Introduction ...
Welcome to Teach Better Biology, Chemistry and Physics!

Each topic within this online service provides you with ready-made resources to develop different teaching skills, which will help you to improve students’ understanding, leading to better results.

- **Preparing to teach** – provides an overview of the topic area at a glance and includes notes on learning objectives and teaching strategies
- **Unpicking misconceptions** – covers most common misconceptions, explains where they may have come from and works through strategies to overcome them
- **Engaging ICT** – provides ideas and suggestions for using technology effectively in the classroom
- **Improving practical work** – encourages maximum exposure to practical work throughout the year with new ideas and guidance on teaching key practicals
- **Boost your subject knowledge** – aimed specifically at teachers, not students, to facilitate a deeper understanding of the key concepts prior to teaching the topic
- **Tackling differentiation** – includes advice on teaching this topic to mixed attainment groups, or specifically to low attaining, or advanced students
- **Understanding the nature of science** – includes teacher notes and student activities to encourage students to think about the world of science
- **Getting creative** – gives ideas and guidance on teaching creativity in thinking and applying ideas in the context of science

The author team:

- **Michelle Austin** is an experienced Chemistry teacher (AST) and freelance writer of educational materials including local authority APP resources and G&T materials
- **Nigel Heslop** has over thirty years teaching experience in Chemistry and is a highly experienced author of science resources including a best-selling KS3 Hodder Science series
- **Kiran Locke** is a freelance writer and science teacher, with a Biology background and a special interest in EAL and SEN teaching
- **John Mynett** has over twenty years teaching experience in Biology and has spent many years running successful teacher training courses for leading educational organisations
- **Gareth Price** is a highly experienced author, science educational consultant, and senior lecturer at the Centre for Science Education
- **Beverly Rickwood** is an experienced freelance writer and teacher trainer, with over twenty years teaching experience in Physics
- **Nicky Thomas** is an experienced teacher and author of educational resources, and is a trainer for the IoP Stimulating Physics Network
- **James Williams** is a freelance educational trainer and consultant, with over ten years experience in teacher education and is a highly experienced author of educational resources, including a best-selling KS3 Hodder Science series
However confident you are with understanding a topic, teaching that topic for the first time can be daunting. This is particularly true if the current preferred approach to the topic is different from the approach taken when you were taught it. This resource is designed to help you ensure you address the key issues around delivering each topic in an effective and engaging way. This will ensure you are confident that your learners are maximising their progress, understanding and enjoyment through the topic.

**Purpose of the resource:**
The purpose of this resource is to help you to plan how to teach the topic in an interesting and effective way. It does this by helping you to appreciate the key learning required, suggesting appropriate teaching methodology and also suggesting ways in which difficult concepts can be addressed.

**What the resource contains:**
- An overview of the topic.
- Key objectives for the topic.
- Learning outcomes related to each key objective.
- Information about what learners are likely to have studied before meeting the topic, the Key Stage 3 content related to the topic and how the topic is developed in Key Stage 4.
- Suggested teaching strategies including information such as:
  - Practical issues
  - Linking to theory
  - Models and analogies
  - Ways of making the topic real and relevant to learners
  - Any cultural or religious sensitivities to be considered

**When and how to use the resource:**
It would be beneficial to work through this resource as a whole before you start your planning for the topic. You can then return to each of the individual key ideas and objectives before addressing these in specific learning activities.

Though there is a specific resource for each of the topics in Key Stage 3, there will be some links between topics so you may wish to revisit earlier topics when preparing to teach other topics later in Key Stage 3.
Learners may have difficulty fully understanding science because they hold some misconceived ideas. The sources of these misconceptions are many and varied but what they all have in common is that they make learning and applying correct science more difficult. We may hold certain assumptions about the world while some of our learners hold quite different assumptions. It is therefore important that these misconceptions are identified and addressed promptly so that a real scientific understanding can be developed.

**Purpose of the resource:**
The purpose of this resource is to identify common misconceptions that impact on learners’ understanding of the topic, suggest reasons why these misconceptions have arisen and, more importantly, ways in which they can be corrected.

**What the resource contains:**
- Suggestions for how you may identify misconceptions.
- Key questions to assess understanding.
- A wide range of common misconceptions, their sources and suggestions for addressing these.
- The ‘big misconceptions’ discussed in depth. This part of the resource takes the form of PowerPoint slides with an associated voiceover. The voiceover is designed for you, the teacher, but the slides may be used directly with learners.

