Summer 2015 Issue 32

Science in School

The European journal for science teachers

In this issue:

Ebola in numbers

Also:

The magic sand mystery

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EIROforum

Editorial

Welcome to the 32nd issue of *Science in School*

I am delighted to report that as we go to press, EIROforum – our publisher – has just agreed to continue funding *Science in School* until the end of 2020.

This financial commitment represents an even more important commitment from EIROforum: to the young people of Europe and to you, their teachers. EIROforum is a partnership of eight world-class scientific research organisations, and like all other research organisations, they need inspired, committed and knowledgeable scientists now and in the future. For that reason, *Science in School* makes perfect sense to EIROforum, as it invests in Europe's teachers, in Europe's young people and in the future of European science.

With this in mind, Laura, Isabelle and I are looking forward to bringing you many more inspiring teaching ideas, cutting-edge science features, interviews with scientists and teachers, and much more over the next few years. So, if you haven't already thought about submitting an article to *Science in School* and sharing your ideas with colleagues worldwide, perhaps now is the time to do it.

While we look forward to the future, we also have an archive full of useful articles that you can use right now. This year is the International Year of Light and Light-Based Technologies and we have made a collection of more than 40 light-related articles on the *Science in School* website, many of them translated into other European languages. You can find them at http://www.scienceinschool.org/IYL2015. The collection includes teaching activities, science articles and profiles of scientists, and covers a broad range of interesting topics across the sciences, including space telescopes, fusion energy, art conservation and how fish survive in the Arctic. Over the course of this year, we will add even more articles and translate existing articles into other European languages, so do keep visiting our website.

Speaking of which, we continue to welcome feedback on our new website. If you'd like to share your views with us, please complete the questionnaire at https://www.surveymonkey.com/s/7WBM8F6

In the meantime, we hope that this issue sheds some light on new and interesting scientific topics. For example, did you know that some cancers are infectious (page 6)? And do you know what exactly you're doing when you dye your hair (page 10)? We also answer the question of how mathematicians can help to predict the spread of Ebola (page 14). If you'd like something more hands-on, why not get your students to investigate the chemistry of magic sand (page 37) or the physics of chocolate eggs (page 41)? Experiments with blood can be dangerous, so you might like our chemical simulation (page 33). Or – a topic close to our hearts – you could help your students to write creatively about science (page 27).

We'd also like to take a special moment to celebrate other news as we go to press: the reawakening of the Philae lander on comet 67P. We heard the news through the tweets from Philae – or, more accurately, from the scientist tasked with tweeting for Philae, our former intern Karin. You can read her story on page 20.

Eleanor Hayes
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www.scienceinschool.org

About *Science in School*

The European journal for science teachers

Science in School is the **only** teaching journal to cover all sciences and target the whole of Europe and beyond. Contents include cutting-edge science, teaching materials and much more.

Brought to you by Europe's top scientific research institutes

Science in School is published and funded by EIROforum (www.eiroforum.org), a partnership between eight of Europe's largest intergovernmental scientific research organisations.

Inspiring science teachers worldwide

The *Science in School* website offers articles in 30+ languages and is read worldwide. The free quarterly journal is printed in English and distributed across Europe.

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Image courtesy of Nicola Graf

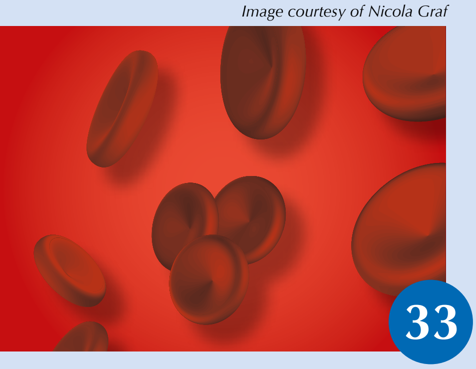


Image courtesy of William Cho; image source: Wikimedia Commons

Image courtesy of ELLS

Getting hands-on experience making crystals

Pixels, pictures and powering up

CERN

CERN's heart beats again

The accelerator at the heart of CERN, the Large Hadron Collider (LHC) in Geneva, Switzerland, is back in operation after a two-year tune-up. In this time, hundreds of engineers and technicians have changed the LHC infrastructure to create higher-energy particle collisions.

The LHC begins its second season with almost double its previous operational energy. Beams inside the 27 kilometre ring of the LHC will also produce more collisions because of an increase in proton bunching and a reduction in the time between bunches.

The new set-up will test the standard model of particle physics and will begin to explore unknown territory surrounding the Brout–Englert–Higgs mechanism, dark matter, antimatter and quark–gluon plasma.

Don't forget the CERN education website hosts many more activities that you can use with your students: http://education.web.cern.ch/education/

Based in Geneva, Switzerland, CERN is the world's largest particle physics laboratory. To learn more, see: www.cern.ch.

For a list of CERN-related articles in *Science in School*, see: www.scienceinschool.org/cern

Image courtesy of CERN

LHC operators celebrating the LHC restart

EMBL

Shining light onto the fabric of life

EMBL's European Learning Laboratory for the Life Sciences (ELLS) inaugurated its 2015 series of workshops for European teachers with a LearningLAB on protein structure and X-ray crystallography.

The programme was a mix of hands-on modules and scientific presentations on structural biology. The visiting teachers learned how to grow crystals from lysozyme – a protein found in egg white – and how to replicate this experiment in the classroom using an experimental kit. First-hand insights into structural biology research were provided by scientists from the 'FluPharm project', who discussed the path to their recent discovery of the 3D structure of the flu virus polymerase and the practical applications that are linked to this major scientific achievement. The workshop also included a visit to the protein-expression and high-throughput crystallisation facilities at EMBL Grenoble, and the X-ray beamlines operated by EMBL at the European Synchrotron Radiation Facility (ESRF).

More LearningLABs will be organised in 2015, starting with one in Greece on DNA and genetic technology and how to experiment with both topics in the classroom, organised in collaboration with the National Center for Scientific Research 'Demokritos' and Vasiliki Kioupi, who was portrayed in issue 30.

To learn more about ELLS activities, visit their web portal at: http://emblog.embl.de/ells

To read the profile of Vasiliki Kioupi see: Kling I (2014) Experienced and experiencing teacher, *Science in School*, **30**, 49-52 www.scienceinschool.org/2014/issue30/VKioupi

EMBL is Europe's leading laboratory for basic research in molecular biology, with its headquarters in Heidelberg, Germany. To learn more, see: www.embl.org

For a list of EMBL-related articles in *Science in School*, see: www.scienceinschool.org/embl

Science in School is published by EIROforum, a collaboration between eight of Europe's largest inter-governmental scientific research organisations (EIROs). This article reviews some of the latest news from EIROs.

ESA

Pixel your space

A new classroom resource from ESA links art, science and technology. 'Pixel your space' is a teacher's guide from the 'Teach with Rosetta' programme. The resource, for children aged 8 to 11, explores what pixels are and how their number affects image quality.

Digital imaging is now a cornerstone in many research disciplines. In space exploration, telescopes and probes carry onboard cameras with huge number of pixels – 1.5 billion in Gaia, the largest digital camera ever to be flown in space, which was launched in 2013 to screen the Milky Way galaxy with unprecedented detail. Your students can now investigate the basic imaging principle behind this camera.

A variety of hands-on activities, mostly manual and a few computer-based, are included in the resource. Pupils are encouraged to create their own pixel artwork, learning about techniques used in Aboriginal art and by the urban artist Invader.

Don't miss the chance to teach pixels and image processing. Download the materials at: www.esa.int/Education/Teach_with_Rosetta/Rosetta_lessons_for_primary_school_level

ESA is Europe's gateway to space, with its headquarters in Paris, France. For more information, see: www.esa.int

For a list of ESA-related articles in *Science in School*, see: www.scienceinschool.org/esa

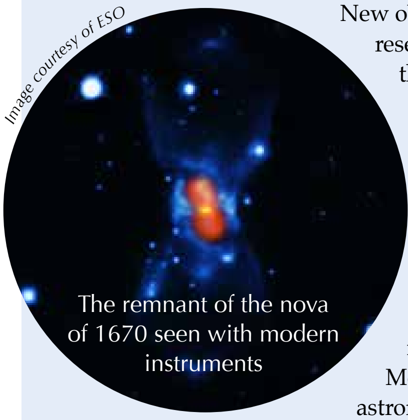
A 'Space Invader' on the International Space Station

Image courtesy of ESA/NASA

ESO

A mysterious explosion in the sky, resolved

Image courtesy of ESO



The remnant of the nova of 1670 seen with modern instruments

New observations by researchers from ESO and the Max Planck Institute for Radio Astronomy in Bonn, Germany, have finally identified a star first observed with the naked eye from Earth in the 17th century.

The phenomenon has represented an intriguing mystery for centuries. More than 300 years ago, astronomers described in detail the oddness of a new celestial body that disappeared and reappeared twice before finally vanishing. In the 20th century, astronomers first thought the phenomenon was the death of a star in an explosion, but subsequent studies rejected this possibility.

Probing the area with sub-millimetre and radio wavelength telescopes located in Chile, Hawaii and Germany, scientists have now uncovered what happened – a spectacular collision of two stars. This rare stellar explosion, called a red transient, spews material from the stellar interiors into space, eventually leaving behind only a faint remnant embedded in a cool environment, rich in molecules and dust. Exactly the profile of Nova Vul 1670.

You can read the original research paper at:

Kamiński T, Menten KM, Tylenda R et al (2015) Nuclear ashes and outflow in the eruptive star Nova Vul 1670. *Nature* **520**: 322–324. doi: 10.1038/nature14257

Download the article free of charge on the *Science in School* website (www.scienceinschool.org/2015/32/eironews), or subscribe to *Nature* today: www.nature.com/subscribe

ESO is by far the world's most productive ground-based astronomical observatory, with its headquarters in Garching near Munich, Germany, and its telescopes in Chile. ESO is the European partner in the ALMA project, which is a collaboration between Europe, North America and East Asia, in co-operation with the Republic of Chile. For more information, see: www.eso.org

For a list of ESO-related articles in *Science in School*, see: www.scienceinschool.org/eso

Image in the public domain; image source Wikimedia Commons

ESRF

Journey to the centre of the Moon

Using samples from Earth, researchers from the Institute of Mineralogy, Materials Physics and Cosmochemistry in Paris, France, have recently gained new insight into the seismic behaviour, inner structure and composition of the Moon. Scientists applied the same pressure (19 Gpa) and temperature (1150 K) present inside of the Moon to a piece of iron. This is the main component of the core of telluric bodies such as Earth, Mars and the Moon. In this way, scientists were able to describe the speed of seismic waves across the metal for the first time, as well as its structure and density, under lunar conditions.

The information provides a reference model to help understand the seismic data obtained on the Moon during the Apollo space programme. It will also be used to interpret the data that will be gathered on Mars during the NASA Discovery Program mission 'Insight' to be launched in March 2016.

You can read the original research paper at:

Antonangeli D, Morard G, Schmerr NC et al (2015) Toward a mineral physics reference model for the Moon's core. *Proceedings of the National Academy of Sciences USA* **112**: 3916–3919. doi: 10.1073/pnas.1417490112

Situated in Grenoble, France, ESRF operates the most powerful synchrotron radiation source in Europe. To learn more, see: www.esrf.eu

For a list of ESRF-related articles in *Science in School*, see: www.scienceinschool.org/esrf

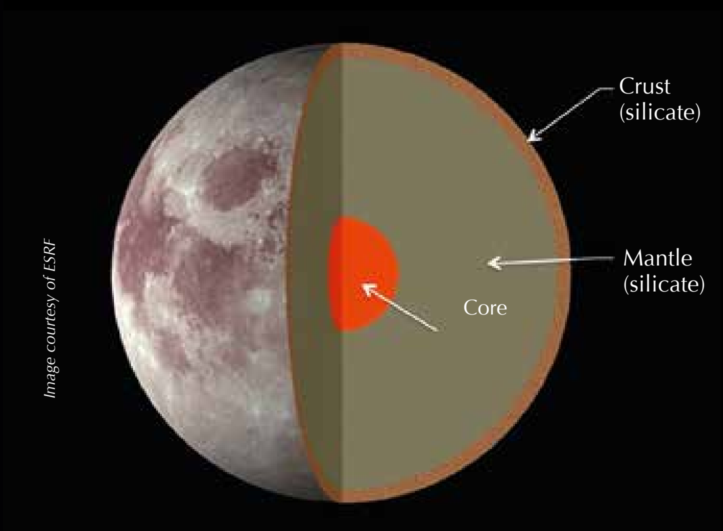


Image courtesy of ESRF

EUROfusion

Boosting the education of the next generation of fusion engineers, and you, at home

EUROfusion has profoundly enhanced its training and education programme for specialists and the interested public. Research on how to harvest the energy source of the Sun is a long-term project. Therefore it is vital to the programme's progress that knowledge is transferred from one generation of researchers and engineers to the next.

Each year EUROfusion offers grants to approximately 30 postdoctoral researchers, engineers and technicians. The research topics are carefully designed to benefit both the successful applicants and the European fusion programme.

For more information, see: www.euro-fusion.org/?p=7413

But there is more to explore from the comfort of your home! In April one of the signatories to the EUROfusion agreement, EPFL in Switzerland, released its first massive open online course (MOOC) on plasma physics and its applications, including fusion energy, astrophysical and space plasmas, and societal and industrial applications. For more information and to sign up yourself, visit: http://tinyurl.com/k4k8hjm

The European Consortium for the Development of Fusion Energy (EUROfusion) investigates the potential of fusion energy as a safe, clean and virtually limitless energy source for future generations. To learn more, see: www.eurofusion.org

For a list of EUROfusion articles in *Science in School*, see: www.scienceinschool.org/eurofusion

European XFEL

Large Pixel Detector: getting closer to watching chemical reactions

The Femtosecond X-Ray Experiments (FXE) instrument at the European XFEL will act as a microscope that can watch ultrafast processes such as the formation or break-up of chemical bonds at the molecular and atomic levels. Snapshots of such fast processes demand a high-tech detector. Such a detector was developed at the Rutherford Appleton Laboratory in Oxfordshire, UK, and has now been successfully tested for the first time in various X-ray sources (synchrotron and free-electron lasers) around the world.

First, the detector has to deliver razor-sharp images while keeping up with the high repetition rate of the European XFEL. The detector must be able to capture a few thousand pictures per second and be able to yield precise results in an extremely wide range of intensities. The tests showed the detector, called the Large Pixel Detector (LPD), could even measure a single photon, a particle of light.

The European X-ray Free Electron Layer (European XFEL) is a research facility currently under construction in the Hamburg area in Germany. Its extremely intense X-ray flashes will be used by researchers from all over the world. To learn more, see: www.xfel.eu

For a list of European XFEL-related articles in *Science in School*, see: www.scienceinschool.org/xfel

Image courtesy of XFEL

ILL

Neutrons fight against dental erosion

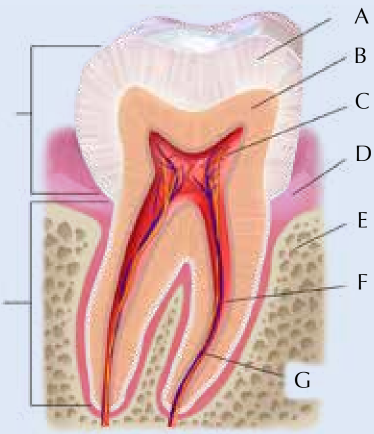


Image courtesy of Blausen gallery 2014; image source: Wikipedia

Section of a human molar tooth and its two parts (the root (I), and the crown (J)) showing the enamel (A) the dentin (B), the pulp (C), the gum (D), the bone (E), the root canal (F), the nerve and blood vessel (G).

A new study carried out at ILL has determined the most accurate microstructure ever obtained of human tooth enamel. The research aims to provide greater insight into the chemistry behind tooth enamel demineralisation caused by our bad eating habits.

The most common treatment for dental erosion is fluoride remineralisation therapy. However, excessive use of fluoride can result in lesions that attack the enamel, so alternative treatments continue to be investigated. The neutron techniques used at ILL represent a tool of choice for studying biological materials containing hydrogen such as calcium hydroxyapatite, which is the main constituent of human tooth enamel.

The research team was able to identify 'for the first time' the location of critical hydrogen atoms within the enamel, work which will be extremely useful for their future analysis of Biodentine, a new material that could be used as a cement to encourage dental regrowth.

ILL is an international research centre at the leading edge of neutron science and technology, based in Grenoble, France. To learn more, see: www.ill.eu

For a list of ILL-related articles in *Science in School*, see: www.scienceinschool.org/ill

EIROforum combines the resources, facilities and expertise of its member organisations to support European science in reaching its full potential. To learn more, see: www.eiroforum.org

For a list of EIROforum-related articles in *Science in School*, see: www.scienceinschool.org/eiroforum

To browse the other EIRO news articles, see: www.scienceinschool.org/eironews

Infectious cancers

Is it possible to pass cancer from one individual to another? For some animals, it is – and, sadly, a unique Tasmanian species is facing possible extinction as a result.

Image courtesy of Arthur Caranta; image source: Flickr

Tasmanian devils and their aggressive behaviour have inspired a cartoon character

By Susan Watt

You could say that sympathy for the devil is what led Dr Elizabeth Murchison to her field of research – not for Satan himself, but for the fierce little marsupials known as Tasmanian devils.

This species, unique to Tasmania, is under threat from a form of cancer that, bizarrely, is spread by direct transmission from one individual to another: infectious cancer, in other words. Called devil facial tumour disease (DFTD), it causes large tumours on the face and inside the mouth of affected animals and has rapidly spread through the Tasmanian devil population. It appears to be both untreatable and invariably fatal.

Biting into evolution

Now based at the University of Cambridge in the UK, Dr Murchison's research is focused on the genetic aspects of DFTD and other transmissible cancers. These strange diseases seem at first sight to completely contradict our understanding of the nature of cancer. Normally, cancers are caused by cells in the body that, due to mutations, have gained the ability to divide and grow uncontrollably. But in transmissible cancers, the

Image in the public domain; image source: Wikimedia Commons

Location of Tasmania (dark orange) in Australia tumours are not made up of cells from the individual with the disease but instead are derived from the individual in which the first case of the disease occurred: the original tumour, which has somehow gained the ability to jump from host to host. The disease is spread by cells descended from the original tumour, which attach themselves to a new host and then produce more tumour cells that can again transfer to another individual.

