

# TEACHING SCIENCE IN THE PRIMARY CLASSROOM

**SAGE** was founded in 1965 by Sara Miller McCune to support the dissemination of usable knowledge by publishing innovative and high-quality research and teaching content. Today, we publish over 900 journals, including those of more than 400 learned societies, more than 800 new books per year, and a growing range of library products including archives, data, case studies, reports, and video. SAGE remains majority-owned by our founder, and after Sara's lifetime will become owned by a charitable trust that secures our continued independence.

Los Angeles | London | New Delhi | Singapore | Washington DC | Melbourne

# TEACHING SCIENCE

IN THE PRIMARY CLASSROOM

3RD EDITION

EDITED BY  
HELLEN WARD & JUDITH RODEN



Los Angeles | London | New Delhi  
Singapore | Washington DC | Melbourne



Los Angeles | London | New Delhi  
Singapore | Washington DC | Melbourne

SAGE Publications Ltd  
1 Oliver's Yard  
55 City Road  
London EC1Y 1SP

SAGE Publications Inc.  
2455 Teller Road  
Thousand Oaks, California 91320

SAGE Publications India Pvt Ltd  
B 1/1 1 Mohan Cooperative Industrial Area  
Mathura Road  
New Delhi 110 044

SAGE Publications Asia-Pacific Pte Ltd  
3 Church Street  
#10-04 Samsung Hub  
Singapore 049483

---

Editor: Jude Bowen  
Assistant editor: George Knowles  
Production editor: Tom Bedford  
Copyeditor: Andy Baxter  
Proofreader: Elaine Leek  
Indexer: Charmian Parkin  
Marketing manager: Dilhara Attygalle  
Cover design: Wendy Scott  
Typeset by: C&M Digital (P) Ltd, Chennai, India  
Printed and bound by CPI Group (UK) Ltd,  
Croydon, CR0 4YY



Editorial Arrangement © Hellen Ward and Judith Roden, 2016  
Chapter 1 © Hellen Ward, 2016  
Chapter 2 © Hellen Ward, 2016  
Chapter 3 © Judith Roden, 2016  
Chapter 4 © Judith Roden, 2016  
Chapter 5 © Hellen Ward, 2016  
Chapter 6 © Hellen Ward and Keith Remnant, 2016  
Chapter 7 © Claire Hewlett, 2016  
Chapter 8 © Maria Elsam and Julie Foreman, 2016  
Chapter 9 © Hellen Ward, 2016  
Chapter 10 © Manette Carroll and Hellen Ward, 2016  
Chapter 11 © Andrew Berry, 2016

First Edition published 2005 (reprinted 2005 and 2006)  
Second Edition published 2008 (reprinted 2010, 2011 and 2012)

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the Copyright, Designs and Patents Act, 1988, this publication may be reproduced, stored or transmitted in any form, or by any means, only with the prior permission in writing of the publishers, or in the case of reprographic reproduction, in accordance with the terms of licences issued by the Copyright Licensing Agency. Enquiries concerning reproduction outside those terms should be sent to the publishers.

**Library of Congress Control Number: 2015949458**

**British Library Cataloguing in Publication data**

A catalogue record for this book is available from the British Library

ISBN 978-1-4739-1204-5  
ISBN 978-1-4739-1205-2 (pbk)

At SAGE we take sustainability seriously. Most of our products are printed in the UK using FSC papers and boards. When we print overseas we ensure sustainable papers are used as measured by the PREPS grading system. We undertake an annual audit to monitor our sustainability.



# WHAT IS SCIENCE?

Hellen Ward

In this chapter a pragmatic approach is taken to address the question, 'What is science?' There is evidence that learners do not enjoy science (Royal Society, 2010) and yet it is a subject with many opportunities for practical and enquiry learning approaches and has elements that promote awe and wonder. In addition, some people claim the subject has suffered for reasons specifically relating to teaching; for instance, teachers feeling they lack sufficient knowledge of the subject that results in poor interest, or the emphasis in the recent past upon teaching to the test, because Year 6 outcomes were nationally reported (Beggs and Murphy, 2005). In this chapter it will be suggested that there could be another reason, and therefore the issues are explored from a different perspective, proposing that perhaps the current view of science is outdated and therefore unrealistic in the 21st century. Learners' perceptions of science show they understand it to be a diverse and fascinating subject and therefore, by taking an 'ideas and evidence' approach to science, perhaps both teachers and learners would be able to leave the stereotypical approach to science in the past where it belongs.