**When and how to use the resource:**
It would be beneficial to work through this resource as a whole before you start your planning for the topic. You can then return to each of the individual misconceptions as you plan each lesson and hence assure that these misconceptions are addressed.

You may wish to use the PowerPoint slides provided with your class to help learners overcome the ‘big misconceptions’ as they stand but they can be adapted if you wish to do so.

Though there is a specific resource for each of the topics in Key Stage 3, there will be some links between topics so you may wish to revisit earlier topics when preparing to teach other topics later in Key Stage 3. This resource is also a good place to start if you move on to teach any of these topics at Key Stage 4 as it will allow you to ensure that these misconceptions have been addressed before moving on to more complex theory and applications.

The suggested methods of identifying misconceptions in each topic can also often be applied to other topics. Overall these will provide you with a comprehensive toolkit that you can apply to different contexts.
Unpicking misconceptions

1 Identifying misconceptions

There are certain areas in the topic of reproduction that many students (and some teachers!) find difficult to talk about openly and so it can become difficult to challenge any misconceptions.

For this reason some misconceptions may never be fully dealt with.

The topic also deals with reproduction in plants and asexual reproduction – which are often regarded by students as far removed from human reproduction.

The concept of inheritance leads to numerous misconceptions that will be touched on here but dealt with in more detail in the Inheritance and variation topic.

- Key questions to ask to identify misconceptions

Why do organisms reproduce?

Emphasis should be placed on the idea that reproduction is a characteristic of life – a means of increasing numbers of cells in order to replace or repair tissues, or increase populations of organisms.

How do different organisms reproduce?

Make sure that students have a clear idea that reproduction involves many different methods. Reference should be made to reproduction in humans, but also the role of flowers needs to be emphasised as another method for reproduction.

Why does the body change at puberty?

Students should understand that puberty is simply a way of preparing the body for reproduction, both physically and emotionally.

What is the role of the menstrual cycle in reproduction?

The menstrual cycle should be introduced in terms of a monthly preparation for release of an egg and possible fertilisation.

2 Common misconceptions

“Sexual reproduction always involves copulation.”

Students often fail to distinguish between sexual reproduction and sexual intercourse – assuming that the former is always accompanied by the latter. By teaching that nearly all organisms reproduce sexually, it can be emphasised that copulation takes place only in a minority of species. Try to emphasise reproduction as a characteristic of life rather than just a characteristic of humans.
“Reproduction is all to do with having babies.”
Students often assume that reproduction is simply a way of increasing population size. Emphasis should be placed on the idea that cell division of body cells is also a form of reproduction and is essential for repair and growth of the body.

“Asexual reproduction is just done by bacteria.”
Sexual reproduction is better than asexual reproduction.’ The differences between asexual and sexual reproduction should be stressed and the advantages of each method highlighted. This allows discussion of how and why a wide range of organisms use asexual reproduction, including many plant and some animal species.

“Pollination and fertilisation are the same.”
Pollination involves the transfer of the male pollen grains to the carpel. Fertilisation is the process in which the male nucleus fuses with the female nucleus inside the egg cell.

“Women can only get pregnant at this time.”
Many misconceptions exist regarding when fertilisation can take place following sexual intercourse in humans. These can be addressed by giving the students a clear understanding of what happens during the menstrual cycle and the behaviour of egg and sperm during sexual intercourse.

“The developing foetus uses the mother’s blood.”
A common misconception is that the mother and foetus share a common blood supply. The structure and role of the placenta is an important focus for this topic.

‘I inherited my mum's eyes.’
Many students believe that characteristics have come from just one of the parents. It is important to point out that both parents contribute information (alleles) for every characteristic, but not all alleles are expressed or shown. More explanation of this will come when students study the topic on inheritance and variation.

“Males are always the dominant sex.”
By looking at reproductive strategies in a variety of organisms, students should become aware that male/female dominance is seen in very few species. It may be worth spending some time trying to define what male and female means (males produce small gametes whereas females produce large gametes).

3 Overcoming the big misconceptions

Follow the links below for presentations on overcoming these two big misconceptions.

▶ Misconception 1: I can only get pregnant after ovulation
▶ Misconception 2: Sexual reproduction doesn’t take place in plants

Once you have listened to the presentations, you can use the content of the slides to work through the misconceptions with your students.
ICT is now a feature of almost all classrooms and learning environments. In a space of ten years it has moved from a ‘room to go to’ with a set of fixed computers into an all-pervasive environment which students can enter through a range of devices from mobile phones through to internet-enabled televisions. In addition to this the students are evolving into producers using ICT not just to create laboratory reports or write essays but also to develop interactive activities for other students and develop their own understanding. This supports the constructivist model of learning which has proved so effective over the last ten years.