In DFTD, one particular aspect of the Tasmanian devil's lifestyle makes such transfer easier: their tendency to bite other animals, including their nearest and dearest – not just during fighting or when scrapping over food, but also during mating and social encounters. Because their biting habit is now exposing Tasmanian devils to a fatal illness, the disease may be providing a powerful evolutionary pressure against biting and favouring less aggressive individuals. However, even if the devils were to evolve to become more sweet-natured, this would not be certain to reduce the impact of the disease. In this case, says Dr Murchison, the tumour would also change in ways that might help it to spread by other means. "The two things are co-evolving at the same time; if the devil were to change, then the tumour would also change," she says.

The ultimate cancers

"Cancers are the product of natural selection operating at the level of a single cell within an organism," she explains. "The only difference with transmissible cancers is that they have managed to escape from their hosts." Normal cancers are an evolutionary dead end, because they die with their hosts. "Transmissible cancers are the ultimate cancers, because they have evolved to survive beyond their hosts, and to continue the evolutionary process beyond the death of the host

REVIEW

- **Biology**
- **Evolution**
- **Ages 15–17**

This article is the first of two on the topic of transmissible cancers in the animal kingdom. Despite their rarity, or perhaps because of it, transmissible tumours offer a unique context to discuss the nature of cancer and the selective scrutiny of evolution. Discussion can be encouraged through a bibliographic review, a scientific inquiry or a project for communicating science (e.g. through posters or a slideshow). Key points could be the differences between normal and transmissible cancers, the 'blind' pressure for survival in the natural world, and how parallel evolution occurs. Evolution acts not only at the population level but also at the molecular and cellular levels.

This article could also encourage science teachers to enhance their professional development in the areas of genetics, cell biology and evolution.

Luis M. Aires, Antonio Gedeao Secondary School, Portugal

Tasmanian devil facial tumour disease

Image courtesy of Elizabeth Murchison

Healthy Tasmanian devil in its natural habitat

Image courtesy of JJ Harrison; image source: Wikimedia Commons

Biology

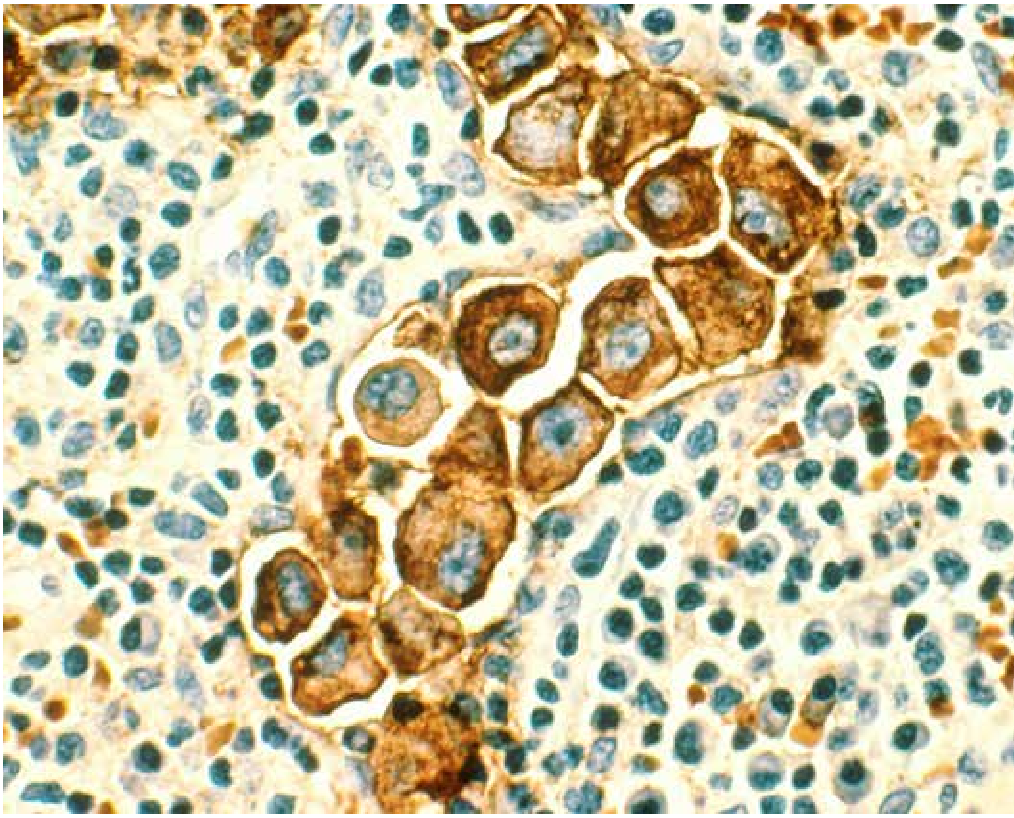
body in which they first evolved," she explains.

The ability of even normal cancers to evolve is shown, for example, in the way cancers develop resistance to chemotherapy. "If you throw something at a population of cells that kills 99 per cent of them but one per cent survives, then that one per cent is going to grow back," says Dr Murchison. "By treating the patient, we are putting selective pressures on their cancer."

Even though cancers are evolving all the time, we know of only one other cancer in addition to DFTD that has evolved to become infectious.

Canine transmissible venereal tumour (CTVT) is a disease that affects dogs in many countries of the world. Happily, CTVT is much more treatable than DFTD and is not usually fatal. The disease has been known for some 150 years but is thought to have evolved far earlier. "We think this cancer originated around 11 000 years ago, close to the time when dogs were first being domesticated by humans," says Dr Murchison. So the tumours that are infecting dogs today are from the same cell lineage as this original ancient tumour – making them the oldest known living mammalian-derived cells on Earth.

Image in the public domain; image source: Dr. Lance Liotta Laboratory



Breast cancer in the lymph nodes

Evading the immune system

Is it just luck that so few transmissible cancers seem to exist, or are there any fundamental reasons why this change to becoming infectious is so rare in cancers? After all, cancer cells can grow in a laboratory – so why do so few make the leap to being able to grow in a new body?

One obvious difference is that infectious cancer tumours have to find a way to avoid rejection by their new host's immune system, given that they are derived from a different individual. Recent research has revealed that in DFTD, the tumours stop producing a molecule that indicates to the immune system which cells are foreign invaders. Without this molecule, the DFTD cancer is able to get into an animal's body and escape detection by its immune system.

But, says Dr Murchison, many researchers now believe that normal cancers are also able to hide from the immune system to some degree. "The immune system has mechanisms to detect cancer cells," she says. "Possibly the immune system is busy protecting us from thousands of incipient cancers that occur in our body all the time, so the tumours we do see have already acquired some immune evasion adaptation."

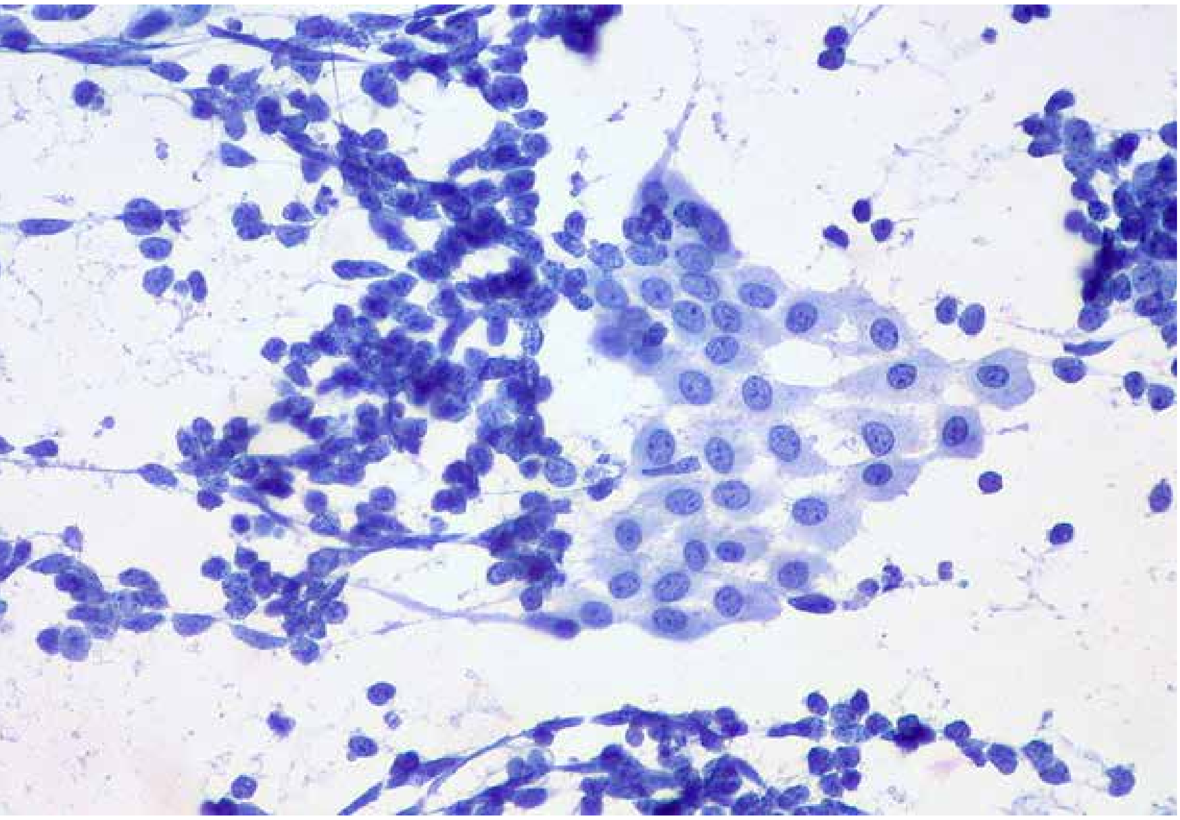
Chillingly, there are even a few cases in humans of cancers being transferred from one person to another. Most of these have occurred in transplant patients, where an undiagnosed tumour in a donated organ has led to cancer in the recipient. But there has also been a single case of a surgeon 'catching' cancer from a patient after he injured himself while operating[w1].

So could we open our newspapers one day and read reports of newly discovered transmissible cancers in humans? Probably not, Dr Murchison says. "Transmissible cancer is unlikely to happen in humans, because it's so rare in nature – we have only seen two examples." But if it ever were to happen, Dr Murchison's work will have helped us to know what to expect, and perhaps to get started on developing useful therapies.

In the next issue of *Science in School*, Dr Murchison will explain some of the latest findings on the genetics of transmissible cancers.

Biology

Image courtesy of Ed Uthman; image source: Flickr



Small cell lung carcinoma cells (plus other benign cells)

Web reference

w1 – Read this nice article about potential transmission of cancer between humans: http://www.abc.net.au/science/articles/2012/10/23/3616950.htm

Resources

For more about devil facial tumour disease (DFTD) and efforts to save the Tasmanian devil, see: www.yourgenome.org/interactives/saving-the-devil

For a short lecture by Elizabeth Murchison explaining her work to a general audience, see: www.ted.com/talks/elizabeth_murchison

For an article on transmissible cancers, see:

Giles C (2010) Sympathy for the devil. *Wellcome News* **62**: 8–9

This issue of *Wellcome News* can be downloaded from the Wellcome Trust website: http://bit.ly/1Fpxe0b

Susan Watt is a freelance science writer and editor. She studied natural sciences at the University of Cambridge, UK, and has worked for several UK publishers and research councils. Her special interests are in psychology and science education.

Image courtesy of jaymantri.com; image source: pexels.com

Colour to dye for

The basic chemistry of hair dyes has changed little over the past century, but what do we know about the risks of colouring our hair, and why do we do it?

Image courtesy of Melanie M; image source: Wikimedia Commons

Pink hair

By Rebecca Guenard

Every two months Barclay Cunningham goes through a process that begins with taking an antihistamine tablet. After a few hours, she smears a thick layer of antihistamine cream across her forehead, around her ears and over her neck. Finally, she shields the area with ripped-up plastic carrier bags.

All this so she can dye her hair.

It didn't start out this way. Cunningham coloured her hair for a decade without any problems. Then, one day, she noticed that the skin on her ears was inflamed after she'd dyed her hair. She fashioned plastic bag earmuffs and carried on colouring. But the allergic reaction persisted, so her precautions became more elaborate. Now if she dyes her hair without these measures, she gets an itchy, blistery, pus-filled rash that lasts for weeks.

Image courtesy of Mayhem Chaos; image source Flickr

Multi-coloured hair

Suffering for the sake of tinted tresses is not a modern-day phenomenon. Humans have dyed for thousands of years (see box p 13). But the chemical history of modern hair dyes reveals that, while they were once part of an innovative industry, progress has stalled, and today they rely on 125-year-old chemistry.

The magic of mixing

Understanding the dyes used on hair is not as simple as understanding the colour wheel. We learn in art class that any colour can be obtained by mixing the three primary colours of red, yellow and blue. If you want orange, you mix yellow and red; if you want purple, you combine red and blue; and if you want brown, you mix all three.

Beauticians are taught the same thing when it comes to hair – that brown dye is a combination of three different dyes. "That's just fictitious information," says Tom Despenza. Tom has years of experience working in research and development at Clairol. He is now retired and owns his own hair colour company.

Instead, says Tom, "brown hair colour is made up of two chemicals." Both chemicals are colourless but they produce brown through a chemical reaction that occurs when they're combined.

Hairdressers are not applying pigments (at least not in the case of permanent hair dye), they are applying a mixture of chemicals to initiate dye formation. The individual molecules have to be linked together before they emit colour, so hair dyes have to sit on the head for 30 minutes to allow this reaction to occur.

A colourful discovery

In the mid-1800s, English chemist William Henry Perkin serendipitously synthesised the first non-natural dye: starting with coal tar, he was hoping to produce the malaria drug quinine but instead created mauve. His discovery revolutionised the textile industry and launched the petrochemical industry. Natural dyes just didn't have the staying power and vivid colours of the dye that Perkin created. Never before had such a steadfast dye been found.

Soon after, August Hofmann (Perkin's chemistry professor) noticed

REVIEW

- **Chemistry**
- **Biology**
- **Art**
- **Ages 14–19**

Many scientists are normally seduced by chemistry's explosions or colour changes. The article shows just how useful this interest can be and why it needs to be encouraged..

The article tells the story of the development of dye – highlighting Perkins' discovery of mauve and showing how this accidental discovery has allowed the formation of many consumer products.

This quirky tale and history of dyes and colour chemistry could lead to a study of the chemical synthesis of organic dyes and of the effect of using them. A challenge would be to see if school chemists can synthesise dyes that could be used in the art department. Teachers could also use the article to link in with relevant topics in history (history of medicines/cosmetics) and art (methods of textile and fibre dyeing).

Graham Armstrong, Kinross High School, Scotland

Image courtesy of Kevin Dooley; image source: Wikimedia Commons

Image courtesy of Juantiagues; image source: Flickr

that a dye he had derived from coal tar formed a colour when exposed to air. The molecule responsible was *para*-phenylenediamine, or PPD, the foundation of most permanent hair dyes today.

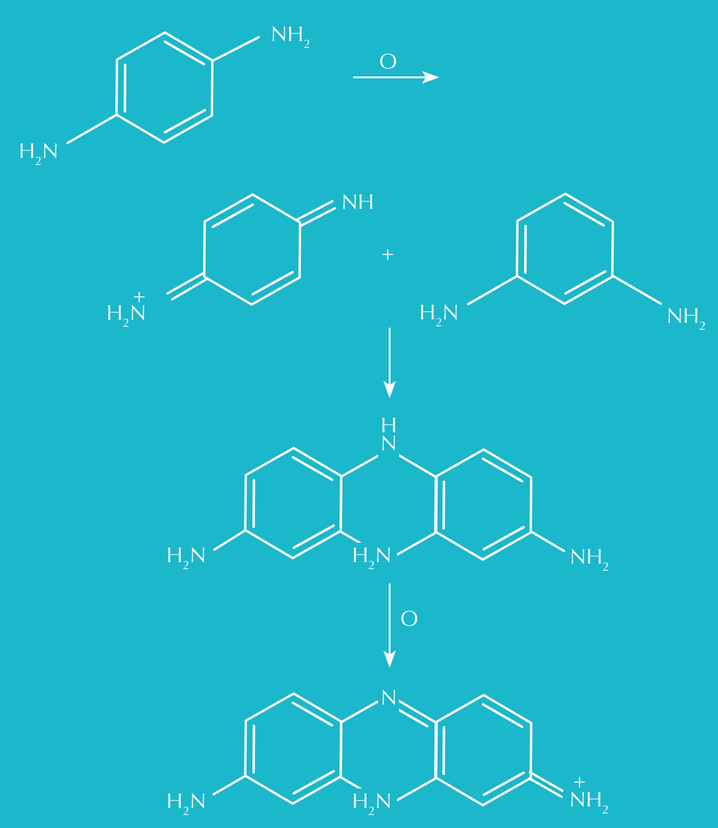
Although hair is a protein fibre, like wool, the dyeing process for textiles cannot be duplicated on the head. To get wool to take a dye, you must boil the wool in an acidic solution for an hour. The equivalent for hair is to bathe it in the chemical ammonia. Ammonia separates the protective

Image courtesy of Lisa Creech Bledsoe; image source: Flickr

protein layers, allowing dye compounds to penetrate the hair shaft and access the underlying pigment, melanin.

Melanin is what gives colour to human skin, eyes and hair. It's the ratio of two types of melanin – eumelanin and pheomelanin – that determines your natural hair colour. And it's the size and shape that the melanin molecules form when they cluster in the hair shaft that gives the unique tones within a hair colour. For example, blonds and brunettes have about the

The oxidative formation of hair dye. A primary intermediate, such as PPD (1,4-diaminobenzene) is oxidised to an imine which then reacts with a coupler. Another oxidation step then yields a dye.



same ratio of eumelanin molecules to pheomelanin molecules, but blonds have fewer molecules overall. Naturally blond hair also contains smaller melanin clusters, which reflect light more than the larger clusters found in dark hair.

