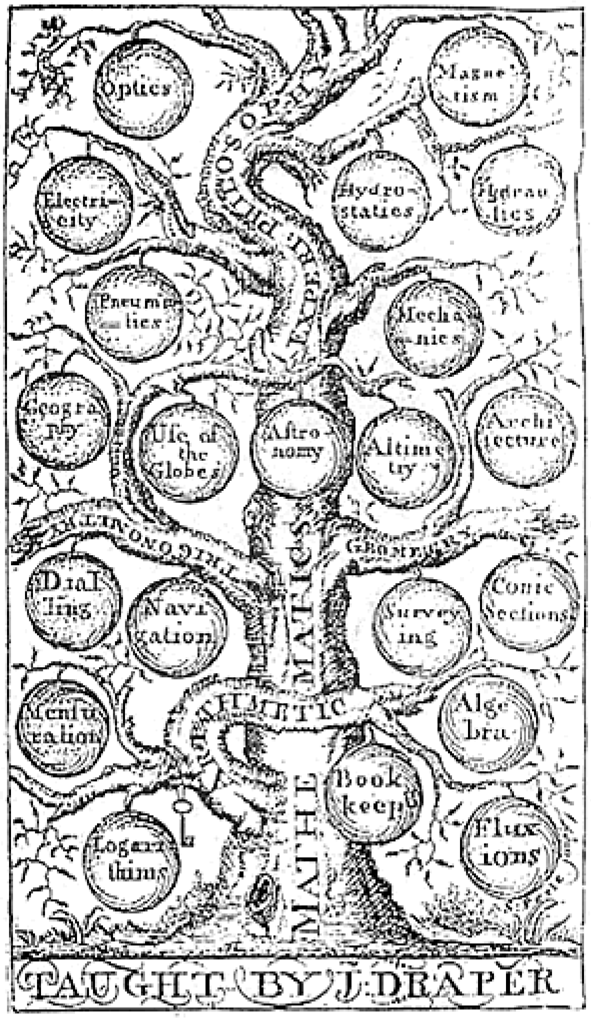
In the middle of the month I did a mathematics master-class for more than 50 Y9 students in Buckinghamshire. I was told in advance who would meet me and at what time, and that all worked a treat. The students, from many different schools in the area, were responsive and worked well together in threes. I like them to work with students from different schools since this helps develop their communication skills – and students from different schools often bring different skills to the workshop. It is an opportunity for students to develop, alongside other skills, Personal, learning and thinking skills (PLTS) that are essential for good teamwork. My initial feeling about PLTS was one of scepticism, but as time goes on I'm seeing the benefit of specifying these skills. I thought it was a 'given' that students would develop such skills naturally, but becoming more aware of exactly what they are helps me focus that bit more on making sure that they are developed. It is always a delight to see young people discussing ideas and helping each other mathematically – that 'buzz' helps to keep me young at heart! (My brain still thinks I'm in my very early 20s, but sometimes my body does not respond that way – doing an Indiana Jones roll on the grass a few years ago as I was setting off with my daughters to see him in a film, resulted in a cracked rib!)

We had an Open Evening recently. The school was open to anyone concerned: students, both present and prospective, and their parents or guardians, governors, neighbours and partners. This involved much planning, which built on the success of a similar event last year. We had the mathematics prefects helping with some of the rooms, where they supervised mathematical games and puzzles, or helped explain how our system of electronic homework works together with other methods. Of course there was plenty of display up on the (working) walls - get some ideas about what can be done to make the most of your walls! This was a long day, and it took time after it finished at 8pm to wind down at home – I've cut out wine during the week as I find I get more done in less time by replacing it with cups of tea!

I spent some time working with PGCE students – our country's future. It was a sheer delight seeing the enthusiasm of this pedagogical partnership. The PGCE course is a rigorous year of practice and theory designed to give them experience of what the career is all about; observing the students working and discussing together raised my (non-alcoholic) spirits tremendously and knocked another few years off my psyche.

I also worked with some existing teachers looking at enhancing an already good department. We worked through some different types of activities seeing how these could replace what the teachers normally did in some lessons. Since everyone has a limited amount of time to teach mathematics we need to look at what can be done to replace existing material with valuable learning activities – not add in new tasks on top of what is already being done. In my own school, we have made more time by eliminating a lot of the 'testing' to which we used to subject students every half term. Not only have we thereby increased our mathematics learning time, we have improved our GCSE mathematics results by seven per cent over the last two years.

I found time this last fortnight to see Ross Noble live – sides still aching, though very little there I could repeat in the classroom! I also spent a Saturday at the British Sundial Society's Newbury Conference. It is amazing how much mathematics can be taught through a sundial. For more details see the sundial case study in the Bowland maths DVD. Of course 'dialing' was once part of the national curriculum in mathematics - note the dialing fruit on the trigonometry branch of this tree showing the mathematics taught by John Draper in 1772.



Carpe diem!