The benefits of using ICT in learning include:

- Increased motivation as the medium has an immediate attraction for students
- Personalisation and differentiation is increasingly possible with modern systems to ensure that students engage with the content that is most appropriate for them
- Immediate feedback as provided by some systems which is a great motivator and guide for students
- Increased involvement in learning as creative author packages allow students to become producers of materials rather than consumers

**Purpose of the resource:**
This resource looks at how you can encourage the pedagogically powerful, approach to using ICT by providing students with tasks where they have to engage with ICT to improve their learning. The resources are suitable for all teachers (you do not need to be an ‘ICT wizard’) and they can be adapted to be platform agnostic (they do not depend on a particular piece of software or system).

**What the resource contains:**
This resource is organised into two strands:

- ICT ideas suitable for a particular topic. These give general advice and suggestions for the types of activities that might work within a topic.
- Bespoke ICT activities designed for a particular topic. These are complete, ready-to-run activities that support learning and act as exemplars of good practice in ICT in learning. These lesson resources include all necessary digital files, student worksheets and full teacher guidance.

**When and how to use the resource:**
The dual structure described above means you can either take an activity off the shelf and use it as it stands or modify it to match your needs better. You might also take an approach developed in one particular context and use it to develop your own activities in another topic.
Friction — help or hindrance?
In this activity you are going to take photos to show everyday examples of when friction is useful and when it is not.

Your task
• Take photos of at least two everyday situations where friction is useful, and at least two situations where friction is unhelpful.
• Post your photos, with a brief reason for why they are helpful/unhelpful, on the class blog that your teacher will give you access to.

Some recommended ICT activities
• Students could use Google Earth to research data about the size of the force of gravity on different planets. Then they can use this data to calculate their weight on these planets, record it in an Excel spreadsheet and produce graphs to compare the differences. (This data can be found on the Web, websites, or other websites such as www.saturnsnews.com, search for “force of gravity”)
• Students could use graph paper to record the size of the force needed to push or pull different objects at the same time required.
• You could also use computer simulations to demonstrate balanced and unbalanced forces.

Activity 1: Friction blog
Students take photos using digital cameras, or mobile phones, to show at least two everyday examples of when friction is useful and at least two examples where it is not useful. They then upload their images, with reasons for their choices, onto a class blog.

Guidance
This activity uses a free blog service, if you wish, and you will need to have access to it before you start.

You will need to set up a class blog beforehand. This can be done very easily and quickly — just visit the site and follow the instructions.

http://skoolblog.org
http://skoolblog.org
http://skoolblog.org
http://skoolblog.org

Science teachers are being increasingly asked to teach outside their specialist area, especially at Key Stage 3. Also, even when teaching in an area where your knowledge is already secure, teachers can find that the approach to teaching their specialist area has changed since they were at school themselves. This can lead to us as teachers feeling less confident about our knowledge and understanding.

**Purpose of the resource:**
The purpose of this resource is to provide key knowledge of all the core areas of the topic it relates to. Not only does it provide the knowledge you require to teach the topic at Key Stage 3, the resource goes beyond this and explores how the topic develops at Key Stage 4, and in some cases beyond. This will help you to avoid the feeling that you are working one page ahead of the learners!

**What the resource contains:**
- A summary of the key concepts related to the topic so that you can see where you may need to improve your understanding before teaching
- An explanation of each of these key concepts, including any necessary mathematical relationships involved. These explanations take the form of PowerPoint slides with a voiceover commentary. Links between key concepts are also discussed where relevant.

**When and how to use the resource:**
It would be beneficial to work through this resource as a whole before you start your planning for the topic. You can then return to each of the individual concepts before addressing these in specific learning activities.

Though the PowerPoints are designed to help you, the teacher, they can be adapted if you wish so that relevant areas can be used with learners.

There is a specific resource for each of the topics in Key Stage 3, but there will be some links between topics so you may wish to revisit earlier topics when preparing to teach other topics later in Key Stage 3.

This resource is also a good place to start if you move on to teach any of these topics at Key Stage 4.
Example Boost Your Subject Knowledge

Boost your subject knowledge

Concept 3: The role of the placenta

It is important to recognise that in mammals the developing embryo or foetus is a separate entity from the mother. The only communication between the two is via the placenta.

After fertilisation, the zygote starts to divide to form a hollow ball of cells called a blastocyst. It is the outer cells of this structure that go on to form the placenta – growing into the lining of the uterus soon after implantation.