Along with ammonia, hair dye formulations contain hydrogen peroxide, a bleaching agent. Peroxide serves two purposes: it reacts with the melanin in hair, extinguishing its natural colour, and oxidises PPD molecules to create larger dye molecules. The trapped colour-emitting molecule will remain in the hair, too big to escape.

Early on, dye chemists realised that if they added a secondary molecule, called a coupler, they could manipulate the resulting pigment – a carbon here, a couple of nitrogens there – and multiply the colour choices that were

BACKGROUND

A long tradition

Archaeological evidence shows that the use of dyes by humans dates back to the Palaeolithic period. Early humans used the iron oxide in soil to decorate their dwellings, textiles and bodies with the colour red. It wasn't too long before they applied the dyes to their heads.

Ancient Egyptians also dyed their hair, but rarely did so while it was on their heads. They shaved it off, then curled and braided it to wigs to protect their bald heads from the sun. Analysing hair samples has also revealed that the Greeks and Romans used permanent black hair dye. They mixed substances that we know today as lead oxide and calcium hydroxide to create a lead sulfide nanoparticle, which forms when the chemicals interact with sulfur linkages in keratin, a protein in hair. When the direct application of lead proved too toxic, the Romans changed their black dye formula to one made by fermenting leeches for two months in a lead vessel. Not as pleasant as today's dyes!

Image courtesy of Gemma Bou; image source: Flickr

available with PPD alone. Different methods have been proposed, but beauty product manufacturers have yet to accept a permanent hair colour formula without PPD or its related compound *p*-aminophenol.

Harmful heritage?

For 125 years, the oxidative reaction of PPD has been the extent of hair dye technology. This is "crazy" according to David Lewis, emeritus professor at the University of Leeds in the UK. "Now, I know a lot about dyes and dye stuffs in the textile industry. We would never dream of using this on textiles," he says. "Primitive, archaic, all these things come to mind. Why do they persist on putting it on human heads?"

Lewis retired from academia ten years ago to launch Green Chemicals, a company that aims to develop safer consumer goods. His company introduced a more environmentally friendly flame retardant, and now Lewis wants to overhaul hair dyes.

One issue is how dyes work: Lewis says that the colour molecules become electron scavengers. This need for electrons is not exclusively fulfilled by other dye molecules, so the electron scavengers also aggressively pursue the skin – causing allergic reactions and potentially damaging DNA.

Globally, haircare products comprise the largest portion of the beauty industry and secure nearly a quarter of the industry's revenue. In the USA, for example, an estimated 70 per cent of women use hair colouring products.

Reflecting on the heritage of hair dyes, you can't help but ask: why do so many people still colour their hair? Why would someone go through the rigmarole and tolerate the expense, the itching and the smell? Whatever drives our desire to change the colour of our hair, one thing is certain: people have deep emotional ties to what covers their scalps.

This is clearly true for Barclay Cunningham. At just 12 years old, she began experimenting with her hair and as an adult, she searched for years for the right hair colour. "Never once has it occurred to me to simply not dye my hair," Barclay says. "The 'me' of hair colour happens to come out of a box. The 'me' that grew out of my head was not right."

Acknowledgement

This article is an edited version of an article first published by Mosaic[w1], the long form journalism site from the Wellcome Trust.

Web reference

w1 – The full article can be read on the Mosaic website at http://mosaicscience.com/story/hair-dye

Resources

For a more detailed look at the chemistry behind different coloured hair dyes, Compound Chemistry has created a graphic you can download at: http://www.compoundchem.com/2015/05/14/hair-dyes/

The history and synthesis of mauve is outlined for teachers at the Royal Society of Chemistry's Learn Chemistry site. Download the PDF at: http://tinyurl.com/qhtdzup

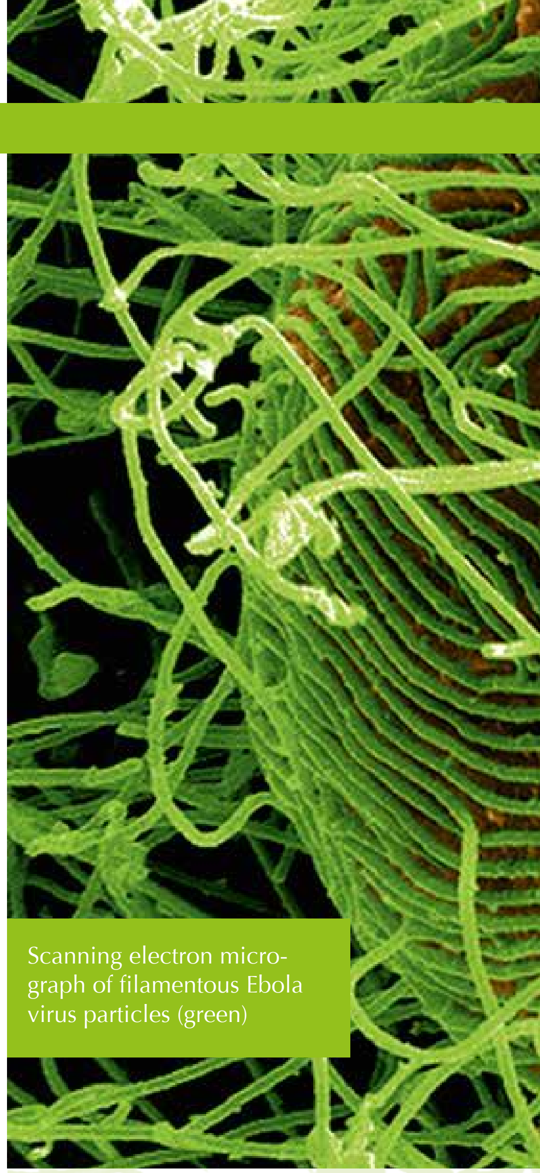
Before chemically fast dyes were made, people had to rely on natural dyes extracted from plants and animals. Indigo was a purple dye used before mauve was invented, and you can learn how to extract the dye yourself:

Farusi, G (2012), Indigo: recreating Pharaoh's dye, *Science in School* **24**: 40–46. http://www.scienceinschool.org/2012/issue24/indigo

Rebecca Guenard is a genuine maths and science nerd with a PhD in chemistry to prove it. She served a tour in academia before finding fulfilment as a science writer. Now she flits from covering one fascinating chemistry topic to the next. She is currently exploring health and beauty chemistry. She has written for The Chemical Heritage Foundation, *Kids Discover* and *Scientific American*. You can see examples of her mind wanderings at atomic-o-licious.com. Or follow her on Twitter @BGuenard.

Ebola in numbers: using mathematics to tackle epidemics

Discovering how infectious diseases spread may seem purely a matter for medical science – but taking a close look at the numbers can also tell us a great deal.



Scanning electron micrograph of filamentous Ebola virus particles (green)

Image courtesy of the National Institute of Allergy and Infectious Diseases (NIH); image source: Flickr

By Marianne Freiberger

During the recent Ebola epidemic in West Africa, airports in the USA, UK and several other European countries started screening travellers arriving from high-risk countries for Ebola symptoms, including an elevated body temperature. This probably seemed like a sensible precaution – but a recent study, based on applying simple calculations to known facts about the disease, shows that it was never likely to be effective.

The study, published in the *British Medical Journal* (Mabey et al, 2014), found that 'an entrance screening policy will have no meaningful effect on the risk of importing Ebola into the UK'. The authors' argument is straightforward: assuming that anyone already showing Ebola symptoms is prevented from boarding an aeroplane, then to be detected by airport screening on arrival, a passenger must have developed symptoms on the flight itself. Because the average time between exposure to the virus and becoming symptomatic is quite long (around a week), the chance of an infected person being identified in this way is very low – no more than 13% at best. Since airport screening is costly, the authors suggest the money would be better spent in West Africa itself, helping to prevent a humanitarian crisis of 'frightening proportions'.

Basic maths

A lot can be revealed using just basic mathematics – but care is always needed in deciding which figures to use. Early on in the Ebola outbreak, the death rate was thought to be around 50% – a figure calculated by dividing the number of deaths by the number of reported cases. But this ignored the fact that the outcome for people who were ill was not yet clear: they were counted as alive, even though some of them would go on to die, which led to an underestimate of the real death rate.

"This mistake happened a lot, and [the 50% figure] was widely reported," says Adam Kucharski of the UK's London School of Hygiene and Tropical Medicine, a colleague of the authors of the airport screening study. "In a very simple analysis, my colleagues and I tried to adjust the estimate. We found the death rate is probably around 70%, which subsequent clinical studies have lined up with."

One hugely important figure at the start of an epidemic is the basic reproduction number, usually denoted by R_0. This number measures the average number of people that one infectious person goes on to infect, assuming that no-one in the population is immune to the disease. For Ebola, R_0 was

REVIEW

- Biology
- Mathematics
- Health
- Statistics
- Ages 15–19

Teaching probability and statistics is not easy; one of the main reasons is the difficulty in finding interesting examples that are relevant to students' lives. This article is therefore a useful resource: Ebola has been in the news for months, and many people, even quite young school students, are worried about the risks.

The main value of this article is to provide a strong link between the life sciences and maths. It offers an example of how important reliable data are for medicine and public health, including how the data are collected, processed and presented. Interpretation errors are also covered in the article, which could lead to a discussion about how statistics can be properly or improperly used.

Many interdisciplinary activities could be based on the article, such as those involving life sciences, probability and statistics, history, economics and geography. The article could also be used as a basis for covering topics such as population dynamics and the effect of modern travel; disease transmission; public spending on health and welfare; links between diseases and economics; data journalism, a method of reporting on events and facts based on big number analysis; and how to read and criticise an article based on statistics. Finally, the article can be used to introduce modelling, a fundamental concept in science, and how it is based on data, or conversely how data are fitted into the model.

Comprehension and extension questions could include:

1. What is meant by 'high-risk countries'? List some high-risk countries for Ebola.
2. How long is the average time between exposure to the Ebola virus and becoming symptomatic?
3. What is the 'reproduction number' and why is it important?
4. What is 'exponential growth'?

Marco Nicolini, Liceo Scientifico Statale Alessandro Tassoni, Modena, Italy estimated at the start of the outbreak to be between 1.5 and 2, which is similar to the number for pandemic flu. Measles, an airborne and highly infectious disease, has an R_0 of around 18.

Again, some basic maths helps to give a rough idea of how quickly a disease might spread. If a disease has an R_0 of 2 and the average infectious person passes the disease on within two weeks of contracting it (which is a realistic estimate for Ebola), in two weeks an infected person infects two others, who together go on to infect four others in the next two weeks, and so on. This is exponential growth, which increases very rapidly: after just 20 weeks, the disease will have infected:

$1 + 2 + 4 + 8 + ... + 2^{10} = 2047$ people

This model is over-simplified, of course. Although exponential growth is often seen at the start of epidemics, epidemiologists actually use more sophisticated models to predict the spread of diseases (see Keeling, 2001, and Kucharski, 2011). However, we can easily see the importance of R_0: the same calculation for measles has the entire world population infected within just 16 days.

R_0 is only an average value across the whole population, however, so the next thing to understand is how this number varies. For example, a recent study (Yamin et al, 2015) suggests that people with Ebola become more infectious in the later stages of the disease, so placing people in isolation during these later stages – and even after death, when the body is being prepared for the funeral – should have a greater effect than targeting them earlier.

Chance and uncertainty

Of course, chance is a major player – especially at the beginning of an outbreak. The first person to fall sick in Sierra Leone, where several thousand people died, happened to be a traditional healer, whose funeral attracted a large crowd. The people who touched the infectious body then took the disease with them as they travelled to other places.

"In situations where there are very small numbers, all it takes is one event and you could have a very different outbreak," says Adam. Again, the basic reproduction number, R_0, is an important factor in what's likely to happen. The chance that a disease outbreak will turn into a large epidemic can be calculated as $1–1/R_0$

BACKGROUND

More about Ebola

- Ebola is a severe and often fatal illness in humans.
- The virus is transmitted to humans from wild animals; once in the human population it spreads from person to person.
- The first known outbreaks of Ebola occurred in remote villages in central Africa, close to tropical rainforests. The most recent outbreak in West Africa, however, has involved major urban as well as rural areas.
- Survival can be improved by early supportive care with rehydration and symptomatic treatment. So far there are no licensed treatments for Ebola, but a range of blood, immunological and drug therapies are being developed.
- As yet, there are no licensed Ebola vaccines although two potential candidates are being evaluated.

Source: The World Health Organization, April 2015

Image courtesy of Melissa Maraj, US Customs and Border Protection; image source: Wikimedia Commons

A passenger arriving from Sierra Leone being screened for Ebola at Chicago's O'Hare airport.

Image courtesy of the UK Department for International Development; image source: Flickr

Checking personal protective equipment in the fight against Ebola

Image courtesy of Gietje; image source: Wikimedia Commons

Screening travellers when they arrive by aeroplane is unlikely to prevent the spread of Ebola.

(see Kucharski, 2011). With an R_0 of between 1.5 and 2 for Ebola, that chance works out at between ⅓ and ½ – that is, between 33% and 50%. So with the recent outbreak, we've been a little unlucky.

There are other sources of uncertainty when it comes to predicting the course of a disease or the impact of interventions. Something may be missing from the model, or an initial uncertainty in an important parameter, such as R_0, might grow as the model simulates events further into the future. Known as the butterfly effect, this is the reason why many phenomena, such as the weather or the stock market, are so hard to predict.

So how can we deal with such uncertainty? "I think that modellers sometimes need to be humble and say that they can't forecast this far into the future," says Adam. "People like to have a definite number; journalists especially are keen to report them. But as with any kind of forecasting, publishing just a single number is a dangerous thing to do."

Sometimes, though, the results of a study are pretty convincing, even when there's inherent uncertainty – the study into the effectiveness of airport screening, for example. "Introducing those screening measures was

Image courtesy of purple

Screening was used at the Eurostar terminal in London, UK.

A flying quarantine ward used to transport ebola patients

Image courtesy of the Center for Disease Control and Prevention; image source: Wikipedia very much a political, rather than a scientific, decision," concludes Adam. We can all be led by our fears when we are frightened, but the predictions of carefully calibrated, evidence-based mathematical models are probably a better guide to action.

Acknowledgement

This article was originally published in a longer form in *Plus magazine*[w1], a free online magazine that opens a door to the world of mathematics with all its beauty and applications.

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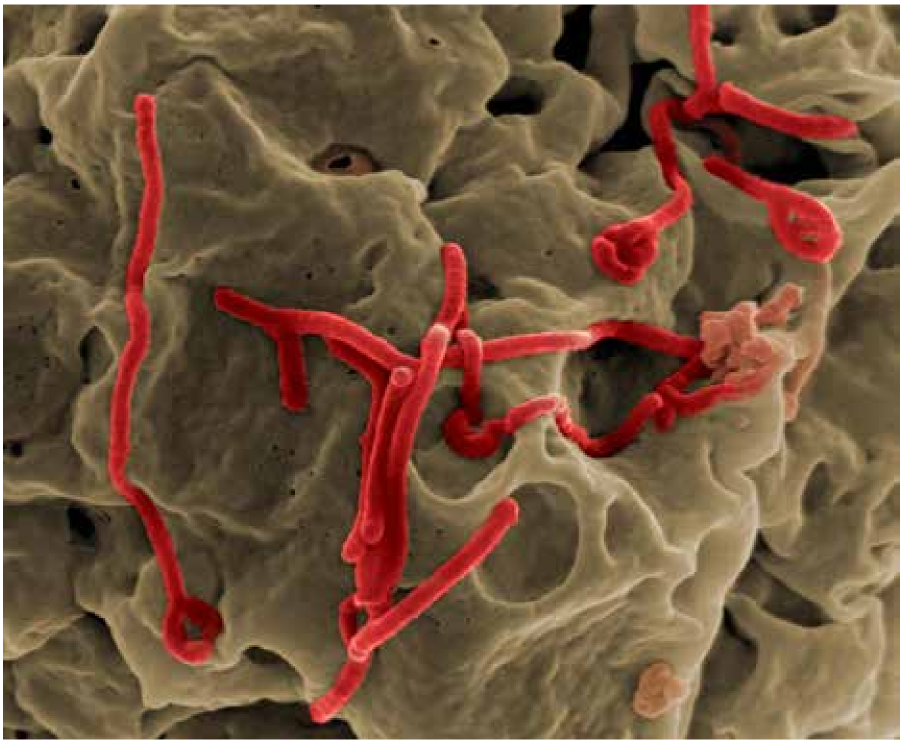
Yamin D et al (2015) Effect of Ebola progression on transmission and control in Liberia. *Annals of Internal Medicine* **162(1)**: 11–17. doi: 10.7326/M14-2255.

This article can be downloaded free of charge from the journal website, www.annals.org

Web reference

w1 – The original article, published in *Plus Magazine*, is available free online. See: https://plus.maths.org/content/ebola-evidence-numbers

Image courtesy of the National Institute of Allergy and Infectious Diseases (NIH); image source: Flickr



Electron micrograph of Ebola virus budding from the surface of a cell.

Image courtesy of the Center for Disease Control and Prevention; image source: Flickr

Preparing to enter Ebola treatment unit

Airport screening is costly and ineffective.