## WHAT IS SCIENCE?

Science is both a way of working and a body of knowledge. Science generates knowledge in the form of ideas, data, diagrams, theories and concepts (Ziman, 2000). Some of this knowledge is generally accepted (for example, that the sun is the centre of the solar system) while other aspects, such as the Higgs Boson, are questioned even by those who can access data from the CERN project. One view of science sees it as an accumulation of knowledge over time; this is the ‘tablets of stone’ approach (Solomon, 2013: 18). In this approach scientific literacy is laid down in books and is carefully built upon, and approved; the knowledge structures are certified and thus agreed to be truthful. The other view is one where knowledge is created and there is no ultimate truth. There is a reaction against science although Rorty suggests ‘there is nothing wrong with science, there is only something wrong with trying to divinise it’ (Rorty, 1991: 34). Ogborn (1985) identifies that science provides the answer to five distinct demands: ‘What do we know?’, ‘How do we know?’, ‘Why do things happen?’, ‘What can we do with this knowledge?’, ‘How can we tell people what is known?’ Science is a complex area of study but provides invaluable opportunities for learning.

Science is a relatively new subject, unlike the study of the classics or mathematics, and the name ‘scientist’ was first used as recently as 1834; although many men of science did not like this new term. While western science can be linked back to the Greeks it was then very different from what is currently thought of as science. Greek philosophy was a process of thinking, informed by observations. The Greeks thought that the world was composed of Earth, Fire, Water and Air. Aristotle, however, added Aether, because he did not believe that the things in the heavens could be constructed from the same sources as those on the earth. Aether was the fifth component (*Quinta* in Latin, leading to the word quintessential) and this filled the space between the earth and the rest of the known universe. Aether was a term, still in use in the 17th century, to explain how light travelled, as well as ideas in alchemy. So this Greek classification system lasted until the Renaissance although it seems rather rudimentary and not all philosophers held identical views. Democritus, another Greek philosopher, wondered in 460 BC what would happen if you continued to cut things into pieces until one piece could be cut no smaller. He decided this smallest thing, which could be cut no further, should be called an atom. This process involves the key features of science: wondering, questioning and then imagining an answer to explain what was happening. However, there was another feature of science happening: Aristotle did not believe the world was composed of atoms and because he was so influential neither did anyone else. Therefore, the idea of an atom was shelved until the ‘Enlightenment’ when the idea was resurrected. Science, like all knowledge,

is a human process and is influenced by the humans who practise it. This is no different today as powerful people still influence what gets believed, or produced and published.

## WAYS OF WORKING: THE IMAGE OF SCIENCE

An image that persists for many in the population is that of the lone scientist grappling with the mysteries of the world. This scientist is often pictured as being untouched by material ambition, or desire for personal prestige or glory, and one who will reject any subjective bias. Science is said to be objective; Osborne (1996) stated that science is able to make claim X about the world because:

X is a true statement about the world.

Scientists believe X.

Scientists have evidence of X.

Rorty (1991) argues that this objectivity is really a desire to win an argument against others who hold a different view. Science has a rational approach and seeks objective truth, although the ideas of 'truth', 'rationality', 'objectivity' and 'science' are often thought of as being the same thing. However, without a recognised and agreed system of 'finding out' there is little likelihood of getting any agreement and this results in a position called relativism. Science, however, is not about an uninterrupted series of instances of miraculous inspiration. The history of science is often neglected in science education and what is taught bears little relationship to the history of science as told by historians (Russell, 1981). There are many new ideas to explain the world but the acceptance of each new idea depends upon the network of support provided for the new idea. Latour (1989) suggested that the ideas were not as important as the people who supported them, and it was more how far the power and influence of this support stretched which affected what people believed. He studied scientists working in a Nobel prize winning laboratory in France and in his book, *Science in Action*, published in 1979 with Woolgar, suggested that what happens in a laboratory is inconsistent with the public perception of science as involving a search for truth and accuracy. Instead, he comments upon an approach that ignores any 'dodgy' or anomalous data that is not in line with the expected. Latour also describes science as culturally framed rather than as a set of fixed processes and procedures. Osborne (1996) rejects this view of science and explains that the reasons why there appeared to be inconsistencies in the research Latour observed were that it was ground

breaking and involved complex approaches. Osborne went on to suggest that what happens in one place and at one time should not be considered as indicative of what happens everywhere at all times. 'Scientists work in communities of practice with established norms' (Osborne, 1996: 58). This notion of working together and relying on persuasion rather than force, and respecting curiosity and an eagerness for new data and ideas leads to the development of 'unforced agreement', which is the true value of science (Rorty, 1991: 39). Scientists, however, are human beings, with a range of human emotions, for example, Newton, working with Halley (the person after whom the comet is named) collaborated to publish the work of Flamsteed (the first Astronomer Royal), against his expressed wishes and despite the fact that his observations were incomplete. Newton wanted the data and regardless of Flamsteed's wishes used his immense network and power to get the work published and hence gain access to the data.