The placenta remains part of the developing foetus and acts as an interface between the blood of the foetus and the mother’s blood. Many tiny ‘fingers’ increase the surface area so that materials can be exchanged between mother and baby.

Oxygen passes from the haemoglobin in the red blood cells of the mother to the foetus. Similarly, waste carbon dioxide passes from the foetal blood to the mother. The placenta also receives other materials from the mother as they diffuse into the fetal blood, including minerals, vitamins and the products of digestion such as amino acids and glucose. Waste products such as urea are passed back to the mother. When the foetus and mother come into contact – to do so could cause clashing blood groups.

The foetus that relies so heavily on the mother’s body is entirely dependent on this support, protect and feed it during its crucial period of growth and development.

Placement forming from blastocyst cells

These finger-like projections of the placenta are packed with blood vessels, allowing exchange of material between the mother’s blood and the foetus.
The spread of ability and achievement within a typical science class of 13-years-olds could be the equivalent of four or five school years. On top of this wide range there may be issues concerned with:

- interest and involvement, (e.g. intelligent students who have no interest in the subject may extend this range),
- study skills or ancillary knowledge (e.g. dyspraxia or dyslexia),
- behaviour (e.g. lack of understanding or a feeling of progress in students can manifest as poor or disruptive behaviour)
- context issues external to school (e.g. Illness in the family, other disruptions or pressures at home, English as a second language).

All of these will potentially broaden the spread and while ability is often viewed as relatively stable, these interest and external issues can vary significantly from day to day and lesson to lesson. This means that differentiation is a key issue for all teachers whether working in streamed sets or mixed-ability groups.

**Purpose of the resource:**
The purpose of this resource is to offer advice on differentiation for teachers facing these issues through a collection of differentiated tasks focusing on key aspects of the topic area. These tasks provide ideas for teachers to develop and use the same principles in other areas as required.

**What the resource contains:**
This resource is organised into two strands:

- An overview of the topic area, looking at the areas where lower or higher attaining students might need extra support or encouragement
- Three bespoke activities taking a differentiated approach:
  - One activity for very low attaining students – this activity includes maximum scaffolding for the students
  - One three-tiered differentiated activity for the whole class – this activity can be used as a diagnostic tool to assess knowledge and understanding
  - One stretching activity – this activity is designed to challenge higher attaining students by providing a more complex task on the same topic

**When and how to use the resource:**
The dual structure described above means you can either take an activity off the shelf and use it as it stands or modify it to match your needs better. You might also take an approach developed in one particular context and use it to develop your own activities in another topic.

The activities will assume some prior teaching of the topic, so could be used one or two lessons into coverage of the topic, or they can be adapted to suit the progress of learning in your classroom. The stretching activities can be used for students who have no trouble with the topic.
Activity 1: Word map

Use the template on this sheet to create a word map for each of the following key words:

- melt
- evaporate
- condense
- freeze
- flow
- vibrate

Write the key word in the oval at the centre. You do not need to have something in every box.

Example of interactive activity

Activity 1 Question 1

Complete this paragraph about forces. Drag the words into the correct spaces.

Forces can be ___________ or pulls. We cannot ___________ them but we can ___________ their effects. An example of a force is a book falling to the floor when we drop it – this force is called ___________. We measure forces in units called ___________ using a ___________.

Options: feel, forcemeter, see, gravity, pushes, newtons
Practical work is popular with students and is routinely given as one of the attractions of science for students. Practical work is a motivator and this, in itself, has been shown to improve the attitude and achievements of students. The short message is that ‘practical work works’.

However, not all practical work is equally valuable. The *Improving Practical Work in Science* project found that many practicals were designed to produce given phenomena to record or known data to collect. These practicals do produce the increase in motivation but do not mine the useful aspects of practical work where students engage not just with equipment and techniques but with scientific concepts. Students should be encouraged to explore more, make mistakes, and find reasons why data may be confusing or difficult to interpret. This is more demanding for teacher and students but, ultimately, generates greater involvement and understanding.

**Purpose of the resource:**
Certain topics may initially seem more or less suited to practical work. This resource aims to encourage practical work that facilitates learning by providing a rich bank of practical work suggestions for any topic area. By providing teachers with core guidance and support, the resource aims to encourage even the least confident to engage with and discover the learning benefits of practical work.

**What the resource contains:**
This resource offers ideas for incorporating practical into all schemes of work with a clear aim for the practical as an every-day short skill-building exercise, a more involved activity where students have to adapt given methods or even full investigations where they may have to develop methods and analysis.