Image courtesy of Dan Paluska; image source: Flickr

Resources

To learn more about Ebola, see:

The World Health Organization's factsheet: www.who.int/mediacentre/factsheets/fs103

Kucharski AJ, Piot P (2014) Containing Ebola virus infection in West Africa. *Eurosurveillance* 19(36): pii=20899. This article can be downloaded free of charge from the journal website, www.eurosurveillance.org

You can now join the fight against Ebola by downloading a free app and donating your spare computing power to the Outsmart Ebola Together computing project. The idea is to form a virtual supercomputer, made up of the donated computing power of (hopefully) tens of thousands of volunteers, which will screen millions of molecules that might be used to disable the virus. The best candidate molecules can then be tested physically in the lab and perhaps modified to perform better, and may ultimately lead to anti-viral drugs. See: www.worldcommunitygrid.org/research/oet1/overview.do

Visit the *Plus Magazine* website for a classroom activity exploring basic epidemiological models. It uses basic probability and can be used to discuss exponential growth and geometric progressions. See: http://plus.maths.org/content/build-your-own-disease-0

To learn more about the spread of infectious diseases, see:

Bos K (2014) Tales from a plague pit. *Science in School* **28**: 7–11. www.scienceinschool.org/2014/issue28/black_death

Heymann J (2013) Evolving threats: investigating new zoonotic infections. *Science in School* **27**: 12–16. www.scienceinschool.org/2013/issue27/zoonosis

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Quammen D (2012) Where will the next pandemic come from? and how can we stop it? *Popular Science*. www.popsci.com/science/article/2012-08/out-wild

Marianne Freiberger is a co-editor of *Plus Magazine*[w1]. Together with Rachel Thomas, she has written the popular maths book *Numericon: A journey through the hidden lives of numbers.*

Out of the darkness: tweeting from space

Image courtesy of ESA / ATG medialab

The Rosetta mission's comet landing leads to amazing and unexpected destinations in the field of science communication.

By Julia Roberti

It was one of those rare moments that made headlines worldwide, summed up in 140 characters:

Philae Lander @Philae2014 Nov 12
Touchdown! My new address: 67P! #CometLanding

The fingers hurriedly tapping on the keys, and tweeting the message in 10 languages, are those of Karin Ranero. Previously an intern with *Science in School*, Karin is now an editor for the German Aerospace Center (DLR) web portal and *DLR Magazine*. She was also part of the team tasked with running the Twitter account for one of the global stars of 2014 – not a footballer, an actor or a singer, but a tiny robotic probe named Philae, which went where nobody and nothing had gone before: the surface of a comet.

In November 2014, people around the world held their breath as a live web stream showed the pinnacle of the European Space Agency (ESA)[w1] Rosetta mission[w2] as it carried the Philae lander to its final destination – Comet 67P – after a 10-year journey across the Solar System. Five hundred million kilometres away from Earth, the orbiter and lander communicated with each other and with researchers here on Earth. But

REVIEW

- **Physics**
- **Careers**
- **Space**
- **Ages <11–19**

This article describes how one young scientist covered the landing of the Philae probe via the social media platform Twitter. It could be used to encourage students to consider careers in science, demonstrating that science careers do not necessarily involve working in a laboratory. It could also be used as an introduction to space and discovery, arousing students' interest in something they have seen on the news.

The article could form the basis of a discussion about the technology and careers that are involved in the project. For example, the students could discuss the photography, forces, how the lander got to the comet, the landing, solar energy, the computer systems to run the project, the engineering involved, rocket science, the science of comets and how the communication systems work. It could also provide a stimulus for a project on space and astronomy.

Mike Sands, Longcroft School, UK

Image courtesy of ESA / ATG medialab

The Philae lander

Image courtesy of Geber86 / iStockphoto.com

unlike during the first Moon landing, many people followed Philae's adventure via a very modern channel: Twitter.

Karin is one of the people in the team that gives Philae its voice and soul. "My job combines a bit of everything I have learned," explains Karin, who was an intern at the European Southern Observatory (ESO)[w3] before moving to *Science in School*, which is based at the European Molecular Biology Laboratory[w4]. "I studied astrophysics, but I realised that communicating science was what I enjoyed the most. I wanted to learn how to better connect with people, so I also pursued further studies in psychology. After

Image courtesy of ESA

Wide-angle view of Comet 67P, as seen by Philae on 12 September 2014

The orbit of Comet 67P. The 6.5-year journey around the Sun takes it from just beyond the orbit of Jupiter at its most distant, to between the orbits of Earth and Mars at its closest.

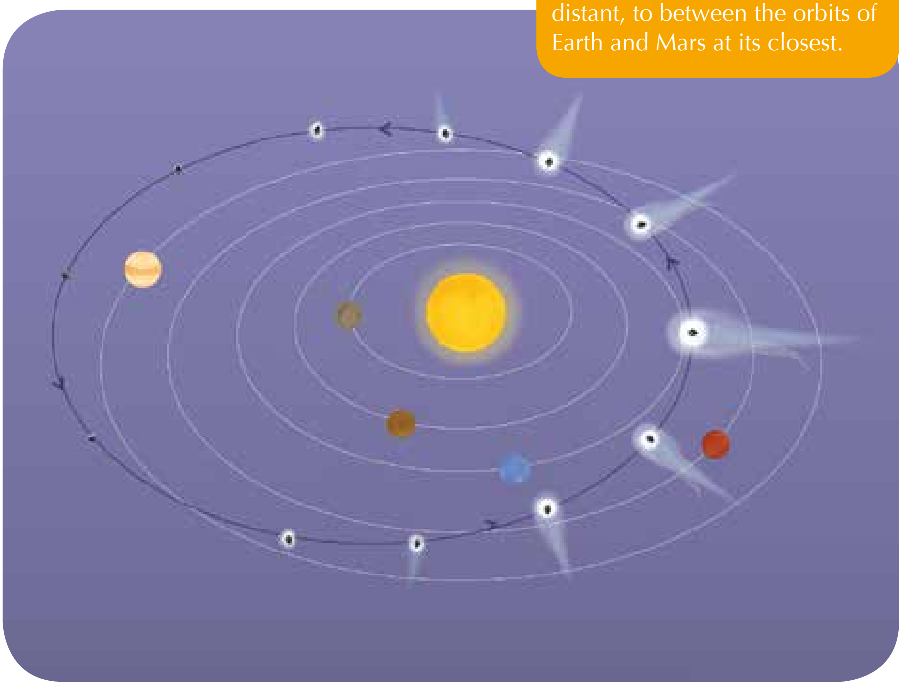


Image courtesy of ESA

completing my bachelor degrees, I worked in the communications department of the Teide Observatory (*Instituto de Astrofísica de Canarias*) where, among other things, I was responsible for its contribution to the Liverpool Telescope's National Schools' Observatory project. During my time there, I also worked closely with museums, which is why I then decided to pursue a master's degree in museum studies." All of this experience is being put to good use in Karin's current job. "If you explain something and people can relate to it, that draws their attention and makes them want to know more – with Philae, it helped that we were able to tell this story in a fun way."

And that is exactly why @Philae2014 exploded on Twitter, reaching 400 000 followers, gathering retweets from the US White House and feeding headline stories around the world.

Philae Lander @Philae2014 Nov 12
Finally! I'm stretching my legs after more than 10 years. Landing gear deployed!
#CometLanding

The story was enriched by interactions with the Rosetta spacecraft's own Twitter account, run by a team at ESA. Karin explains that tweets between Philae and Rosetta resemble a conversation between friends on a great adventure – not pieces of metal in cold outer space, but beings full of emotion. "We had a great time working with the Rosetta team and the scientists at the DLR Lander Control Centre. We tried to think of conversations beforehand, but they could change in a minute."

Philae Lander @Philae2014 Nov 12
I'm on the surface but my harpoons did not fire. My team is hard at work now trying to determine why.
#CometLanding

Image courtesy of ESA

Comet 67P as seen from Philae on 31 January 2015, from a distance of 28 km

Image courtesy of ESA

View of Comet 67P as seen from Philae on 14 February 2015, from a distance of 8.7 km

Indeed, being Philae gives Karin a direct line to DLR's Lander Control Centre. "In such moments of tension, it is important to wait for advice from the experts who first have to figure out what is happening," she says. When Philae's harpoon system failed to anchor the lander on the comet, for example, Philae bounced and landed in a rugged region a few kilometres away from its target, something Karin points out was good luck disguised as bad luck. Philae imaged structures and examined an area that might never otherwise have been seen.

> **Philae Lander** @Philae2014 Nov 12
> My #lifeonacomet has just begun @ESA_Rosetta. I'll tell you more about my new home, comet #67P soon… zzzzz
> #CometLanding

Before exhausting its batteries, Philae sent plenty of data to keep researchers here on Earth busy – and there could even be another twist in the tale. "Philae's landing site will protect it from excessive radiation," Karin adds. "Scientists are hopeful that when Comet 67P gets closer to the Sun, Philae will have enough energy to wake up – and we will be waiting for it. I will never forget the atmosphere in the Lander Control Centre during the landing. It was a spectacular, once-in-a-lifetime event that will be written about in history books, and it was a privilege to be part of it." And thanks to Karin and her team, thousands of people feel the same way. Mission accomplished.

The Teide Observatory, where Karin worked earlier in her career

Image courtesy of Niels Hollenberg; image source: Wikimedia Commons

BACKGROUND

Brief interview with Karin

How did you first become interested in science? Was there a particularly important moment or person or did your interest grow gradually?

I think I became interested in science because my father is an engineer; he always encouraged me to question things. In the beginning, I wanted to become a paediatrician, but with time, I realised that it was not for me. My interest in space arose in secondary school: the size of the Universe amazed me, its beautiful nebulae and galaxies inspired me, and I was awed by its violence. Back then, I realised I wanted to learn more about our place in it. I got my first telescope at the age of 17 and have been involved in science since then. I will never forget the first time I saw Saturn through my telescope – breathtaking!

What do you most enjoy about working in science? What are the drawbacks?

I enjoy everything – the excitement of learning about new discoveries, meeting the people behind the discoveries, seeing years of hard work pay off, all in the name of humanity. Scientific advances are meant to improve our quality of life and further our understanding of where we come from and where we are headed.

The only drawback is that sometimes I have to work in the middle of the night, for example when there is a launch. But, in the end, even that is not a drawback, because I must say that I truly enjoy it. I am extremely lucky to have a job in which I learn new things every single day.

Tell us about some particularly memorable moments in your career.

Oh my! I have had quite a few memorable moments in my career – it has been quite varied. In 2006, while I was working as a science communicator at the Teide Observatory, I had the pleasure of accompanying space engineer Lester Waugh and Chris Draper, industrial manager at the aerospace company EADS Astrium, when they came to Tenerife to test the motor system for the first of the ExoMars missions[w5], to be launched in 2016. We conducted various tests in and near the Observatory, as the conditions of the soil there are similar to those on Mars. That was my first true contact with space – science professionals. Until then, I had mainly dealt with telescopes and astronomical discoveries.

Another highlight was definitely being able to participate in activities relating to the International Year of Astronomy at ESO in 2009, particularly the 'Around the world in 80 telescopes' project[w6], in which we connected live with 80 observatories worldwide, non-stop for a full 24 hours.

The latest highlight of my career has been covering the first-ever comet landing by the Philae lander on Comet 67P live on Twitter!

What would you like to do next?

At present, I am extremely happy where I am. In future, I would like to continue working for the science and space industry doing what I do – continuing to communicate the wonders of Earth and the Universe, and the people behind the discoveries. Nothing inspires me more.

The Teide Observatory, where Karin worked earlier in her career

Image courtesy of ESA / ATG medialab

Artist's impression of the Rosetta mission, showing the deployment of the Philae lander to Comet 67P

Image courtesy of ESA

Physics

General science

Web references

w1 – The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. See: www.esa.int

ESA is a member of EIROforum[w7], the publisher of *Science in School*.

w2 – The Rosetta mission aims to research the history of how our Solar System was formed by investigating one of the oldest and most primordial of heavenly bodies, a comet. See: www.esa.int/Our_Activities/Space_Science/Rosetta_overview

w3 – ESO is by far the world's most productive ground-based astronomical observatory, with its headquarters in Garching near Munich, Germany, and its telescopes in Chile. See: www.eso.org

ESO is a member of EIROforum[w7], the publisher of *Science in School*.

w4 – EMBL is Europe's leading laboratory for basic research in molecular biology, with its headquarters in Heidelberg, Germany. See: www.embl.org

EMBL is a member of EIROforum[w7], the publisher of *Science in School*.

w5 – Is there or was there ever life on Mars? ESA's ExoMars programme was established to answer this question. See: http://exploration.esa.int/mars

w6 – The webcasts of ESO's 'Around the world in 80 telescopes' project, which were broadcast live on 3-4 April 2009, are available online. See: www.eso.org/public/events/special-evt/100ha

w7 – EIROforum is a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combine their resources, facilities and expertise to support European science in reaching its full potential. As part of its education and outreach activities, EIROforum publishes *Science in School*. See: www.eiroforum.org

Molecules that Amaze Us

By Paul May and Simon Cotton
Reviewed by Jose Viosca

Molecules are everywhere, both inside us and out, but they are more than just common. The ones you will find in *Molecules that Amaze Us* are incredible. Did you know that limonene gives odour to many citrus fruits, but that the molecule mainly responsible for the smell of oranges is a very different substance called octanal? Or that capsaicin, the molecule that provides the heat sensation when eating chili peppers, is also a major compound of defensive pepper sprays? And that, the same compound has also been used for pain relief for thousands of years since the Mayan civilisation? If you find these examples intriguing (and who doesn't?), then you shouldn't miss the chance to read this book.

The stories behind many molecules in this book can provide teachers with dozens of fantastic examples on a multitude of topics – or just catch students' attention – in chemistry and biology lessons. Metabolism, physiology, medicine, perfumery and gastronomy are some of the contexts in which the molecules in this book play a role. The wide array of those applications makes the book a very good overall introduction to science in general.

Molecules that Amaze Us is an engaging book that provides a balanced mix of entertainment and education. It is written with rigour by experts in each field (not just in chemistry and biology, but also in many related fields such as biochemistry, pharmacology and neuroscience), but the language is very accessible and its pages are visually appealing thanks to hundreds of images, photos and cartoons.

The book builds upon a successful website called *Molecule of the Month* that was begun by the same authors in 1996 and achieves a very difficult task: keeping both the novice and the expert interested.

Details

Publisher: CRC Press (Taylor and Francis Group)

Publication year: 2014

ISBN: 9781466589605

Image courtesy of Nicola Graf

Image courtesy of Chris Gladis; image source: Flickr

This is all you need for this activity.

Once upon a time there was a pterodactyl…

Adapting the steps of the scientific method can help students write about science in a vivid and creative way.

By Lauren Burrow

Today, scientists need more than top-class research skills. They need to have good writing and communication skills too: after all, what good is a discovery if you can't communicate it to others? One way to develop this skill is to adapt the long-established scientific method to encourage excellence in writing creatively about science.

Just like writing, the scientific method starts with an idea and ends with a publication. The basic idea of writing creative non-fiction is storytelling: finding a narrative way to share factually accurate scientific knowledge in a captivating and vivid manner. For example, if the class has been studying the oceans' dead zones, students could tell the story of how a particular animal's survival, a sea turtle for instance, is affected, and write from the animal's point of view. This approach can help younger students to understand science and gives older students the chance to explain their scientific knowledge to others – all while nurturing the creativity that's essential for a successful scientist.

To see how the writing process can replicate the step-by-step process that scientists use in their normal work, let's look first at the two processes side by side, and then at the writing process in more detail.

REVIEW

- All sciences
- Ages <11–16

This article promotes interesting ways of encouraging students to communicate science more creatively. This type of writing or communication may go some way to supplementing public understanding of science, and the approach is worth trialling in all junior science classrooms.

All science teachers could benefit from trying these ideas at some stage, as they may help them make science more accessible to a wider range of students. This activity is applicable to all general science topics, although perhaps less so to those that are more mathematical.

Marie Walsh, Ireland

General science

Primary

Scientific process	Writing process
Define the question that you want to answer.	Idea development: choose the topic that you want to write about.
Construct the hypothesis that you will test.	Drafting: select a specific angle or point of view that you'll follow to write about your chosen topic.
Design the right experiment to test your hypothesis, and run it.	Writing: write the piece based on the draft, reviewing and adding material where needed.
Analyse your results, and deduce whether you need more or different experiments.	Revising: ask other people to read and comment on your text, then amend it.
Discuss your results with your peers and ask for input to make the results more meaningful and valuable.	Proofreading: check the text in detail.
Publish your results to share them with the scientific community.	Publishing: finalise your text and share it with your chosen audience.

Material

You just need pens and paper.

Procedure

1. Idea development

The first step is for students to come up with their own ideas and begin to organise them to use as a basis for their writing. Two exercises – 'popcorn' and 'power writing' – are good ways to get started as they help students to quickly pick research topics, review previously studied topics and expand their understanding.

Popcorn: Students brainstorm as a class about a particular science topic while the teacher lists everything that 'pops' up, perhaps on a big sheet of paper. The teacher can help students to categorise the list by colour-coding individual comments with highlighter

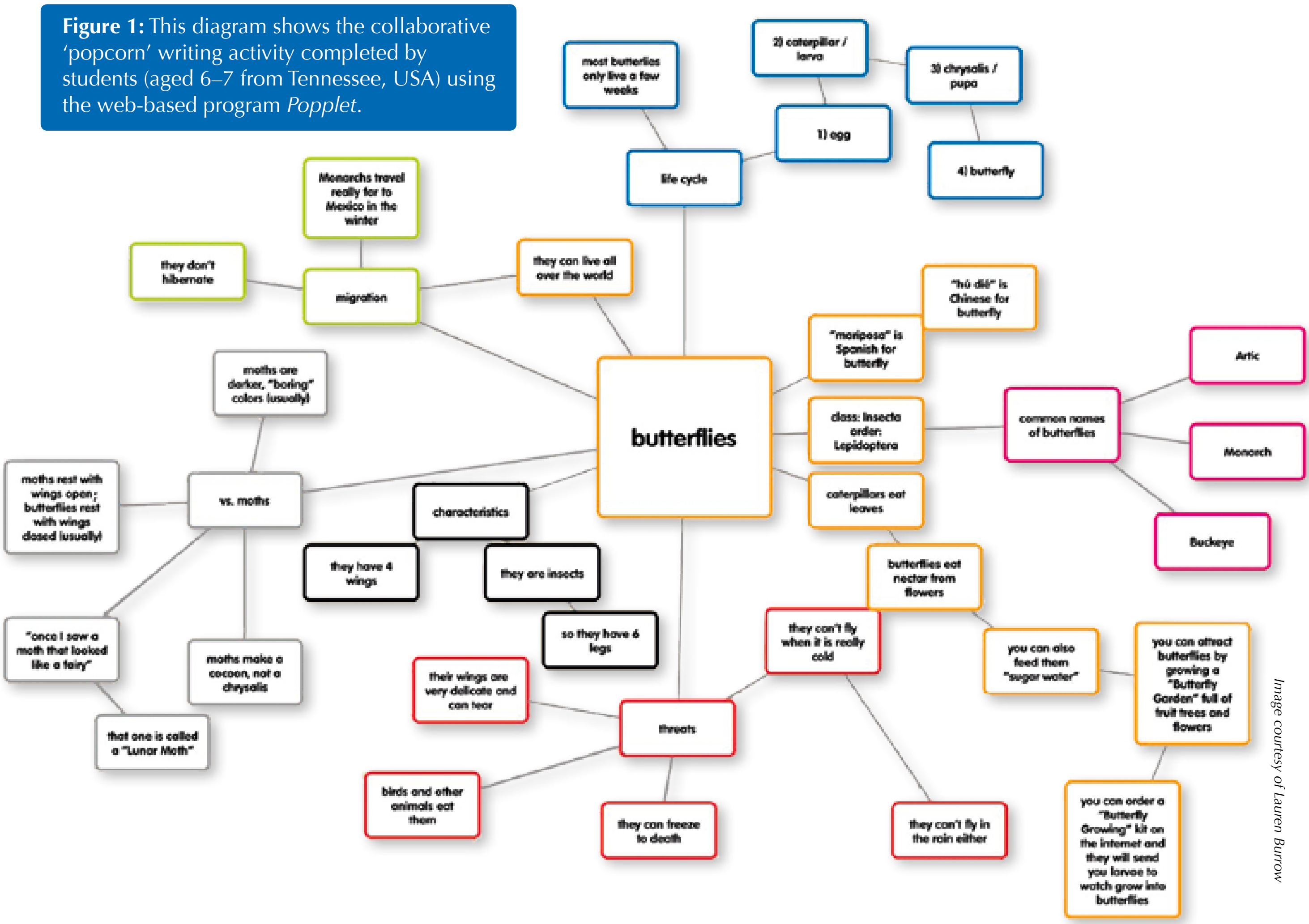


Figure 1: This diagram shows the collaborative 'popcorn' writing activity completed by students (aged 6–7 from Tennessee, USA) using the web-based program *Popplet*.