It can also be a trait of human nature to continue to believe something even when the evidence to support it does not exist. An example of this can be observed in relation to Joseph Priestley, the English scientist, who supported the idea of phlogiston. Priestley had many more supporters than the French chemist Lavoisier, who did not believe in phlogiston. The existence of phlogiston was the dominant theory of the time, and the theory stated that material that burnt contained a substance called phlogiston ('to burn' in Greek) which was released during burning. Although phlogiston was introduced by Swedish scientists in the 1700s, Priestley like most men of science at the time believed in its existence. They thought that when a candle was burned the phlogiston came from the candle into the air around it, then, when the air was saturated by this phlogiston (i.e. there was no more space), the candle would be extinguished. Phlogiston was colourless, had no smell and had no mass! It was also thought that when breathing, phlogiston was removed from a person's body and as a way of testing, to prove the existence of phlogiston, a mouse was placed in a sealed container. The notion was that when the air became full of phlogiston the mouse would die. However, there were many experimental issues relating to this theory, which meant Priestley often had to make small adjustments and changes over time to ensure his measurements remained constant. Therefore, although the results did not match the theory, the scientific community stuck with the phlogiston idea long after it was found to be false. Lavoisier, who went on, with others, to develop the way chemicals are named today, was executed during the French revolution, but not before he burnt all the books he could find that mentioned phlogiston. Priestley died never accepting that phlogiston did not exist.

There are many examples of theories, such as phlogiston, that have to be thrown out because of changing ideas, or instances where the science



was found to lack believable evidence. Sometimes, the way scientific discoveries are reported and recorded is also unbelievable. Galileo, for example, is said to have been in a church and it was while watching a pendulum swing that he noted its laws; and yet many thousands of people, over time, would have seen the same thing (Matthews, 1994). The textbook story tells of his genius, sitting there making observations, but in reality it was not only 'the genius' who was observing. Like Newton, who was probably not hit on the head by an apple, Galileo had the ability to imagine a different idea from other observers and thereby create a new and different explanation that was exceptional. In each of these situations the two men arrived at their conclusions not by observation alone, as it was not possible for others to repeat these events and gain the same readings, but by the use of mathematics.

By 'jobbing backwards' it is easy to misrepresent the history of science as a tale of unqualified success, in which one enlightened genius after another was driven by the logic of the situation to take the inevitable step forward – 'such optimal paths are historical fictions, arrived at by belief ignoring a vast body of knowledge that was no less scientific in its time' (Ziman, 1976: 130).

This view of science as a changing story of endeavour, challenge and creativity is more appealing than the image of genius and an approach with only one 'method' that is termed 'the legend of science' (Kitcher, 1993). Whilst most people are aware that knowledge has developed and moved forward, as evidenced by the fact that few today believe that illness is caused by 'humours' or that 'all life on earth was created at one time', the view of how this science knowledge has been produced has remained constant. 'The legend of science' is a stereotypical view of the subject, an idealised viewpoint with only one method of guaranteed, unassailable competence (Campbell, 1974; Kitcher, 1993); and this ideal is what is taught in school

Yet science has much more to offer and perhaps it would have a greater appeal to learners if the approach to teaching the subject did not hide behind an elitist view that often results in many considering the subject as uninteresting and irrelevant. This is important because contrary to the numbers of interested learners in schools and colleges, television programmes and museums focusing on science are popular. There were 3.1 million general visitors in 2012/13 visiting the Science Museum in London. One value of science is that it produces knowledge that can be utilised to solve real problems; for example, advances in biochemistry can be utilised to create drugs and vaccinations that reduce childhood mortality, or advances in genetics which may, even within the next generation, produce 'three-parent' children who will have no genetic disorders. These are some of the ways in which science is contributing to improving human life. Yet science that is taught without the history of changing

methodology and challenge fails to tell a story of science which can foster involvement. Science is not static, it is forever developing and that development began in earnest with scientists like Mendeleev and Galileo.

One of these developments was the inclusion of mathematics, meaning that the qualitative medieval science began its transformation to that of the modern era. Science was providing technological advancement. Francis Bacon argued that the true value of science was its increasing ability to predict and control nature. He contended that the old way of debating things was not scientific and that in order to find truth, evidence was needed from nature. Galileo apparently observed the swinging of the lights in a cathedral, and from these observations he devised and developed his work on pendulums that resulted in a critical discovery which allowed the study of momentum, the measurement of time, and the development of the gravitational constant – ideas and inventions that are still used today. Although evidence in terms of observations and measurements was reported, the mathematics Galileo used was based on how the world should behave but not how it actually does! He identified that his ‘world on paper’ was not the same as the world of his observations. A number of scientists have tried to recreate his findings, some of which were found at the time to be ‘falsifiable’. Naylor (1974) tried out a number of Galileo’s famous experiments and concluded they would not provide the evidence for the theories proposed. Galileo however had powerful sponsors, and although he did not use a recognisable scientific method, because of this power his ideas were accepted. However, hindsight has shown his ideas had merit and without this step forward other discoveries might not have happened. It is unfortunate that these challenges and examples, where the discoveries do not hold to the idealistic view of science, are hidden from primary school children (and their teachers) by textbooks and stories which adhere to ‘the legend’.