The resources also include
- a video of the set practical for teachers to watch with key advice on running the practical and facilitating and maximising learning
- a ready-to-use worksheet, technician notes, equipment lists, risk assessments, and
- teacher guidance for running the lesson.

**When and how to use the resource:**
As this resource provides many ideas for practicals, including the ready-to-use practical activity, this resource should be used initially when planning lessons for the next few weeks to fit the practical work where most appropriate in the sequence of learning episodes for the topic.

The exemplar practicals can, of course, be modified to meet particular needs in specific classrooms and the advice offered can help teachers who are planning their own practical activities.
Videos

Improving Practical Work
Activity: Drawing force diagrams

Force diagrams use arrows to show the size and direction of forces acting on an object.

You can see the forces on this ball are balanced. The resultant force is zero, so the ball stays still.

A resultant force is one force with the same effect as several forces. You calculate the resultant force by adding forces in the same direction and subtracting forces in opposite directions.

1. Try out the balanced forces experiments.

Copy and complete the table using the example to help you.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Forces (and direction)</th>
<th>Force diagram</th>
<th>How do you know the forces are balanced?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball on table</td>
<td>Weight (down)</td>
<td>reaction</td>
<td>The ball doesn’t change how it moves – it stays still</td>
</tr>
<tr>
<td></td>
<td>Reaction (up)</td>
<td>weight</td>
<td></td>
</tr>
</tbody>
</table>

Continued…
What is the nature of science?
Scientists and philosophers of science have varying degrees of agreement over what the true nature of science is and what aspects should be taught at school level. Aspects of the nature of science were consolidated in the science curriculum through the idea of ‘How Science Works’. Guidelines were made available but there were no set models to teach How Science Works and it was left to science teachers, as scientists, to understand and create models to teach the nature of science.

However, different scientific disciplines have varying ways of ‘doing’ science and understanding science. Some people talk about ‘the scientific method’ as if there was one simple agreed way of ‘doing’ science. In reality there is no one method and it is these complexities that we address in these introductions and in the resources provided for each Topic.

The purpose of this resource:
These introductions and the activities present a model for understanding the nature of science as it applies in school-based science teaching.

If we understand the nature of science we are, in effect, also understanding how scientists work. It is possible to tackle the nature of science from a purely philosophical standpoint, but this would not deliver useful learning to students about science and how scientists work. It would also not deliver aspects of the practical nature of science and how scientists undertake experiments and investigations.

By providing students with specific tasks that will involve higher-level thinking skills, such as synthesis and evaluation and giving them an opportunity to look at the development of scientific ideas over time or understand some basic principles of logic, they will learn and better understand how science operates and how scientists work.

What the resource contains:
The nature of science tasks for the students are organised into themes. These themes provide the model for teaching about the nature of science.

The tasks for the students that make up the themes are designed to help students develop skills and understanding that allow them to see science not as discrete subjects without links and background, but as part of a growing and developing set of inter-related disciplines that use logic, argumentation, experimental and investigative skills in order to develop explanations for phenomena they may observe in nature.
These skills are not confined to aspects of the Nature of Science and should be thought of as a core set of skills that can be used across all the activities in all the subjects. The skill sets developed will be useful for any students who decide to study science at higher levels or who wish to pursue a career in science or science related subjects.

Although the tasks are linked to specific topics in science, they are not necessarily specific to that topic. The skills that the task develops should be seen as valuable in different topics and subjects.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAS: Ideas about science and scientists</td>
<td>The starting point for exploring what science is (and is not). Contains a working definition of what science is and looks at the images of scientists as well as the notions of ‘authority’ and ‘proof’ in science.</td>
</tr>
<tr>
<td>HOS: A brief history of science</td>
<td>Charting science across the ages covering the foundations of science through to the scientific revolution and modern scientific discoveries.</td>
</tr>
<tr>
<td>SOP: Science or pseudoscience</td>
<td>This theme introduces philosophy of science and the ideas of Popper and Kuhn. It provides a way of distinguishing science from non-science and looks at the concept of the ‘scientific method’.</td>
</tr>
<tr>
<td>HSW: How scientists work</td>
<td>This theme examines how and where scientists do investigations in science as well as the skills needed to carry out scientific investigations. Aspects of moral and ethical considerations are also included.</td>
</tr>
<tr>
<td>HSC: How do scientists communicate?</td>
<td>The process of communicating science, from peer review through to looking at science in the media – the difference between types of communication are studied.</td>
</tr>
<tr>
<td>AIS: Argumentation in science</td>
<td>This theme looks at logic, arguments, inductive vs deductive science, inference and what constitutes good or poor argument in science.</td>
</tr>
</tbody>
</table>

**Table 1 Nature of science themes**

The first three topics and themes covered are:

| Cells and tissues | HOS3 The scientific revolution |
| Reproduction | IAS3 What is a scientist? |
| Environment and adaptation | SOP1 Science or pseudoscience |
Nature of science

IAS3 What is a scientist?