Image courtesy of woodleywonderworks; image source: Flickr

Presenting their creative story in front of the class is rewarding for pupils.

pens. Older students can use web-based programmes like *Popplet*[w1] to create digital concept maps collaboratively, with or without the teacher (figure 1).

Power writing: This activity uses the class discussion points from 'popcorn' as prompts. It should be a sustained, uninterrupted 5–15 minutes (depending on ages and abilities) in which students rush to add as many factual details as they can to the existing writing (figure 2). Students can use illustrations, statements, phrases or even concept maps to help them further develop their own understanding. If students are hesitant, teachers should remind them that there are no wrong answers at this point: the activity is just about expressing their thoughts, feelings and ideas, and they'll have a chance to verify these later on. Written prompts are also useful; for example, 'Describe what the animal *looks* like…', or 'What does this topic *remind* you of in your life?'.

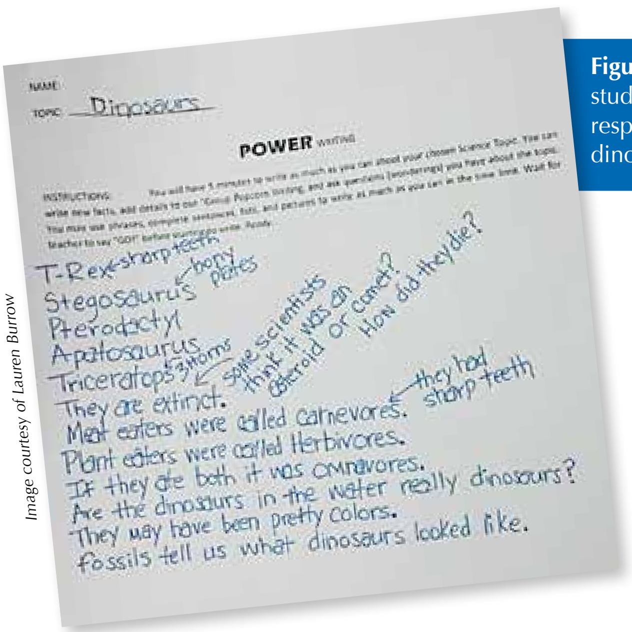


Image courtesy of Lauren Burrow

Figure 2: An 8-year-old student's 'power writing' response to the topic of dinosaurs

2. Drafting

Before they start on their writing, students should choose a point of view from which to discuss the scientific topic – in the same way as they select a hypothesis to test when doing science. For example, they could look at the water cycle from the point of view of a water droplet or a cloud. Students should not create fictitious characters or situations, but use their understanding of science to express information in a captivating way.

Students should then start drafting by creating an outline. They can do this using their own 'power writing' efforts, adding numbers or arrows to pull the information into a coherent order and crossing out anything that doesn't relate to their intended science story. At this stage the students can also do another round of power writing on their chosen topic. Another method is the 'round robin' activity. Either way, allow time for students to say their story outlines out loud and get feedback from their teacher and other students.

Round robin: As a class, students take turns to tell the story from the viewpoint of the chosen character (e.g. a water droplet in our example of the water cycle). Each student should provide only one sentence of the story, with each sentence recorded on a strip of paper. At the end, students physically rearrange or remove the strips to produce a logically ordered story.

Image courtesy of Lauren Burrow

The traditional steps of the writing process. The doubling-back arrows indicate the optimal recursive process that students should undertake to ensure best writing. Adapted from Blasingame & Bushman (2005)

3. Writing

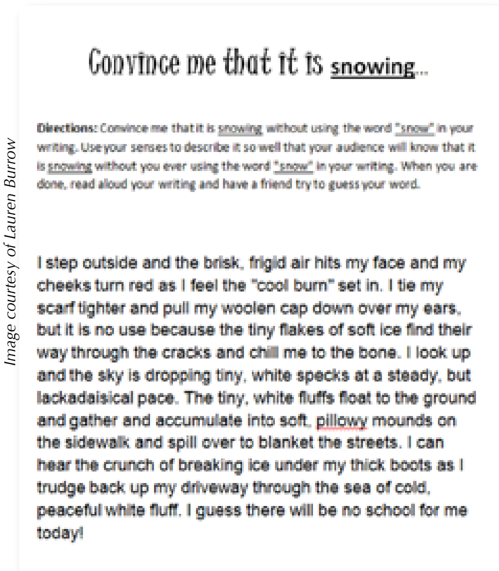
As students begin to write their stories, encourage them to use all their senses – just as they might when making observations in an experiment. This will produce a richly descriptive text, which they can then revise and edit. To promote this kind of sensory-based writing, try the 'convince me' exercise, to reactivate your students' creative writing while remaining scientifically accurate.

Convince me: In pairs or as a class, students have to convince another student or the teacher that it is raining, snowing, night time, and so on, without using the topic word in their description. This can be done verbally or in writing (figure 3).

4. Revising

The revision step is often the one students dislike most, so encourage them to see this as an opportunity to pep up their writing and to make it really active and exciting. You can make the task more manageable by asking students to rewrite just small sections of their work, or of each other's work. A good way to do this is using the 'explode the moment' trick developed by creative writing instructor Barry Lane (Lane, 1993).

Image courtesy of Lauren Burrow

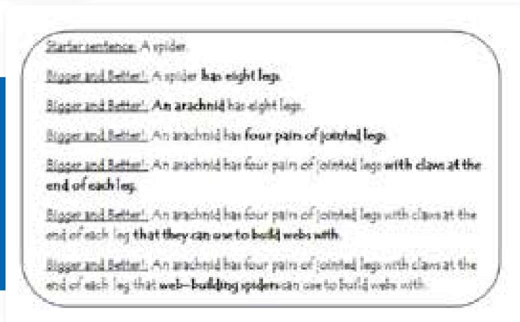


Convince me that it is snowing...

Directions: Convince me that it is snowing without using the word "snow" in your writing. Use your senses to describe it so well that your audience will know that it is snowing without you ever using the word "snow" in your writing. When you are done, read aloud your writing and have a friend try to guess your word.

I step outside and the brisk, frigid air hits my face and my cheeks turn red as I feel the "cool burn" set in. I tie my scarf tighter and pull my woolen cap down over my ears, but it is no use because the tiny flakes of soft ice find their way through the cracks and chill me to the bone. I look up and the sky is dropping tiny, white specks at a steady, but lackadaisical pace. The tiny, white fluffs float to the ground and gather and accumulate into soft, pillowy mounds on the sidewalk and spill over to blanket the streets. I can hear the crunch of breaking ice under my thick boots as I trudge back up my driveway through the sea of cold, peaceful white fluff. I guess there will be no school for me today!

Figure 3: A 10-year-old student's 'Convince me' response to the prompt: "convince me it is snowing without using the word *snow*."



Starter sentence: A spider.

Bigger and Better!: A spider **has eight legs**.

Bigger and Better!: **An arachnid** has eight legs.

Bigger and Better!: An arachnid has **four pairs of jointed legs**.

Bigger and Better!: An arachnid has four pairs of jointed legs **with claws at the end of each leg**.

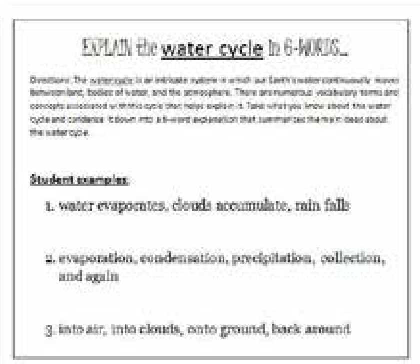
Bigger and Better!: An arachnid has four pairs of jointed legs with claws at the end of each leg **that they can use to build webs with**.

Bigger and Better!: An arachnid has four pairs of jointed legs with claws at the end of each leg that **web-building spiders** can use to build webs with.

Figure 4: An example of the 'explode the moment' exercise in which each student takes turns making a sentence bigger and better by adding another detail or clarification

Image courtesy of Lauren Burrow

Image courtesy of Lauren Burrow



EXPLAIN the water cycle in 6-WORDS...

Directions: The water cycle is an intricate system in which our Earth's water continuously moves between land, bodies of water, and the atmosphere. There are numerous vocabulary terms and concepts associated with this cycle that helps explain it. Take what you know about the water cycle and condense it down into a 6-word explanation that summarizes the main ideas about the water cycle.

Student examples:

1. water evaporates, clouds accumulate, rain falls
2. evaporation, condensation, precipitation, collection, and again
3. into air, into clouds, onto ground, back around

Figure 5: These are examples of students' (aged 11 from Texas, USA) six-word explanations of the water cycle.

Image courtesy of woodleywonderworks; image source: Flickr

Working in small groups can boost each other's imagination

Explode the moment: After students have written a rough draft of their stories, they identify the most important action part of their text and mark it with a firecracker symbol. Then, they 'explode' just that moment of the story, rewriting it and adding new details that will make it really stand out (figure 4).

Revision is not only about adding: sometimes, eliminating the writing that they have worked so hard on can be even more difficult. The fun of physically cutting out text with scissors can encourage students to get rid of repetitive or irrelevant information. You can help wordier students to master the art of succinct writing by practicing 'six-word stories', in which they have to summarise an idea in six or fewer words (figure 5). Teaching verbose students to be more conscious of their word choices can lead to critical writers who understand the importance of writing clearly and concisely.

5. Proofreading

Students often find proofreading discouraging, seeing it as the teacher's chance to rip apart their ideas and highlight all of their writing errors. However, just like in science, where a hypothesis that turns out to be false is not a failure, proofreading gives students the power to identify their mistakes and to learn from them. To jumpstart the process, teachers can point out a few errors that students often make and then provide them with a simple proofreading checklist to allow them to correct the rest of their work. Explaining that the rules of grammar exist to give writers flexibility and variety of expression (Lane, 2008) may help to change students' negative perceptions of grammar.

6. Publishing

The most important step of any writing process is the last one: making sure the completed work is shared with others and celebrated. Today there is a plethora of publishing outlets through which students can share their science stories with peers, family and the world – whether with traditional methods or technology-enhanced techniques. Traditional in-class storytelling can promote public-speaking skills in front of a peer audience, while publishing with easy-to-use digital storytelling software can provide experiences that really motivate students during the publication phase.

In the end, not only will the scientists-to-be in your classroom have produced a piece of writing of which they can be truly proud, but they should be well on their way to developing a flexible and creative

Image courtesy of Erica Szlosek, US Fish and Wildlife Service; image source: Wikimedia Commons

Concentrating to find the right term

writing style. This will be a real asset to them later on, when they need to appeal not only to other scientists but also other science VIPs: investors, decision-makers or even the media.

References

Blasingame J, Bushman JH (2005) *Teaching Writing in Middle and Secondary Schools*. Upper Saddle River, NJ, USA: Pearson. ISBN: 9780130981639

Lane B (1993) *After 'The End': Teaching and learning creative revision*. Portsmouth, NH, USA: Heinemann. ISBN: 9780435087142

Lane B (2008) *But how do you teach writing? A simple guide for all teachers*. New York, NY, USA: Scholastic. ISBN: 9780545021180

Web reference

w1 – For more information on the web- and iPad-based programme *Popplet*, see: http://popplet.com

Resources

For more examples of and resources on creative non-fiction, refer to: http://creativenonfiction.org

For a digital version of the 'round robin' activity in which a class of second-grade students in Sydney, Australia, interpreted the water cycle from the point of view of a water droplet, see: http://water.usgs.gov/edu/watercycle2ndgrade.html

For a longer, more formal example of a round robin activity, in which a teacher in Wisconsin, USA, adapted a creative non-fiction story into a script for a play about how water is critical to the development of a new town, see: http://water.usgs.gov/edu/dryville.html

For more information on 'six-word stories', see: www.sixwordmemoirs.com/

For a traditionally written example of a creative non-fiction piece about the water cycle, as told from the point of view of a drop of water, see: http://water.usgs.gov/edu/followadrip.html

For more information on digital storytelling, see: http://digitalstorytelling.coe.uh.edu/

The free SAS Writing Navigator provides guidance and support for students throughout the writing process: www.sascurriculumpathways.com/portal/#/writingnavigator

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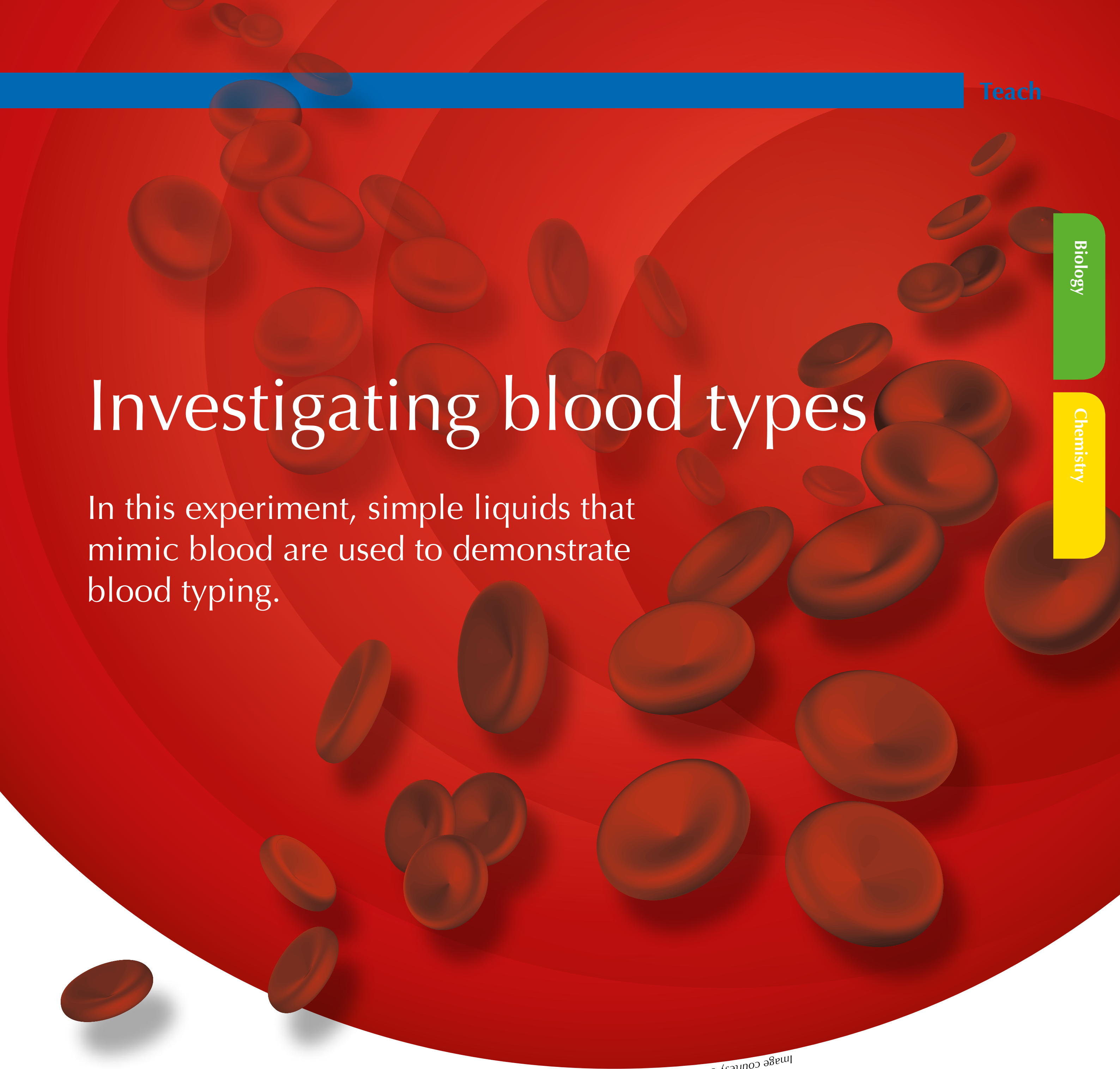
Dr Lauren E Burrow is an assistant professor of early childhood education at the University of Memphis, USA. She was previously a classroom teacher for seven years in multiple educational settings. She has taught a broad range of people from very young children to adult learners. As a classroom teacher, she often integrated science and writing practices with her students; she continues to promote hands-on, interdisciplinary practices in writing and science with her college-aged students.