## INDUCTION AND DEVELOPING THEORIES

This example of evidence not fitting the theory is not a feature within primary science because learners are only told ‘the facts’ that are in line with an idealised view of science. In learning to learn, it is advised that the journey might be hard and that some of the best learning comes from initial failure and mistakes; yet in science the perceived thoughts are those of correctness and accuracy. History demonstrates that there is not always one idea, or that initial ideas are subsequently further developed and new ‘truths’ emerge. Yet when, on occasions, the results of practical work do not give the ‘expected’ answer this is not anticipated because

learners are taught that science is something that naturally follows from observation to the answer. In reality, the unexplained outcome can be used to truly review and evaluate what is happening, thus enriching the learning. Duschl (1990) suggested that science education needs to address not just what is known but how that knowledge has come to be accepted. There are many types of science and ways of gaining knowledge about science, and only one of these is from direct observation. Inductive reasoning is where observations are made and then theories are developed from these observations. The fundamental idea behind this is that knowledge is gained from direct sensory experiences. There are many stories in science where this process is said to have operated. Charles Darwin was supposed to have observed birds on the Galapagos islands and from noticing their differing shapes developed the idea of evolution.

‘ Darwin’s conversion to the theory of evolution – once thought to have been a typical ‘eureka’ experience stemming from his famous voyage to the Galapagos Archipelago – is now generally seen as a slow and largely post-voyage development in his scientific thinking. (Sulloway, 1985: 122) ’

Observation and measurement play a vital part in science but, as Medawar (1969) argued, instead of just observations science also needed a theory, or an incentive to engage a scientist into making the observations in the first place. His comments were linked to his analogy that, otherwise scientists would ‘browse a field like cows, looking for something to catch their eye’.

## CASE STUDY

### Shells in the fields

Whilst walking on a costal path in Cornwall I came across some sea shells in a field. They were at some distance from the sea, and as I collected them for a science teaching activity later that week, I speculated on how they had arrived there. Were they dropped by children who had collected them and, running back to their holiday cottage, had a few spilt out of their buckets? Could it be that they had been thrown up the cliffs and deposited in the field on a very windy or stormy day? Or, could there be another explanation, such as do shells grow in fields in Cornwall? The next day, in another field, again about 200 metres from the sea, while on a cliff walk, I found more shells, some of these had damage and so another thought occurred: could they have

*(Continued)*

(Continued)

been dropped by gulls? So was I, to use Medawar's view, 'browsing the field like a cow?' Or, when I observed something, did I begin to raise questions and make stories about how the shells might have arrived in the location? This in turn raises the question of, 'Is there only one method of science?'

Primary science in England has until recently only valued the fair test method of investigation and identified this as the only way to do science. In the current National Curriculum (DfE, 2013b) the inclusion of different methods of enquiry is encouraged, and this may help to break down the 'legend of science' approach. When developing learners to 'work scientifically', it is important not to just start with observations and follow an inductive approach, as induction does not operate well in a world without regularity or where objects cannot be seen at all. Many suggest that induction is not a valid scientific process and ask, 'Why would scientists make observations in the first place unless they had already spotted a problem or query?' In the shell example, was it by chance that the first shell was spotted? Whilst in some areas of science the question of why an observation would be made without a theory is a valid query, in other fields of science, such as observing the behaviour of people and other animals (surveying and pattern seeking), observing plants growing and seeing seasonal change (change over time), the very act of observation can and should be used to stimulate thoughts. The initial observations prompt questions and this can result in a hypothesis or idea (or story) being developed, and then decisions can be made on which further observations or measurements are needed to test this theory; this is a hypothetico-deductive process. It is possible I might have been looking at birds, chatting to my companion or thinking about dinner and would never have seen the shells at all!

Popper (1965) argued that induction does not exist; he said the starting point for all science is speculation and from this speculation observations are then made. Gibson (1977) identified that observer and the object are part of an energy flux which is perceived by the observer as something general before cognitive processes take place. Rorty (1991) suggested objects are printed as replicas on the retina and then this information is used in conjunction with information and previous experience to link to what is already known and thus to prompt a response, for example that 'shells do not grow in a field'. So was the image of the shell imprinted on the retina without intention and once there was the image linked to ideas already held and did a resulting

speculation create further ideas and stories? Whilst Fleming was the first person to identify penicillin, it is thought that other plates in other labs at other times had shown the same results. Others therefore had seen the same things but not thought the same thoughts and the petri dishes were thrown away because they were thought to be contaminated. However, to be scientific there has to be a respect for curiosity, and an eagerness for new data. This is true in all aspects of science, so that further observations and measurements would be needed to even begin to decide on which theory might explain the spoilt petri dishes, or shells found in the field. In science others have to have access to the data to inspect the approaches and data and then approve the findings without being forced or bribed.