This is an exercise for year 7 students to think about what scientists actually look like in real life with an exploration of images of scientists, and links with IAS4 Exploring stereotypes of scientists.

The IAS Introduction provides a list of the main stereotypes identified by research – these will be examined in more detail in IAS4, but during this task look out for some of those stereotypes coming through in the descriptions and discussions so that a link between the tasks can be made.

Activity: What does a scientist look like?

Studies show that the typical concept of a scientist held by young students is that of a middle aged, balding man, with grey hair and wearing glasses.

Use the presentation Activity: What does a scientist look like? as a prompt to guide a discussion about what a scientist looks like and what it is they do. A scientist could work in a lab, in the field, with computers and do experiments scientists work in lots of different places.

Then ask students to match the real scientists to their sciences. Show the students images of some female scientists, for example:

- Professor Kathy Sykes – physicist
- Liz Bonin – biologist/TV presenter
- Professor Alice Roberts – medical doctor/TV presenter

Ask if the students notice anything about the images (i.e. they are all of women). Discuss the idea that not all scientists are professors or doctors (for example, Liz Bonnin – a science presenter with no doctorate). The key ideas to get over in this activity is that scientists are just normal people and they often do not conform to the ideas and stereotypes that people can have of them.

- There are many women scientists.
- There are younger and older scientists.
- Not all scientists have doctorates (many are neither Dr, nor Professor).

Different scientists work in different environments and places, including laboratories, in the field, in offices working on experiments and modelling on computers.
Answers and discussion

The most likely result of the draw a scientist task is a stereotype of a scientist as described.

An interesting point to develop here with the students is whether they really think that is what scientists look like or are they drawing what they think you want them to draw which is a stereotype because that is easier than trying to provide a ‘real’ image.

Exploring where they get their images from is also useful as is a brief discussion on whether or not they think the science teachers they know in school are ‘real’ scientists. For example, if some of the teachers have doctorates do they perceive them to be more of a scientist than teachers who do not? Do they see the teachers primarily as teachers or as scientists who teach?

These discussions can inform task ▶ IAS4: Exploring stereotypes of scientists which is a more in-depth look at how scientists are portrayed in the media especially films and TV.

Another interesting line of enquiry is whether or not the students can name any scientists in literature.
Creative teaching and teaching creativity

The Getting creative resources

The Getting creative resources in this product provide a set of nine exemplar lessons that focus on the application of creativity in science. This document explains some of the thinking behind the production of these lessons and will:

- define creativity and introduce the 3E model
- identify key skills relevant to creativity
- distinguish between teaching creatively and teaching creativity in science
- make the argument that creativity in science is teachable
- identify factors which support creativity in science classrooms

What is creativity?

Even defining creativity excites lively debate. Creativity involves divergent, open-ended thinking and convergent, closed analysis and includes but is not limited to, insight, innovation and product development. The National Advisory Committee on Creative and Cultural Education (NACCE, 1999) definition sums up much current thinking: ‘Creativity is imaginative activity fashioned so as to produce outcomes that are both original and of value’.

This definition identifies five aspects of creativity. ‘Imaginative activity’ is not simply a recall of existing knowledge and this activity must be ‘fashioned’ i.e. it must involve some effort in a more or less formal process rather than effortless daydreaming. ‘Outcomes’ must be produced. Artistic or craft outcomes are often seen as the only outputs acceptable as evidence of creativity but increasingly researchers are recognising that new ideas or scientific theories are as valid as an outcome as a painting or novel. Finally, the definition talks of outcomes that are ‘both original and of value’. Both of these are measurable by external judges - even if ‘value’ can be contentious.

Scientists are constantly creating ideas, hypotheses and theories (products fashioned by imaginative activity) which they then test. The community then accepts the ‘original’ ideas that are perceived to be of ‘value’ and adds them to the body of knowledge. Creativity is central to science and for every Beethoven there is a Newton, for every Picasso an Einstein.