Investigating blood types

In this experiment, simple liquids that mimic blood are used to demonstrate blood typing.

Image courtesy of Nicola Graf

By Tim Harrison

The topic of blood types is often taught in school science lessons but experimenting with real blood may not be possible for many good reasons—because of the concerns of parents, the need for comprehensive risk assessments to prevent infection or the transmission of blood-borne disease, or the reluctance of students to use their own blood.

In this practical activity, simple chemical solutions are used to simulate blood types. The activity can be used in lessons, for a science club or as part of a forensic science day for students of many ages.

The science of blood

Blood is a sticky red fluid containing several kinds of cell suspended in a watery liquid called plasma: red blood cells, white blood cells and platelets (figure 1). Many chemicals are also suspended or dissolved in the plasma, including proteins, sugars, fats, salts, enzymes and gases. Each person's blood has certain inherited

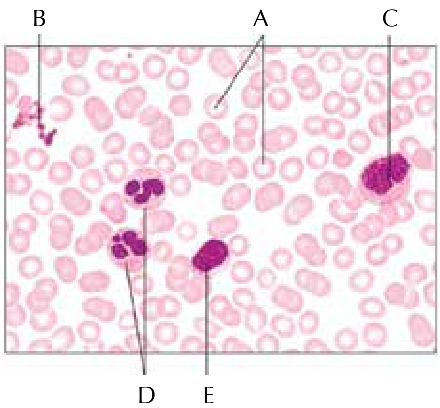


Image courtesy of Magdalena Wajrak

Figure 1: Photomicrograph of a human blood smear showing red blood cells (A) platelets (B) and white blood cells (C, D and E).

Anti-A agglutinin + blood: clumping	Anti-B agglutinin + blood: clumping	Blood type
Yes	No	A
Yes	Yes	AB
No	Yes	B
No	No	O

Table 1: Deducing ABO blood type using antigens

Image courtesy of Magdalena Wajrak

Using the dimple tray

characteristics that distinguish it from the blood of other people.

Until the 1980s, blood was primarily differentiated by ABO blood typing, which relies on the presence of three substances on the outside of red blood cells, called antigens. Although for forensic purposes, this technique has since been replaced by other methods such as DNA fingerprinting, for clinical purposes, ABO blood typing is still used before giving someone a blood transfusion to prevent complications such as rejection.

The presence or absence of A and B antigens on red blood cells determines a person's ABO blood type. This leads to the identification of four main blood types: A, B, AB (when both antigens are present) and O (when neither antigen is present), as shown in figure 2. A third important blood antigen is the Rhesus (Rh) factor, or D antigen. People with the D antigen are Rh positive, and those who lack it are Rh negative.

In order to type a person's blood, antibodies (called agglutinins and sometimes referred to as antiserums) are added to a few drops of blood. These agglutinins bind to the antigens on the surface of the red blood cells, causing the cells to aggregate or clump. If clumping occurs in a blood sample, then that associated antigen is present. Once all antigens have been tested, the blood type can be deduced (table 1).

ABO blood typing experiment

Safety note: Wear safety glasses and gloves. See also the general safety note on the *Science in School* website.

REVIEW

- **Biology**
- **Chemistry**
- **Blood**
- **Immunology**
- **Agglutination reactions**
- **Displacement reactions**
- **Ages 14–19**

This interesting practical activity addresses a basic topic of biology: blood types. Although the theory may be familiar to students, experiments on blood are normally avoided for reasons explained by the author. This, however, is an easy simulation to try in the laboratory using a simple chemical reaction.

The subject of this article could be related to other important topics such as immunology in biology, displacement reactions in chemistry, and even civil rights in ethics. The experiment could also be useful for awakening students' interest in the need to investigate new materials and technologies that allow us to make safer and faster transfusions.

Suitable comprehension questions could include:

1) What is the importance of knowing your blood type?
2) Why does clumping occur? What is the relationship between antigen and antibody?
3) Do you know an example of blood typing other than ABO?
4) What is the difference between agglutination and displacement reactions?
5) Why is it important to investigate new sources of universal donor blood?

Ana Molina, IES Gil y Carrasco, Ponferrada, Spain

Materials

Each group will need:

- Two spotting tiles (dimple trays)
- Two pipettes, one for each blood sample
- 2.0 mol dm^{-3} hydrochloric acid solution in a dropping bottle labelled 'Anti-A'
- 2.0 mol dm^{-3} sulfuric acid solution in a dropping bottle labelled 'Anti-B'
- Identified 'blood samples' (aqueous solutions made thicker with glycerol and dyed with food colouring to resemble blood), labelled by blood type:
  - 'O' = distilled water
  - 'A' = 0.1 mol dm^{-3} silver nitrate solution
  - 'B' = 0.1 mol dm^{-3} barium nitrate solution
  - 'AB' = a 50:50 mixture of 0.1 mol dm^{-3} silver nitrate and barium nitrate solutions
- Unidentified blood samples, made from the same solutions as the identified blood samples, labelled 'victim 1', 'victim 2', etc.

Procedure

Explain the scenario to your students: there has been an accident and you need to know the ABO blood type of the victims before they can be given blood transfusions. It is the students' job to use the blood samples

Image courtesy of Magdalena Wajrak

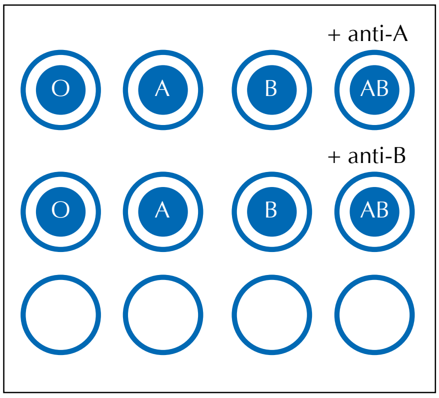


Figure 2: Blood samples on a dimple tray

Image courtesy of Magdalena Wajrak

Recording observations

	Group A	Group B	Group AB	Group O
Red blood cell type	A	B	AB	O
Antibodies in plasma	Anti-B	Anti-A	None	Anti-A and anti-A
Antigens in red blood cells	A antigen	B antigen	A and B antigens	None

Image courtesy of InvictaHOG ; image source: Wikimedia Commons

ABO blood typing

BACKGROUND

More types of artificial blood

The need to identify the blood type of patients before blood transfusion may soon be a thing of the past. Recently, UK-based researchers at the University of Edinburgh announced that they had made type O negative red blood cells from stem cells. If scaled up successfully, this method could lead to a new source of universal donor blood, and there are plans for a small-scale clinical trial in 2016.

Furthermore, researchers are developing products based on haemoglobin (the oxygen-carrying protein in blood), for example in a polymerised and powdered form, that can be stored for months at room temperature, unlike blood, which has to be refrigerated.

and work out the type of blood each victim has.

1. Using a clean pipette, put one drop of one of the identified blood samples into each of the first wells of the first two rows of your dimple tile. Complete the rows with the other blood samples, as shown in figure 2.
2. Add a drop of anti-A antiserum to each dimple in the first row and record your observations in table 2. If you're not sure of a result, add another drop of anti-A antiserum.
3. Add a drop of anti-B antiserum to each dimple in the second row and record your observations, also in table 2. If you're not sure of a result, add another drop of anti-B antiserum.
4. Use your results to conclude how each blood type (O, A, B and AB) reacts to the antibodies.
5. Take a clean dimple tray and test the victims' blood using the same method. Record your observations in table 3.
6. Use your results to assign the correct blood type to each victim

About what happens

These tests mimic how different blood types react with agglutinins, by using simple chemistry. With older students you may wish to discuss this chemistry, pointing out the differences between the antibody-antigen reaction which is being modelled and the simple displacement reaction that is actually happening.

In this experiment, instead of clumping blood cells, the (white) precipitates make the solutions clump in the spotting tiles.

Barium nitrate(aq) + sulfuric acid(aq) → barium sulfate(s) + nitric acid(aq)

Silver nitrate(aq) + hydrochloric acid(aq) → silver chloride(s) + nitric acid(aq)

The clumps that form are dark red, instead of white, because of the food colouring present.

Blood type	Observations with anti-A. Did clumping occur?	Observations with anti-B. Did clumping occur?
A		
B		
AB		
O		

Table 2: Record the clumping behaviour of the identified samples.

Victim	Observations with anti-A. Did clumping occur?	Observations with anti-B. Did clumping occur?	Blood type
1			
2			
3			
4			

Table 3: Test the unidentified blood samples (found at the accident scene).

Acknowledgement

This activity was developed by Magdalena Wajrak of Edith Cowan University in Perth, Australia. The solutions used in this version came from a group of science technicians from the Association of Science Technicians in Independent Schools in Western Australia (LABNETWEST)[w1].

Web reference

w1 – To learn more about LABNETWEST, see: http://labnetwest.asu.au

Resources

While A, B, AB and O are the most common blood types, there are other rarer blood types, as this article in *Mosaic* explores: http://mosaicscience.com/story/man-golden-blood

From the same website, why not explore why we have blood types at all? Visit: http://mosaicscience.com/story/why-do-we-have-blood-types

For further *Science in School* articles about forensic science projects, see:

Wallace-Müller K (2011) The DNA detective game. *Science in School* **19**: 30-35. www.scienceinschool.org/2011/issue19/detective

Gardner G (2006) The detective mystery: an interdisciplinary foray into basic forensic science. *Science in School* **3**: 35-38. www.scienceinschool.org/2006/issue3/detective

Tim Harrison works at the University of Bristol, as the school teacher fellow at the School of Chemistry. This is a position for a secondary-school teacher that was created to bridge the gap between secondary schools and universities, and to use the resources of the School of Chemistry to promote chemistry regionally, nationally and internationally.

The magic sand mystery

Using an everyday toy can introduce mystery into the classroom and help explain chemistry.

By Ran Peleg, Dvora Katchevich, Malka Yayon, Rachel Mamlok-Naaman, Johanna Dittmar and Ingo Eilks

How do you make a sand castle when your sand cannot get wet? In this activity students between the ages of 12 and 16 spend 2–3 hours investigating a well-known toy, magic sand, to understand its chemical properties. This challenge leads students to investigate hydrophobicity and surface chemistry using the five phases of inquiry-based learning: engage, explore, explain, extend and evaluate.

What is magic sand?

Magic sand (also known as hydrophobic sand) is mainly known as a gimmick that you can buy in toy stores or via the Internet (figure 1), but chemistry teachers have known about it for many years and the science behind the toy has a range of real-world uses.

Image courtesy of Benoit Rochon; image source: Wikimedia Commons

REVIEW

- Chemistry
- Ages 14–18

This article describes an activity from the TEMI project, which aims to teach science using the IBSE approach, starting from little mysteries, magic or myths. The proposed approach is friendly and engaging, but it is also effective in leading students through a rich learning route, where they can explore a methodology similar to those used in real scientific research. Moreover the addressed topics (e.g. chemical bonds, the properties of water molecules, and organic chemistry), which are often perceived by students as heavy and boring, emerge spontaneously as part of the inquiry into the mysteries of magic sand.

For these reasons I recommend the article to science teachers looking for an inspiring way to introduce organic chemistry to students aged 14–18. The web references are also valuable for discovering other resources from the TEMI project and to stimulate teachers to use acting and storytelling in science teaching.

Giulia Realdon, Italy

Chemistry

Image courtesy of Johanna Dittmar

Figure 1: Magic sand as a toy

Unlike normal sand, magic sand has a hydrophobic surface that repels water, so it does not get wet. Instead, magic sand clumps together under water and behaves unlike normal sand. Although some versions are sold as a toy, hydrophobic sand is also produced industrially and is used for water sealing (e.g. foundations) or for collecting oily impurities or small spills. Another intriguing application can be found in pet stores under the brand name Kit4Cat. This product is designed to collect cat's urine for medical examinations in a way that the cat finds less stressful than the alternative of a catheter. Many videos on magic sand can be found on Youtube[w1].

Image courtesy of Dvora Katchevich, Malka Yayon and Ran Peleg

Ran Peleg presenting the Magic Sand Mystery at the TEDx teacher outreach event at the Weizmann Institute in Israel[w1]

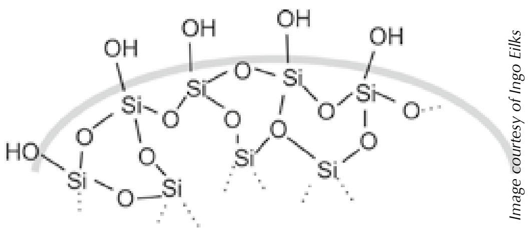


Image courtesy of Ingo Eilks

Figure 2: The chemical surface of regular sand

One way to create magic sand is to treat normal sand with trimethylsilanol ($((CH_3)_3SiOH)$) vapour. The trimethylsilanol forms covalent bonds with the hydroxyl (–OH) groups on the sand molecules' surface, replacing the hydrophilic –OH groups with hydrophobic siloxaneones.

Another method is to coat the sand particles with extremely thin layers of hydrophobic material such as wax, resin, bitumen or plastic. In this method the hydrophobic coating forms intermolecular interactions (not covalent bonds) and is thus less resilient to hydrophobic solvents (such as acetone). The latter method is more economical and if you cannot find magic sand to buy, you can make your own using normal sand and a waterproofing spray.

The mystery of the magic sand

Within the context of the science-education project TEMI (Teaching Enquiry with Mysteries Incorporated), we invented a story to be used in the 'engage' phase to increase students' interest by creating a personal context and making learning more meaningful. The TEMI team in Israel proposed the story of James (see box).

Materials

Each student, or group of students, will need:

- One tablespoonful (15 ml) of normal sand
- One tablespoonful (15 ml) of magic sand
- 50 ml of water
- Two 100 ml beakers
- Two droppers

Students may also request different solvents such as oil, acetone, ethanol, hexane or liquid soap.

Safety note: Some of these solvents are highly flammable and care should be taken to follow local safety regulations. See also the general *Science in School* safety note, online.

Image courtesy of William Cho; image source: Wikimedia Commons

Procedure

1. Introduce the students to the mystery of magic sand by telling the story of James (see box). This is the 'engage' phase.
2. Give the students a sample of the normal sand, and a sample of magic sand, putting each into a 100 ml beaker.
3. Provide water and droppers and ask the students to build sandcastles with both samples by wetting the sand. Alternatively, the teacher can demonstrate the behaviour of the magic sand, as shown online[w1].
4. Based on the story, the students will start to compare the magic sand with the normal sand. During this 'explore' phase (see the box for learning phases), the students investigate the behaviour of the magic sand using water and various other liquids, thus developing a feeling for the differences between hydrophilic and hydrophobic substances.
5. Provide access to the other liquids suggested above so that the students can see how the two types of sand might react to them.

About what happens

In the 'explain' phase, help the students to learn about intermolecular interactions, especially hydrogen bonds. Normal sand can form such bonds, since the surface is polar (see figure 2), and so the water creates a connection between the sand grains that can hold the grains together.

Magic sand is different. The surface of the grains of magic sand is hydrophobic (apolar), so hydrogen bonds cannot form between the sand particles or with water molecules. The sand repels water, but can be 'wetted'

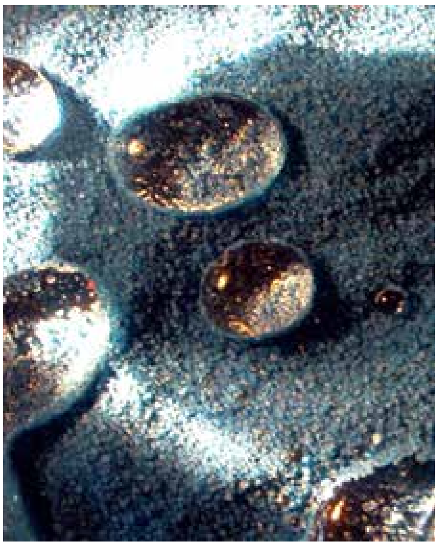


Image courtesy of Steve Jurvetson; image source: Wikimedia Commons

Water forms droplets to minimise contact with magic sand

BACKGROUND

James's story

James is an old man, but ever since kindergarten he has been crazy about building sand castles. Over the years, they got bigger and bigger, more detailed and more elaborate: he would make fairytale figures, animals and buildings. James became a champion sand-castle builder but one day he entered a competition that was a little different. He went to the beach and was assigned a small patch of sand. He took a bucket of water and poured it over the sand, but something really strange happened: the sand would simply not get wet. How can you build a sand castle when the sand won't get wet?

At first James was convinced he would lose the competition. But in the end he was able to build a sand castle.

Now it's your turn. James gave me a sample of the sand that I can give you. How do you think he managed to build a sand castle? Can you?

Chemistry

Figure 3: Students testing which solvent is best for building a sand castle with magic sand

Image courtesy of Dvora Katchevich

by nonpolar liquids, such as vegetable oil, which form van der Waals interactions with the magic sand's surface. This would of course be one solution to the problem of building a sand castle with the magic sand.

Ideas for follow-up activities

In the 'extend' phase, the students can search for optimal ways of building a sand castle. They may be encouraged to ask questions and to design their own experiments to answer them (figure 3), for example, what is the best solvent to use and at what ratio? For the 'evaluate' phase, they can also investigate the technical applications of hydrophobic sand, as briefly mentioned in this article. Students could then write a report on magic sand and its chemistry and uses, or create a useful guide on how to use magic sand.

BACKGROUND

The TEMI project

This activity was developed as part of the Teaching Enquiry with Mysteries Incorporated (TEMI) project, an inquiry-based science-education (IBSE) project funded by the EU under the 7th Framework Programme from 2013 to 2016. TEMI provides science teachers with tools needed to teach IBSE using unexpected and surprising phenomena and by implementing an innovative model for inquiry learning.

IBSE focuses on student inquiry as the driving force for learning. Teaching is organised around questions and problems in a student-centred process and students learn through and about scientific inquiry rather than by teachers presenting scientific content knowledge.

The problem-solving process in TEMI is based on the 5E model of inquiry learning, which structures the learning process into five phases: engage, explore, explain, extend and evaluate. This model was proposed in the 1980s in the USA and has since influenced science teaching in many countries (Bybee et al, 2006).