The shells in the field is an example of one way in which science works, it also demonstrates that a hypothetico-deductive method is more common than an inductive one. From the first observation a range of ideas emerged, but to be scientific a preferred theory would need to be selected and then checked against further evidence, rather than just collecting evidence without having a reason why it was being collected. It is now recognised that science is a hypothetico-deductive activity where theories are created, and falsified. It is a principle that is based upon a theory being in the mind of the scientist before observations were taken; and while this has become a more accepted approach, Lawson (2004) suggests that teachers and children still hold to inductivist approaches. Perhaps this is because science in school is more to do with following instructions and finding evidence to support 'the one idea' to which the answer is known. Ziman (1978: 23) goes one step further to explain why the hypothetico-deductive approach is the way scientists work, and suggests that this explains why some theories and models look like other things. Using the Rutherford–Bohr picture of the atom, as an example, in which the atoms are viewed as a planetary system of electrons in orbit around a nucleus. Ziman suggests that perhaps its basis was not just the principles of classic physics but also that it was familiar to scientists because they were used to such systems in astronomy. In the classroom some things can be explored just by using observation but for investigative work it is important that learners' own ideas and questions are used along with a range of approaches to finding answers.

## KNOWLEDGE OF SCIENCE

The question of whether science tells the truth about the world and whether it explains nature is hotly debated outside primary science. Here, the issue of truth and reality will not be discussed; partly because it could form a

book in its own right but also because in a practical guide to teaching science in primary school a focus on approaches that support teachers is more valuable. One starting point in finding a practical answer is to suggest a classification system to support the understanding of the different types of phenomena in science. Harré (1986) classified things into three Realms; the first Realm included all things that are tangible and can be seen by the eye; examples of Realm 1 objects include an apple, the moon and springs. Realm 2 objects such as bacteria, viruses and atoms cannot be seen with the eye, only by using instruments and thus, in describing them, metaphors or analogies to things that can be seen are used. Whilst most of the scientific theories discussed in secondary schools involve Realm 2 objects there are some that are used in primary schools, such as forces at distance. Realm 3 objects are theoretical objects for which there is no direct evidence of their existence. In primary schools the majority of what is taught concerns items in the Realm 1 category, and it is vitally important that a basic understanding of these Realm 1 entities is developed at this phase of education because future scientific learning will be built upon this knowledge. However, some teachers will question the reality of science and its changing models and ideas, so in addition to understanding different types of phenomena it is useful to use a map analogy.

The building of science knowledge and its link to nature was first likened to a map by Korzybski (1931). When someone wants to get from A to B, a street map is useful but what is portrayed on the map is not the same as what is seen when one is in the street, although it is a helpful way of representing this reality. This metaphor of a map is a popular way to explain science (Korzybski, 1931; Toulmin, 1953; Ziman, 1978), because it can be used to clarify how ideas and concepts link together; for example, as more roads and motorways are built a map becomes more complex and it illustrates how even more places are linked; so too, as more in science is discovered there is an increase in complexity. Maps of one region can be linked to other areas and in the same way links can be made to other scientific theories which in turn make the scientific map more detailed, reliable and ultimately more worthwhile. This metaphor of a scientific map can also be used to discuss how science can be perceived at various levels of difficulty.

But in order to use a map, simple conventions first have to be taught; to begin, a learner must understand that a map is a 'bird's eye view' that is not necessarily to scale – that a map is a simplification and if you hold it in the wrong way then all sorts of trouble can ensue. In science, understanding the Realm 1 objects can start the process of understanding the directly observable. The abstract ideas should come later, in the same way that learning about maps would not provide concrete or first-hand experience because the symbols, conventions and signs on a map epitomise reality at an abstract level.

A perennial problem for learners is that at each new stage in science they are often told ‘to forget what they were told previously’. Some materials, such as solids, are replaced by atoms, each of which has three elementary particles, which in turn are replaced by the ideas of quarks, and then the mind-blowing idea that a single atom contains more than 90 ‘things’, and so it goes on. If the map analogy is used, then just in the way that maps can be produced with various scales and detail, so too with science; as concepts increase the ‘science map’ can be used to illustrate the increasing complexity. Thus at Key Stage 1 there might be a map of the whole of the world, but not in terms of detailed information. This large-scale map for young children is analogous to the idea that there are things called materials and they have simple properties, just like a map of broad generality. The map will contain Realm 1 objects. If more detail is needed, for instance, at the level of particles, then a higher resolution is needed to discuss and understand Realm 2 objects, but the basic skill of holding the map the right way up, knowing the language, and having engaged with the process can make learning more meaningful.