Modeling creativity

The creative person goes through three key stages in any activity. First they engage, perhaps with a problem (‘how can I purify this water supply?’) or just an interest (‘how do birds know when to start migrating in the autumn?’). Then they explore the issue, develop ideas and formulate outputs that may be solutions to problems, explanations or artistic artefacts. The final stage is to communicate their ideas to the community around them. The Engage, Explore, Excitement model below illustrates this process.
Sometimes a scientific idea or a work of art is ahead of its time and is rejected until years later. Sometimes, creative people fail to engage with their relevant community and the work is not rejected but lost. Mendel’s work on genetics was lost for nearly 50 years for exactly this reason. But, if they sell their idea they create excitement which can, in turn, help other people to engage with the issue.

Key creativity skills

Many of the skills and attitudes necessary to navigate the 3E model are not exclusive to creativity. Exploring a scientific issue requires a mix of scientific knowledge and skills such as identifying key variables, handling equipment safely, analysing data and linking it to existing ideas. However, when looking at teaching creativity in science lessons it is useful to focus on some more obviously ‘creative’ aspects of the process. The list below provides the subset of skills addressed in the Getting creative resources.

**Engage**

E1.1 Recognise situations where a creative thinking strategy is appropriate.
E1.2 Identify key aspects of a situation relevant to study.
E1.3 Recognise situations where scientific knowledge and understanding can be applied.

**Explore**

E2.1 Generate novel ideas and approaches.
E2.2 Identify key ideas and approaches which are likely to be fruitful.
E2.3 Search for information intelligently, modifying the search as data becomes available.
E2.4 Link different areas of knowledge and experience to generate new insights
E2.5 Identify the key features of a successful solution or outcome.
E2.6 Tolerate uncertainties and work through setbacks.
E2.7 Apply collaborative working skills appropriately and effectively.

**Excite**

E3.1 Identify the key audience for a new idea or development.
E3.2 Recognise the particular needs of a range of audiences.
E3.3 Develop persuasive and informative communications in a range of media.
Teaching creatively or teaching creativity?

All teachers seek to teach creatively. They bring enormous energy and imagination to a difficult task and are, as a profession, very willing to try out new ideas and approaches. Teaching creatively improves results even in tasks that are not traditionally regarded as creative. As a teaching strategy, seeking to be more creative in the planning and delivery of the curriculum has real benefits in terms of motivation and achievement amongst your students.

However, the science curriculum is a large body of knowledge which, by the very nature of science, can get larger with every passing year. Is there room for teaching creativity in this demanding mixture? Evidence from many studies show that offering students a chance to be creative improves their progress in terms of understanding and attitude. Also, since creativity is a central component of science to teach creativity is to teach science. The Getting creative resources identify opportunities to include creativity as a learning objective without avoiding many of the other things required by the curriculum.

Teaching creativity

Many people used to believe that creativity is a trait you were born with (‘Oh, she’s very creative’) and could not be taught any more than you could be taught to be optimistic or to like Thai food. However, this attitude is changing and searching online for creativity skills now produces millions of hits leading to pages that describe how you can learn to be more creative using a particular set of techniques. You can be taught to brainstorm.

How can you create a supportive environment for creativity in your classroom? Factors affecting creativity have been researched over the last 50 years in terms of the characteristics of the creative person, the creative process and creative products and the environment (physical, social and intellectual) in which the activity occurs. Much of this work comes down to identifying factors that support creativity.
Celebrate creativity

Encourage students to see that creativity is valuable and has a place in science lessons. Often students think creativity is about ‘art’ so take opportunities to mention creative leaps by scientists to create new ideas and when students put forward a new idea or insight make sure you celebrate their achievement.

Tolerate ambiguity and uncertainty

Encourage students to hold ideas in their heads, or share them in class, even if they are not sure about exactly where the ideas are going. Encourage them to ‘think aloud’ and take some risks rather than waiting until every detail is fixed. If an idea is wrong it needs to be corrected (but don’t hurry!) but if it is merely half-formed let it develop a bit - it may come out right after all. And never punish mistakes – just move on from them.

Encourage team work

Almost all creative endeavours benefit from teamwork – but make sure students know how to work together in a mutually supportive and respectful way. Use teams as a way for students to develop some self-regulation. They will be much less willing to let down their peers by not making an effort than you!

Use creative strategies and teach creativity skills

You can find a variety of strategies to encourage creative working online. Most of these attempt to organise and regularise the creative process so need to be handled carefully – grinding through the steps in published strategy like DOIT or SCAMPER will not make people more creative if other conditions are wrong. Do also teach individual skills like brainstorming or concept mapping. These building blocks can help students to function creatively when given the space.