Information on all these aspects, instructions and examples can be found on the project website[w2]. The website also contains other media, such as instructions for lesson plan design, videos of mysterious phenomena, and a smartphone app for independent learning about amazing scientific phenomena.

Reference

Bybee RW, Taylor JA, Gardner A et al (2006) *The BSCS 5E instructional model: Origins and effectiveness.* Colorado Springs, CO, USA: Biological Sciences Curriculum Study

Web references

w1 – Watch the Youtube video of Ran Peleg presenting the Magic Sand Mystery at www.youtube.com/watch?v=soqnBdPOwoo

w2 – Further resources can be found on the TEMI project website (available in several languages): www.teachingmysteries.eu

Resources

For more ideas on using magic sand in the classroom, see:

Anonymous (2000) Magic sand. *Journal of Chemical Education* **77**: 40A. doi: 10.1021/ed077p40A

Goldsmith RH (2000) Illustrating the properties of magic sand. *Journal of Chemical Education* **77**: 41. doi: 10.1021/ed077p41

Vitz E (1990) magic sand: Modeling the hydrophobic effect and reversed-phase liquid chromatography. *Journal of Chemical Education* **67**: 512–515. doi: 10.1021/ed067p512

Ran Peleg, Dvora Katchevich, Malka Yayon and Rachel Mamlok-Naaman are based at the Weizmann Institute of Science, Israel, and Johanna Dittmar and Ingo Eilks are based at the University of Bremen, Germany. Together they developed this activity and are grateful for the generous support of the TEMI project by the European Union under the 7th Framework Programme for Research Funding, Science in Society, under Grant Agreement No. 321403.

Kinder eggs and physics?

These simple physics experiments add an extra surprise to your Kinder Surprise chocolate eggs.

By Ľudmila Onderová and David Featonby

Most people are likely to have come across Kinder Surprise® chocolate eggs. These hollow chocolate eggs contain a surprise, in the form of a small toy (figure 1), hidden inside a plastic egg-shaped container. However, not everybody realises that the plastic inner containers can also be used in simple physics experiments.

The experiments presented here, which are quick and easy to do and use readily available materials, challenge students to predict and explain the results. They can be used as teacher demonstrations or experiments for small groups of students. Depending on the level of explanation provided, the activities

Image courtesy of Jozef Ondera

Figure 1: A Kinder Surprise egg and a selection of the toys that can be found within

can be used with children as young as seven or as old as 16.

A self-righting toy

The shape of the plastic egg can be exploited to create a well-known children's toy, a self-righting dummy.

Materials

- A plastic container from a Kinder egg
- Plasticine® or other modelling clay
- A small, heavy object such as a metal nut or small magnet
- Optional: pencils and stickers to decorate the egg

Procedure

1. Use the Plasticine to fix the heavy object into the bottom of the plastic egg.
2. Close the egg.
3. Decorate the outside of the egg (optional, figure 2).
4. Push the egg: it should right itself easily because its centre of gravity has been lowered by the additional weight.

A demonstration of buoyancy

Demonstrate how the floating behaviour of the plastic eggs depends on their density.

Materials

- 3 plastic containers from Kinder eggs
- A large bowl of water
- Salt solution (NaCl, at least 3% *w/v*)

Procedure

1. Fill one plastic egg with pure water (to fill it, submerge the open egg in water and close it there).
2. Fill another egg with the salt solution.
3. Keep the third egg empty, i.e. filled with air.
4. Put the three eggs into the bowl of water and observe their behaviour.

One egg will float on the surface of the water, another will sit just below that level, and the third will sink to the bottom. Present this experiment to students as a mystery problem– their task is to explain the different behaviours of the eggs (figure 3). The students could do some further investigative work by putting different numbers of small coins into the eggs and noting the floating depth.

About what happens

When solving this mystery, students soon discover that the eggs are of different weights and hence different masses. Since the volume of the eggs is the same, it must be their density that is causing the difference in behaviour. The highest density belongs to the heaviest egg (the one filled with salted water), and since its density is greater than the density of the water in the vessel, the egg

REVIEW

- **Physics**
- **Gravity**
- **Buoyancy**
- **Pressure**
- **Friction**
- **Ages <11–16**

What an interesting and innovative way to investigate some of the most fundamental concepts of physics! The activities can be used to carry out investigations into, for example, the centre of gravity, stability, resultant force and pressure in liquids.

All the materials required are readily available and the instructions are easy to follow, making the activities suitable for students to perform in groups. Why not ask the students to predict what will occur, investigate, observe what happens and then reflect on their findings? This can be a fun and playful way to eliminate misconceptions and learn what is behind behaviour that is usually taken for granted.

I am sure that the students will enjoy collecting the Kinder Surprise plastic containers for their physics lessons – a great excuse to eat chocolate!

Catherine Cutajar, Malta

Image courtesy of Jozef Ondera

Figure 2: A self-righting dummy made from a plastic egg

Image courtesy of Jozef Ondera

Figure 3: The different behaviours of the loaded eggs

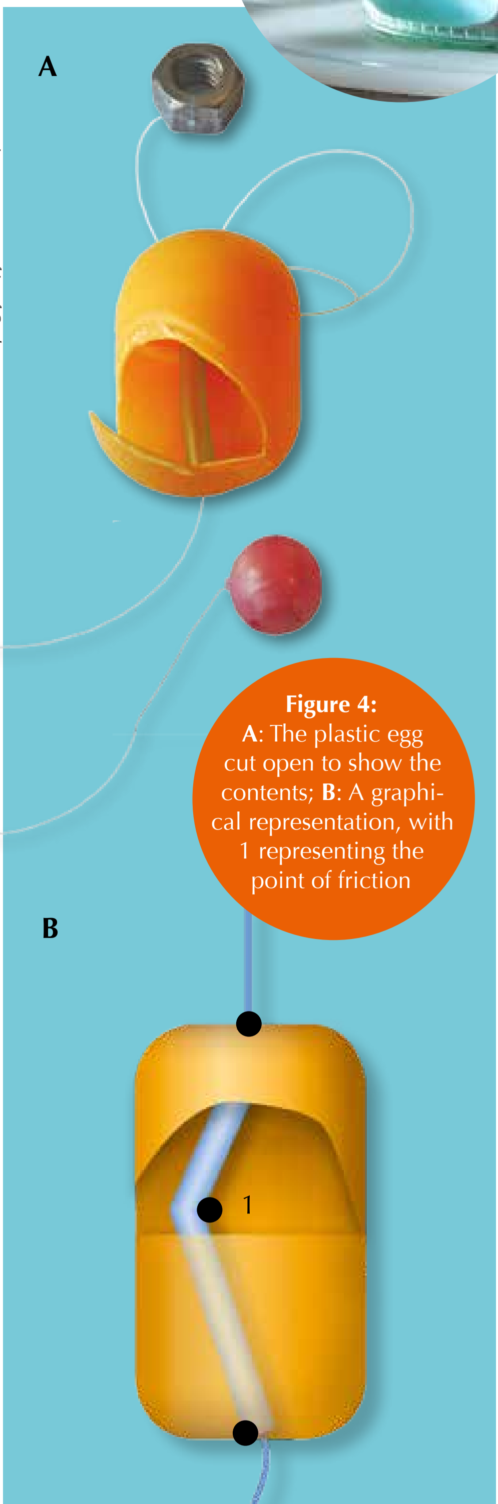


Image courtesy of Jozef Ondera

Image courtesy of Jozef Ondera and Nicola Graf

Figure 4: **A**: The plastic egg cut open to show the contents; **B**: A graphical representation, with 1 representing the point of friction

sinks to the bottom. The egg filled with pure water has approximately the same density as the water, so it hovers just below the water surface (with the plastic of the container being sufficiently light to hold it there). Finally, the egg filled with air has a lower density than water, so it floats on the water.

The mysterious motion of a Kinder egg

Puzzle your students with the effect of friction inside the plastic egg.

Materials

- A plastic container from a Kinder egg
- Fine cotton or nylon thread
- A steel ball with a hole in it (or a nut)
- A wooden or cork ball with a hole in it
- A short length of bent hose or a plastic drinking straw, somewhat longer than the plastic egg
- A pair of scissors or other sharp implement to pierce the plastic egg

Procedure

To prepare the experiment:

1. Make holes in both ends of the plastic egg.

Image courtesy of Jozef Ondera

Image courtesy of Jozef Ondera

Figure 5: **A**: The plastic egg slides down to meet the wooden ball; **B**: With the steel ball below, the egg remains part-way down the thread.

2. Pass the thread through one hole, through the bent hose or drinking straw, then through the other hole (figure 4).
3. Close the egg.
4. Attach the steel ball (or the nut) to one end of the thread and the wooden or cork ball to the other end.

To perform the experiment:

1. Ask your students to hold the steel ball in their hand and let the egg (or the nut) hang down.

   The egg slides down the thread towards the wooden or cork ball (figure 5A).
2. Your students should then repeat the experiment, changing the position of the balls so that they are holding the wooden or cork ball.

   This time, the egg does not move down but stays in a stable position on the thread (figure 5B).
3. Ask your students to explain what they observe. What is happening inside the egg?

About what happens

When the light wooden or cork ball hangs below the egg, the thread is not under significant tension and there is little friction between the thread and the hose (figure 4B), thus the egg can move easily. If we turn the whole system upside down so that the steel ball hangs down, the thread is under significant tension and presses onto the angle of the bent hose (figure 4B); this significantly increases the frictional force so that the egg cannot move any more.

A similar effect could be obtained in other ways, and it might be interesting to ask your students to discover them: to create the same resultant behaviour but with a different method.

Against the flow

Demonstrate how a difference in pressure causes the plastic egg to float against the flow of water.

Figure 6: Against the flow: the plastic egg floats on the water instead of falling out of the tube.

Image courtesy of Jozef Ondera

Materials

- A plastic container from a Kinder egg
- A long transparent tube that is closed on one end, e.g. a measuring cylinder. Its diameter should be slightly larger than that of the plastic egg
- Water

Procedure

1. Put the empty egg into the tube so that it falls to the bottom.
2. Start pouring water into the tube.

   The egg rises up the tube.
3. Completely fill the tube with water, cover the top with your hand and turn the tube upside down.
4. Hold the tube in an upside-down position and remove your hand, allowing the water to flow out.

   Instead of falling out of the tube, the egg floats on the water (figure 6).

A Kinder Surprise egg

Image courtesy of Jozef Ondera

About what happens

Once the system is upside down, water begins to flow around the egg. Thus the egg is effectively surrounded by water. Below the egg is atmospheric pressure; above the egg, the pressure is equal to atmospheric pressure minus the pressure of the water surrounding the egg. Hence the egg experiences an up-thrust equivalent to this pressure difference. Put another way, because the water surrounds the egg, the egg will float upwards.

The egg equilibrium

Demonstrate how moving the centre of mass changes the equilibrium position of the plastic egg.

Materials

- A plastic container from a Kinder egg
- A water-proof marker
- Approximately 30 cm of thin wire
- A non-absorbent object, the right size and shape to fit firmly into one end of the plastic egg and with a density greater than air and less than water (e.g. expanded polystyrene)
- A transparent container of water, e.g. a measuring jug
- A pair of scissors or other sharp implement to pierce the plastic egg
- Water

Figure 8: The plastic egg turning upside down in water

Image courtesy of Jozef Ondera

Image courtesy of Jozef Ondera

Procedure

To prepare the experiment:

1. Using the water-proof marker, mark each end of the egg (e.g. a circle on one end and a cross on the other). (If you are using the old design of the Kinder egg, see figure 7, you can simply use two halves of different colours.)
2. Pierce holes on both sides of the middle of the plastic egg. Pierce additional holes at both ends of the plastic egg.
3. Wedge the non-absorbent object firmly into one half of the plastic egg.
4. Thread the wire through the holes and twist the ends together to make a handle, then close the egg.

To perform the experiment:

1. Holding the egg by the wire, note which mark (e.g. circle or cross) is on top.
2. Push the egg to set it swinging.

   The egg returns to its previous position, with the same mark on top.
3. Immerse the egg in the jug of water. As the water enters through the holes in the egg, the egg turns upside down (figure 8).
4. Remove the egg from the water.

As the water flows out of the egg, the egg returns to its original position.

Figure 7: The orange egg is the new (hinged) design; the green egg is the old (two-part) design.

Image courtesy of Jozef Ondera

About what happens

In air, the egg is in a stable equilibrium position with the non-absorbent object in the lower half of the egg: the centre of mass is below the axis of rotation, which passes through the pivot. Thus when the egg is deflected from its equilibrium position, the moment of the gravitational force with respect to the rotational axis causes the egg to return to its original position.

When the egg is submerged, water enters the egg (as can be seen by the escaping bubbles of air), but the non-absorbent object ensures that only the upper half of the egg can fill with water. As the upper half becomes heavier than the lower half, the position of the centre of mass changes and the egg rotates, so that the centre of mass is once more below the axis of rotation.

Kinder-egg circus artist

Can your students discover what makes the plastic egg turn somersaults?

Materials

- Per group of students, one plastic container from a Kinder egg
- A selection of objects of different shapes (including balls), sizes and weights that are small enough to fit into the plastic egg
- An inclined plane

Procedure

1. Place the pre-prepared plastic egg onto the inclined plane and observe your students' amazement: instead of simply rolling down the slope, the egg turns end over end, doing somersaults like a circus artist!
2. Give each group of students a plastic egg and a selection of objects, and ask them to reproduce the behaviour of the egg you demonstrated.

   Alternatively, you can give them the pre-prepared egg as a 'black

Physics

Image courtesy of Jozef Ondera

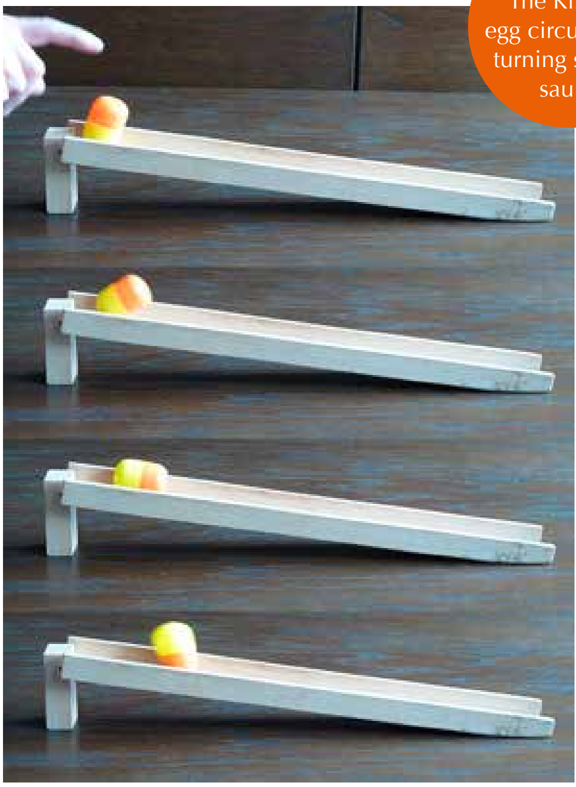


Figure 9: The Kinder-egg circus artist: turning somersaults

box' and ask them to explain its behaviour without opening it.

By shaking and turning the 'black box', the students will realise that there is a round object inside the egg. By putting different balls into an empty egg, they will find a ball of the right size and sufficient weight to make the egg to turn somersaults. Then they should be able to explain the behaviour.

About what happens

When the egg is placed on the inclined plane, the ball inside will, as a result of gravity, roll down to the rounded end of the egg. This causes the upper end of the egg to lift up and the whole egg (the circus artist) to overturn. The ball inside the container will then roll down again, causing the egg to somersault further.

Your ideas?

We hope that our suggestions have given you some ideas for your own experiments. Why not leave a comment on the online version of this article, telling us how you used our ideas and what other experiments you tried? Did they work well? What could have been improved?

Acknowledgement

This article has been adapted from an original paper in *Physics Education* (Onderová & Featonby, 2015).

Reference

Onderová L', Featonby D (2015) Kinder eggs and physics? *Physics Education* **50(1)**: 8–14

Resources

Further toys and simple contraptions for use in physics lessons are described in:

Aref H, Weaire D, Hutzler S (2007) Toying with physics. *Europhysics News* **38(3)**: 23–26

Fort J, Llebot JE, Saurina J et al (1998) A counterintuitive toy: the bird that never falls down. *Physics Education* **33**: 98–101

Featonby D (2005) Toys and physics. *Physics Education* **40(6)**: 537–543

Güémez J, Fiolhais C, Fiolhais M (2009) Toys in physics lectures and demonstrations – a brief review. *Physics Education* **44(1)**: 53–64

Onderová L (2009) Physics: a black box? *Science in School* **12**: 40–43. www.scienceinschool.org/2009/issue12/blackbox

Tifi A, Natale N, Lombardi A (2006) Scientists at play: teaching science process skills. *Science in School* **1**: 37–40. www.scienceinschool.org/2006/issue1/play

Tifi A, Natale N, Lombardi A (2006) Scientists at play: contraptions for developing science process skills. *Science in School* **2**: 20–23. www.scienceinschool.org/2006/issue2/play

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David Featonby 'retired' from school physics teaching after 35 years in the classroom, and until 2011 was a teacher network co-ordinator for the UK's Institute of Physics. He has represented the UK at Science on Stage and now works voluntarily with the international Science on Stage (Europe) committee as UK representative and member of its European executive board. David is the author of various hands-on articles in *Science in School* and *Physics Education* and has led workshops at many conferences throughout the UK and Europe. He is particularly interested in showing the physics in everyday things to the public, whatever their age.

Designing a flood-proof home, Sandlings Primary School, UK

Beat the Flood

This challenge will enable pupils aged 7–14 to discover the impact that flooding has on people's lives, and how science and technology can mitigate its effects and help find potential solutions.

By Julie Brown

Imagine living with the danger that your home could be flooded at any time. Our climate is changing and for many people living near riverbanks, the fear of flooding is constant. 'Beat the Flood'[w1] is a challenge for pupils aged 7–14 that will enable them to discover the impact that flooding has on people's lives, and how science and technology can mitigate its effects and help find potential solutions.