This grounding will eventually lead to an understanding of more complexity and abstraction. The analogy of science as a map also helps with the idea of reality, as no one imagines a map to be exactly the same as standing in a street. This can be shown simply by switching from a ‘Google map’ to a ‘satellite view’. A map is an abstract representation. Just as with maps and places, as learners become more proficient through experience and practice, an unfamiliar place becomes familiar and the map is no longer needed to get from A to B. It is the same in science, as scientific theory becomes accepted so it becomes part of the known.

Science is an intellectual construct and the laws of nature are prescribed as a result of this human activity, and this is why sometimes scientific knowledge changes – in the same way as the maps of old, including those that contained ‘here be dragons’, altered because more first-hand information was available. Voyages of discovery meant that more was known and as a result more detail could be added to the map; even if sometimes the details were not completely accurate. However, as more specialised equipment became available then accuracy and detail improved. Despite this greater detail and precision, however, a map is still a map, a representation, and no matter how many maps are produced, reality can never be truly replicated.

## THE NATURE OF SCIENTIFIC IDEAS

Enabling learners to make the link between their ideas and the evidence for them can be encouraged through simple activities. A good activity to

make explicit the need to look objectively and to respect evidence to support conclusions follows, starting with Figure 1.1.

**FIGURE 1.1**

What ideas are generated by this picture?



Many ancient sets of footprints have been found and these have fascinated scientists for centuries. Learners can be asked to reveal the ideas they hold as a result of looking at Figure 1.1. When shown this drawing recently, some learners stated that they thought the drawings were of footprints. When asked why they thought this, it was clear that they had brought evidence from everyday life to their interpretation of the drawing, for example having seen birds' footprints in the snow. They also stated that one animal was bigger than the other, as evidenced by the size of the footprint, and that the animal with larger prints had claws. While the smaller animal moved with both feet together, the larger footprints were made one at a time. An adult learner suggested that the small footprints were made by an animal with a small brain who had not evolved a brain big enough to have co-ordinated movement.

When more evidence (Figure 1.2) was presented, the learners put forward ideas of a meeting between the two animals, resulting in the smaller animal flying away, having a piggyback or coming to a 'sticky end'. The evidence that supported these ideas was elicited and questions were asked which focused the learners on what evidence explicitly supported their ideas and whether all the ideas could be correct.





**FIGURE 1.2**  
More evidence  
is provided;  
have the ideas  
changed?

In this case all the ideas had merit, although learners developed their favourite story, but it was not possible to discount the other views. In fact, there was no evidence to suggest that both footprints were made at the same time! Once the learners realised that in this type of science lesson the expectation was for them to promote ideas, to discuss evidence, and that their responses could be modified as more evidence came to light, they were ready and willing to use their enthusiasm and creativity in other activities. Challenging learners to use their ideas and collect evidence can occur in most activities, and as it starts to form their ideas, is more in line with Popper's view of science.

Tracks in everyday modern life provide as many challenges as using examples from pre-history. The tracks in Figure 1.3 were made on a beach in the USA in 2004. Looking at the different tracks should provide some evidence as to the ‘animals’ that made them. Enabling learners to be creative just requires less teacher direction and an understanding that science can be meaningful. Making tracks at school to solve problems is discussed in Chapter 5.

**FIGURE 1.3**  
What made  
these tracks?



On another occasion, everyday materials were used to link science to real life. Learners were asked to apply this approach to an everyday setting. A range of cans of proprietary soft drinks, i.e. a ‘Coke’, a ‘Diet Coke’ and a ‘7 Up’, and a tank of water were used to challenge learners to provide ideas of what would happen when the cans were placed in water. Learners used previous knowledge of floating and sinking to arrive at suggestions. These included ‘Diet Coke will float as it is lighter’ and ‘They will all sink because they are heavy’. The cans were placed into the water one by one, with an opportunity for the learners to observe what happened to each can, and learners were asked if they would like to alter their ideas based on the new evidence. In the event, the ‘7 Up’ sank, the ‘Coke’ floated just off the bottom and the ‘Diet Coke’ floated just below the surface, which resulted in amazement and quick suggestions as to why this might be. The learners then had to think of ways to test out their ideas.

Suggested tests included weighing the cans, measuring the liquid, counting the number of bubbles in set amounts of each liquid and the use of secondary sources to research the composition of each liquid (for example, amount of sugar). One child suggested that if the cans

had been placed in the tank in a different order a different result would have occurred. Identifying learners who require support or challenge is an additional advantage of working in this way. Although no writing was involved in the original part of the session, this did not make this activity less valuable. When the learners tried out their tests they recorded their results and communicated their findings in poster form later in the week.