Make space for creativity

Give students time to generate, and reflect, on ideas. Allow students some space to choose their own projects. To be truly creative we seem to need some control over the agenda. This is difficult in schools but engineer spaces for students to define and respond to their own interests and problems rather than being constantly driven by the specification or curriculum.

Model creativity in your teaching

Students will recognise, and value, the lessons where you have thought about new ways to present material or think about a problem. Aim to be a creative teacher yourself – it will provide a model for your students to copy even if you never teach a single lesson about ‘creativity’.

Encourage creative responses

If you always ask for a task to be completed in the same way then that is what your students will do. Repetition of a technique (always write up your experiments in this way, use this template to design an investigation etc.) has a use but can easily drift into mind-numbing ‘drill and kill’ which degrades understanding and destroys creativity. Ask students to respond to tasks in new ways (report your results verbally, or in a presentation, or as a short film clip recorded on your phone). Encourage students to see that thinking about ‘how’ to report information forces them to think about what the information ‘means’ and that this is creative.
Getting creative

Context

This activity would provide an interesting start to a topic on forces or materials. The design considerations of shoe creators provide an excellent introduction to discussions about forces, strength of materials, rigidity, flexibility and so on. The activity also illustrates a situation where scientists have to identify key features of an unknown object, abstract from their observations to general principles to explain the science behind what they see and, possibly, go on to make predictions in a field where their knowledge is, as yet, incomplete.

Aims

Creativity skills

Engage
E1.2 Identify key aspects of a situation relevant to study
E1.3 Recognise situations where scientific knowledge and understanding can be applied

Explore
E2.4 Link different areas of knowledge and experience to generate new insights or strategies
E2.5 Identify the key features of a successful solution or outcome
E2.6 Tolerate uncertainties and work through setbacks

Key scientific ideas

- A force can change the shape, position or movement of an object.
- Frictional force depends on the surface of the bodies in contact and the force pushing them together. It is independent of the area in contact.
- Durability is a measure of a material’s resistance to wear.

Resources

►Activity: Shoe solutions presentation

Activity: Shoe solutions

● Introduction (10 min)
Show students slide 1 of the presentation ►Shoe solutions. The figures show the weekly amount spent in the UK in 2010. Ask students to match the figures with the products. (If this seems too demanding, ask them to identify the figure for the UK’s weekly shoe budget.) When they have had a guess, show the answers by showing slide 2 (in millions of pounds:}
chocolate 43, beer and wine 189, clothing 490, medicine etc. 83, petrol and diesel 569, shoes 125).

Ask those students who got correct answers how they managed to do this. Unpack any strategies they used to improve their chances of guessing correctly.

**Creativity note** This is an ‘unfair’ exercise, since the data is completely outside students’ scientific experience. They need to just have a guess. However, they will have some ideas and can rule out some figures as far too high, or too low. This building of a rationale for a ‘good guess’ is often part of the creative process when a scientist is working outside their comfort zone. Encourage students not to be frightened of situations where they don’t already know the answer – sometimes these can be the most interesting and can reveal the true scientists in the group.

**Looking for clues (20 min)**

Show students slide 3 in the presentation. Explain to the class that they will now look at some physical artefacts and they will have to guess what they are used for. This is almost equivalent to the previous ‘guess the budget’ activity – they will have to pick up clues from the data and use their existing knowledge to make sensible guesses.

The class will probably be surprised at how easy this is compared with the budget guesses – the objects are obviously shoes. Stress that in this activity you are looking for them to go beyond the obvious to work out how the things they observe tell them something about the shoes. You are looking for insight backed up by evidence in terms of observable features and background scientific understanding of how these features work. So, the aim is for students to see that the snowshoe spreads the weight of the wearer across a larger surface area, making it easier to walk on snow without sinking.

**Creativity note** Creativity requires the application of knowledge and understanding in novel situations; part of this is to recognise which scientific concepts might be relevant to the situation.

**Shoe solutions (20 min)**

Now ask students to produce labels for the shoes in the photographs, showing how the features of the shoes help them to work more effectively. The labels can be added directly to the slides or stuck onto printouts of the slides and mounted on the wall.

**Creativity note** Encourage discussion to identify the way the shoe designers have solved problems. Sharing ideas should clarify the students’ understanding as they explain and will help them to learn from one another as they take on others’ perceptions.

**Summary (5 min)**

Ask the class to explain scientifically why some of the shoes they have looked at have been made in that way. What are the properties of the materials that are most significant? How has the shoe structure supported its function? What compromises had to be made in its manufacture?