Working in teams, the children design and build a model of a flood-proof home for their family on the fictitious island of Watu, then test it by putting it in water and squirting it with a hose pipe. They consider how

REVIEW

- **Physics**
- **Geography**
- **Maths**
- **Economics**
- **Ages 11–19**

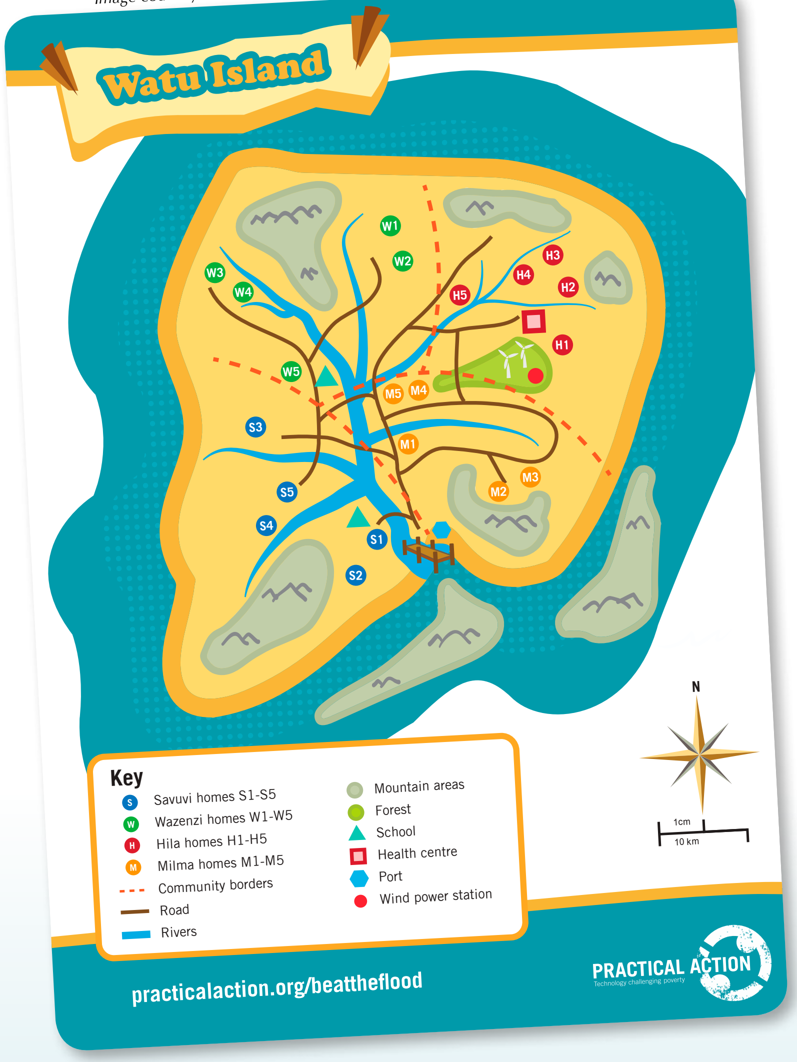
This article is a great opportunity to collaborate with other teachers of your school. It could be used as part of a physics lesson. However, pupils also need to use knowledge from different disciplines such as geography, science, and maths, and make complex decisions integrating many factors such as cost and sustainability. Therefore, it is ideal for interdisciplinary teaching and it could foster some interesting discussions on how several science or non-science subjects (e.g. geography, maths and economics) could work together.

Beyond this, it presents a novel way for students to construct their own knowledge and be engaged in meaningful inquiry-based activities.

Christiana Th Nicolaou, Saint Demetrios Elementary School, Nicosia, Cyprus flooding affects the whole community, and work out where the best place for a home would be. The challenge is suitable for a whole-day activity, or can be divided into several activities spread over many classes.

This activity encourages pupils to work as a team and enables them to take on specific roles within a group, such as team leader, designer, researcher or architect. Pupils also need to use knowledge from different disciplines such as geography, science and maths, and make complex decisions by integrating many factors such as cost and sustainability. In addition to giving them a flavour of the different technology-related careers they could get into, this challenge will also lead pupils to realise that there is no 'perfect house' that would solve the global problem of flooding: helping people access appropriate, sustainable technology is the best way to use science and technology to combat poverty.

Image courtesy of Practical Action



Beat the flood: action!

The activity unfolds in three steps:

1. The pupils test potential modelling materials to determine how sturdy and waterproof they are.
2. The pupils test the resistance of various structures to water, movement and wind.
3. Using their previous conclusions, the pupils build a model house using the structure and materials that they think will be most resistant to flooding.

Materials

To test the strength of the materials, each group will need:

- Two sets of clamps and stands
- A set of ten 10 g weights
- Samples of the materials described in the materials cards[w2]: cling film, foil food trays, lolly sticks, straws, grass, aluminium foil, plastic bags, clay

To test the absorbency of the materials, each group will need:

- One stand with clamp
- One timer
- Six 100 ml glass beakers
- Food colouring
- Water
- Ruler
- Samples of the materials described in the materials cards[w2]: cling film, foil food trays, lolly sticks, straws, grass, aluminium foil, plastic bags, clay

To test the strength of the structures, each group will need:

- One Structures template 1 sheet[w2]
- One Structures template 2 sheet[w2]
- Drinking straws
- Modelling clay
- Digital scales
- Sticky tape
- Hairdryer
- Glue gun
- Scissors

Throughout the activity you will need:

- The teacher's guide[w3], containing a detailed description of the lesson plan and the activities
- The pupils' worksheet[w2], containing the map of Watu Island, the community cards, detailed descriptions of the materials available, and the tables to record results of testing

Images courtesy of Practical Action

- The presentation[w4] to stimulate the discussion. You could view it in PowerPoint or print out copies of the slides.

Procedure

Before the class starts, you may find it useful to cut and laminate the various cards (map of Watu, community and materials cards), as well as the cube and pyramid structures from the structures template sheets, as they will be used a lot.

General discussion

Encourage your pupils to discuss flooding, how widespread it is, how it affects different communities and people, and how its effects can be mitigated. In addition to the PowerPoint presentation, you can also use a video[w5] to show a practical example of flooding in Bangladesh.

Research ideas and information

1. Divide your class into small groups and give an A3 size map of Watu Island and one card from the Watu community cards[w2] to each group.
2. Working in groups, pupils should look for information on how and where to build the most efficient flood-resistant house for their own community. You may use the *Learning from others* sheet in the pupils' worksheets[w2] and the poster[w5] to enrich their research.

Depending on the time available you may implement a combination of the activities below, before building your own model house.

Image courtesy of Practical Action

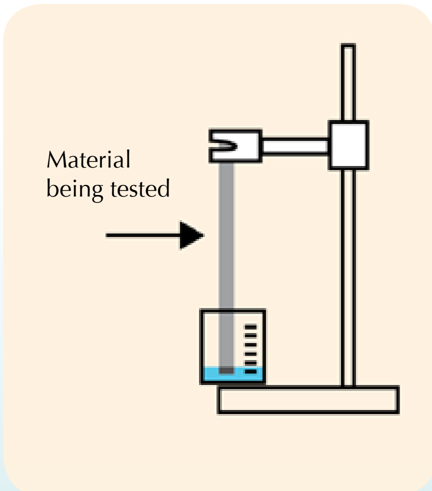


Image courtesy of Practical Action

Experiment to test the absorbency of materials.

Test the absorbency of materials

The aim of this activity is for pupils to determine which modelling materials are the most water-resistant and would therefore be good for a flood-proof house. It takes approximately 30 minutes.

1. Set up clamp stands so they are about 15 cm high.
2. Measure and cut a standard sample of 15 cm x 2 cm for each material available to ensure a fair test.

Image courtesy of Practical Action/Bren Hellier

Testing tensile strength of materials at Judgemeadow Community College, UK

3. Attach the sample to the stand and clamp so it is held in a vertical position over a beaker containing coloured water, 25 cm deep.
4. Start the timer once the material is lowered into the water.
5. Leave it in for 3 minutes then remove from the water.
6. Record how high up the material the water was absorbed, using the table provided in the pupils' worksheets.
7. Repeat the tests twice more with fresh pieces of the same material, and take an average result.

Test the strength of materials

The aim of this activity is for pupils to determine which modelling materials are the strongest and would therefore be most resistant to wind and rain and make a good flood-proof house. It takes approximately 30 minutes.

1. Set up the clamps on the stands about 15 cm apart, with clamps facing each other.
2. Measure and cut a standard sample of 15 cm x 2 cm for each material available to ensure a fair test.
3. Clamp one sample of material between the two stands.
4. Add 10 g weights to the midpoint of the material until the material bends or breaks.
5. Record the weight necessary to break or bend the material in the table given in the pupils' worksheets.
6. Repeat the test two more times with fresh pieces of the same material and take an average result.

Test the strength of different structures

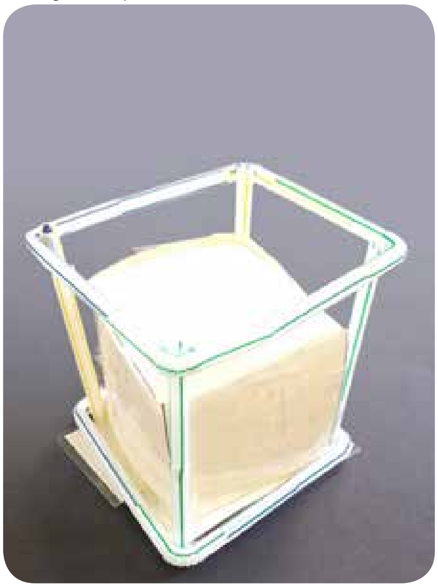
The aim of this activity is to determine what kinds of structure resist

Images courtesy of Practical Action

Image courtesy of Practical Action

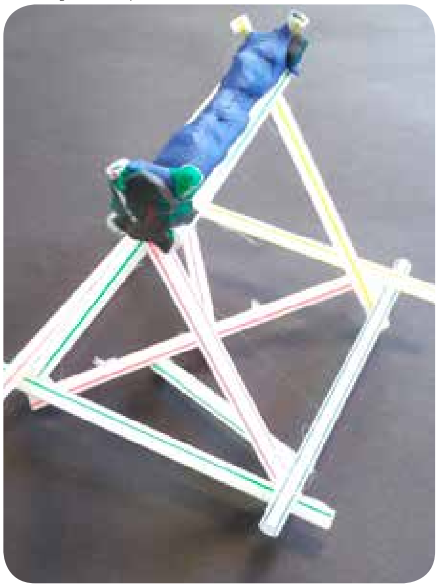
Pupil at Northlands Primary School, UK, building a model house

Image courtesy of Practical Action



How strong is the structure with the clay inside the frame?

Image courtesy of Practical Action



How strong is the structure with the clay on the frame?

movement and therefore potential damage from water and wind. Use it to emphasise the importance of understanding the local conditions when designing houses. It takes approximately 30 minutes.

1. Use the laminated structures from structures templates 1 and 2 in the pupils' worksheet[w2] to create pyramids and cubes. For each type of structure, create one with 10 g of modelling clay inside and one without.
2. Develop a range of frame structures using the straws, some without weight and some with 10g of modelling clay added.
3. Develop a structure that combines a frame with straws and laminated shapes.
4. Test the resistance of the structures to water: put them in a tray of shallow water and simulate waves by shaking them.
5. Test the resistance of the structures to wind: put them on a dry surface and blow a hairdryer on them.

Consider cost and sustainability

By considering cost and sustainability, pupils will touch on some of the real-life compromises that engineers face. You could give the pupils a fixed budget or just ensure that they appreciate how important cost and sustainability are in their design.

Hand out the material cards and summary of costs sheets (in the pupils' worksheets[w2]). These will help the pupils to make the link between modelling materials and the real-life materials they represent. This activity should take approximately 20 minutes.

Design, build, test and evaluate the models

1. Using the results of their experiments and information from the materials cards, pupils should work in small groups to design their house using the materials and the structure that they feel are most appropriate. Allow one hour for the pupils to complete the design specification, design ideas and final design worksheets (in the pupils' worksheets[w2]).
2. Allow one hour for the pupils to build their model based on the design created in step one.
3. Pupils should test their models by standing them in a tray half full with water and squirting them with a hosepipe.
4. After testing, pupils may redesign their models if necessary.
5. In groups, pupils should evaluate their work then feed back to the rest of their class. They can use the *How well did they do?* worksheet in the pupils' worksheets[w2] to rate other groups' work, so that an overall winning design can be chosen by the class.

Web references

w1 – The web page of the 'Beat the Flood' challenge includes all the necessary teaching materials, as well as examples of pupils' work and links to case studies of the challenge being run in schools. See: www.practicalaction.org/beattheflood

w2 – The pupils' worksheet contains all the information that the pupils will need at each step of the activity, including the various tables to fill in. You can download it from the *Science in School* website: www.scienceinschool.org/2015/issue32/PA#w2, or from here: http://practicalaction.org/beatthefloodpupils

Image courtesy of Practical Action/Bren Heller

Pupils at Sandlings Primary School, England, testing their flood-proof house

w3 – To read the detailed descriptions of the lesson plan and the activities, download the teacher's guide from the *Science in School* website: www.scienceinschool.org/2015/issue32/PA#w3It is also available here: http://practicalaction.org/beatthefloodteachers

w4 – The PowerPoint presentation offers a structure for a classroom discussion on flooding. You can download it from the *Science in School* website: www.scienceinschool.org/2015/issue32/PA#w4or from here: http://practicalaction.org/beatthefloodteachers

w5 – Watch a video showing how Practical Action designed houses for a region exposed to flooding in Bangladesh: www.practicalaction.org/video-beat-the-flood

Resources

Watch a video by children's TV celebrity Ortis Deley explaining how using the right materials is a vital part of helping a community become flood-proof: www.practicalaction.org/video-beat-the-flood

Flooding is also an issue in Europe and solutions are starting to emerge. The BACA architecture studio in London, UK, is building the first amphibious house on the Thames: www.baca.uk.com/index.php/living-on-water/amphibious-house

Beat the Flood is one of several science, technology, engineering and mathematics challenges offered by Practical Action. Each is set in a different scenario and involves pupils working together to find a solution to a problem faced in the developing world. For more information, visit: www.practicalaction.org/stem

A range of other resources that help teachers embed global learning into their science teaching can be found at: www.practicalaction.org/schools

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Julie Brown is Practical Action's education manager. She has more than 20 years, experience working in the education sector at both primary and secondary levels. Currently leading an EU-funded project involving six partners and four countries, Julie is passionate about encouraging teachers in Europe to integrate global issues into science and design and technology teaching. She believes that when young people make the link between science and poverty reduction through engaging practical activities, they are more likely to develop a positive attitude towards global poverty reduction, and a desire to make a difference themselves.

Image courtesy of Practical Action

Designing a flood-proof house based on previous observations

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Safety note

For all of the activities published in *Science in School*, we have tried to check that all recognised hazards have been identified and that suitable precautions are suggested. Readers should be aware, however, that errors and omissions can be made, and safety standards vary across Europe and even within individual countries.

Therefore, before undertaking any activity, readers should always carry out their own risk assessment. In particular, any local rules issued by employers or education authorities MUST be obeyed, whatever is suggested in the *Science in School* articles.

Unless the context dictates otherwise, it is assumed that:

- Practical work is carried out in a properly equipped and maintained science laboratory
- Any electrical equipment is properly maintained
- Care is taken with normal laboratory operations such as heating
- Good laboratory practice is observed when chemicals or living organisms are used
- Eye protection is worn whenever there is any recognised risk to the eyes
- Pupils and / or students are taught safe techniques for activities such as handling living organisms, hazardous materials and equipment.

Credits

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EIROforum

***Science in School* is published and funded by EIROforum, a collaboration between eight of Europe's largest inter-governmental scientific research organisations, which combines the resources, facilities and expertise of its member organisations to support European science in reaching its full potential. See: www.eiroforum.org**

CERN

The European Organization for Nuclear Research (CERN) is one of the world's most prestigious research centres. Its main mission is fundamental physics – finding out what makes our Universe work, where it came from, and where it is going. See: www.cern.ch

EMBL

The European Molecular Biology Laboratory (EMBL) is one of the world's top research institutions, dedicated to basic research in the life sciences. EMBL is international, innovative and interdisciplinary. Its employees from 60 nations have backgrounds including biology, physics, chemistry and computer science, and collaborate on research that covers the full spectrum of molecular biology.
See: www.embl.org

ESA

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world.
See: www.esa.int

ESO

ESO is the foremost inter-governmental astronomy organisation in Europe and the world's most productive ground-based astronomical observatory by far. It operates telescopes at three sites in Chile – La Silla, Paranal and Chajnantor – on behalf of its member states. At Paranal, ESO's Very Large Telescope is the world's most advanced visible-light astronomical observatory. ESO is a major partner in the revolutionary astronomical telescope ALMA and is building the 39-metre European Extremely Large Telescope, the E-ELT. See: HYPERLINK "http://www.eso.org/" www.eso.org

ESRF

The European Synchrotron Radiation Facility (ESRF) is one of the most intense sources of X-rays in the world. Thousands of scientists come every year to ESRF to carry out experiments in materials science, biology, medicine, physics, chemistry, environmental science, and even palaeontology and cultural heritage. See: www.esrf.eu

EUROfusion

The European Consortium for the Development of Fusion Energy (EUROfusion) comprises representations of 28 European member states as well as Switzerland and manages fusion research activities on behalf of Euratom. More than 40 European fusion laboratories collectively use the Joint European Torus (JET), which has remained the world's largest magnetic fusion device since it was built in 1983. Smaller national experiments in Germany, Switzerland, and the United Kingdom complement the experimental programme. The aim is to realise fusion electricity by 2050.

European XFEL

The European XFEL is a research facility currently under construction in the Hamburg area of Germany. It will generate extremely intense X-ray flashes to be used by researchers from all over the world. See: www.xfel.eu

ILL

The Institut Laue-Langevin (ILL) is an international research centre operating the most intense steady neutron source in the world. Every year, more than 800 experiments are performed by about 2000 scientists coming from all over the world. Research focuses on science in a variety of fields: condensed matter physics, chemistry, biology, nuclear physics and materials science. See: www.ill.eu

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