## PUPILS' PERCEPTIONS OF SCIENCE

Many people know that scientific ideas have changed; for example, that the world was thought to be flat, that coelacanths were thought to be extinct or that gold cannot be made from lead. The world has changed significantly from that of 100 years ago and so somehow thinking that a learner will be confused if a more up-to-date idea of science is provided seems inadequate. There is a link between the economic development of a country and its citizens' attitudes to science. The ROSE (Relevance of Science Education) project showed that in developing countries there is a strong positive correlation, whilst in developed countries the trend is a negative one ([www.uv.uio.no/ils/english/research/projects/rose/index.html](http://www.uv.uio.no/ils/english/research/projects/rose/index.html) [accessed 29 May 2015]).

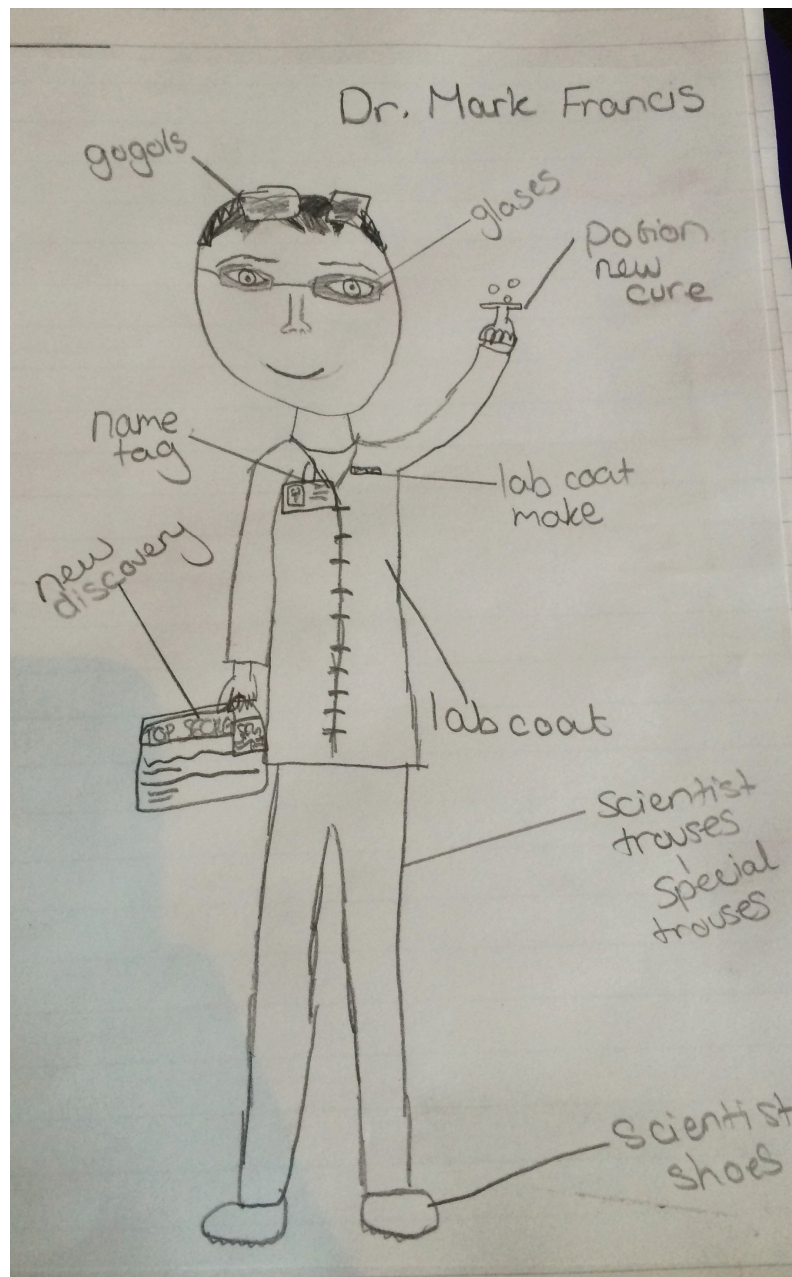
This report also identified that there was little evidence that the public at large were disinterested in science or that their interest in science was waning. In fact the interest in science as judged by the number of science books purchased, the viewing of science media and visits to science museums and fairs, suggests that there was little evidence to support a drop in the public interest in science. The researchers therefore concluded that this is a school phenomenon (Sjøberg, and Schreiner, 2005: 11). The latest PISA report suggests this has not changed (OECD, 2012).

Chambers (1983) was the first researcher to ask learners to draw a picture of a scientist and to investigate the age at which stereotypes of science emerged. This has been linked with the pupils' poor image of science and often issues of gender. The drawings by the learners are very entertaining, and as a result this research tool has continued to be used widely. There is a downside to this approach: if asking for a stereotype then it is rather less than surprising that this is what is provided. Instead of only asking learners to draw a scientist, these learners were also asked to use collage materials, to provide their perception of science. Whilst collage has been used since early times in China and has been used to assess individual subjective perception and subsequent behaviour (Stabler, 1988) it is still an unusual choice for scientific research. The benefit of using the collage is that it does not require written communication skills

and can 'Express the views, opinion and projections of the participants in nonverbal form (the old adage that a picture is worth a 1,000 words)' (Stephen, 2009: 23). Learners who had previously been asked to draw a scientist (Figure 1.4) were then asked as part of their homework to create a collage of science without searching for 'science' on the internet.

**FIGURE 1.4**

Draw a scientist



The outcomes were thought-provoking, but it was what these learners said about science and their understanding of the word as they discussed their collages that was more fascinating.

It appears that the learners are far more aware of the world they live in than the drawing a picture of a scientist activity might suggest. They know about positive and negative aspects of science, they show interest in some aspects, like exploring the universe and how science helps with health and wellbeing. Some were able to identify the ‘bad bits’ of science, like making bombs and war. The collages helped the learners to express their knowledge and understanding in a far more sophisticated way than might have been expected.



**FIGURE 1.5**  
Collage 'What is science?'

## CASE STUDY

### Katie's conversations with her learners

Sam (not his real name) was asked about his drawing of a scientist (Figure 1.4) and whether this was what he really thought scientists looked like. He said, 'If you had asked me to draw a dog I would have drawn you one type, but I know there are many types and most of them would not look like this!'

The learners had very positive things to say about science both out of school and in school, particularly the practical aspects; they disliked writing about something that is found in other research (Beggs and Murphy, 2005). Part of their conversation is produced below.

- Girl 2:* It's very simple at school most of the time. Some days can be good. It's easy though.
- Teacher:* Do you feel challenged with your science lessons in school?
- Girl 1:* Not always no.
- Boy 1:* Well put it this way ... once we had to write about a digestive biscuit, to describe it. We had to just look at it and then write it down. I even had to write the word digestive. Fantastic!
- Boy 2:* It should be more real. They should teach us about the stuff we need to know about the different jobs.
- Boy 1:* I want to build a rocket in the classroom and see what happens.
- Boy 3:* But then not write about it. It's annoying having to keep doing it again. If I had to write about a football game every time and I love playing football I would hate football.

These learners' drawings of scientists showed the expected view of science, but their collages suggested that they were aware of new ways of thinking in line with technological advances. In discussions about school science it is proposed that learners could welcome more challenge, be involved in more real-life opportunities and have a chance to develop a different 'map' of science. Working scientifically provides this opportunity.

Recently this activity has been included in the first science sessions for the Initial Teacher Education postgraduate course at Christ Church University. Ellen's collage (Figure 1.5) is included along with her understanding of what science meant to her. Her understanding and interests are wide ranging.

## ELLEN'S COLLAGE

The immediate ideas that sprang to mind were test tubes, circuits and scientists, including Newton and Einstein. I then thought about how science connects to all life on Earth. I thought about field trips and experiments including collecting and studying bugs, then thought about habitats of different animals (represented by the Nemo poster, where each fish is shown at their correct depth in the sea). I enjoyed studying genetics and the human body when I was at school, and the brain interested me. I then wanted to represent how science covers everything from the atom, to the universe.

Some will continue to point to teachers and a perceived lack of knowledge and confidence, and yet teachers, as evidenced by the Ellen's statement of what science means to her, now have more science knowledge than when the National Curriculum began. Possibly it is time to focus on a different notion of primary science teachers rather than a deficit model.

## SUMMARY

The rest of this book provides practical examples of science in the classroom. The learners who took part in these activities are from schools across a large geographical area. Many of their teachers will say when asked that they lack confidence and so instead the approach is to focus on linking science across the curriculum, suggesting a range of learning and teaching approaches in order to try and rewrite the story of primary science teaching from one of incompetence (Osborne and Simon, 1996) and a lack of confidence (Royal Society, 2010), to a more realistic picture where teachers and children are discovering and drawing their own 'maps' of science. Before proceeding to the practical aspects of the book this chapter will end with an analogy used by Einstein, who many would identify as one of the most successful scientists, but who identified clearly there are many things that are unknown.

Einstein used the analogy of a watch when attempting to explain the universe, suggesting it was like trying to explain the operation of a watch without ever being able to open it. You can hear it ticking and see the movements of the hands, but you are unable to image the mechanism that produces these effects. This he said, 'was the limitation of human understanding'.

*(Continued)*

(Continued)

## FURTHER READING

Mansfield, C.F. and Woods-McConney, A. (2012) ‘‘I didn’t always perceive myself as a ‘science person’’’: Examining efficacy for primary science teaching’, *Australian Journal of Teacher Education*, 37(10): 37–52.

Özel, M. (2012) ‘Children’s images of scientists: Does grade level make a difference?’, *Educational Sciences: Theory & Practice* – Special Issue, Autumn, Educational Consultancy and Research Centre.

Yilmaz, C. and Eylem, B. (2012) ‘Developing children’s views of the nature of science through role play’, *International Journal of Science Education*, 34(7): 1075–91.