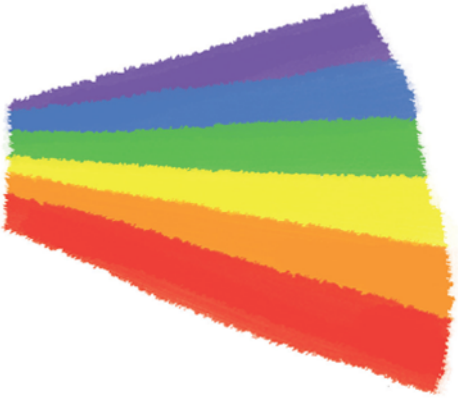
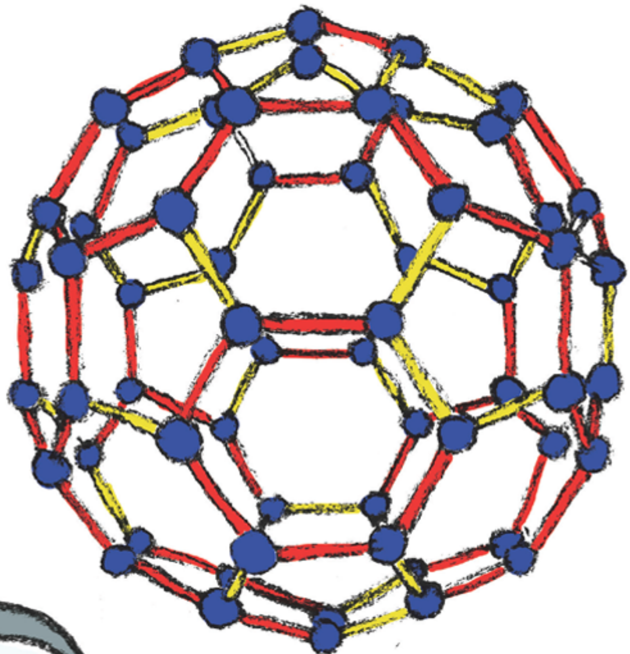
ROUTLEDGE

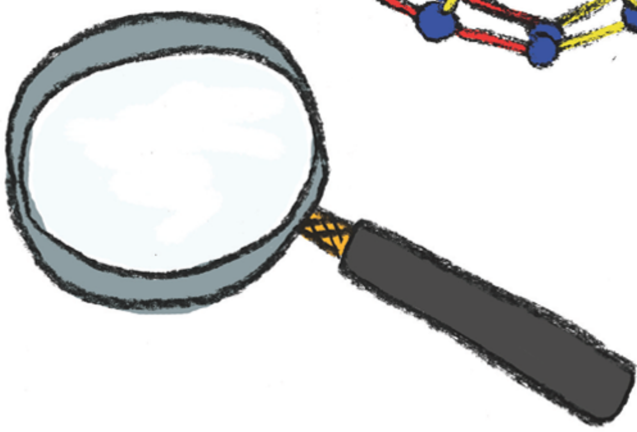


THE REALLY USEFUL SCIENCE BOOK

A Framework of Knowledge for Primary Teachers

Steve Farrow and Amy Strachan





Fourth Edition

The

REALLY USEFUL SCIENCE BOOK

Offering support to both trainee and practising teachers, the fourth edition of *The Really Useful Science Book* is the perfect tool for those who wish to extend their subject knowledge, enhance their teaching and create lessons which link directly to the National Curriculum. The easy-to-follow framework provides comprehensive science knowledge for Key Stages 1 and 2 and is fully updated with new material to inspire stimulating and engaging science lessons.

The book is divided into three sections: Biology, Chemistry and Physics. Each section integrates key scientific ideas and facts with innovative teaching methods and activity suggestions, and user-friendly language and illustrations help to explain key scientific concepts. With links to global learning, discussion of common misconceptions, and ideas for cross-curricular opportunities, each chapter connects knowledge to practice and informs creative and inspiring teaching.

The Really Useful Science Book is an invaluable reference resource for all classroom teachers who wish to develop the confidence to teach enquiry-based practical science with relevance to pupils and their global community.

Steve Farrow was Senior Lecturer in Science Education in the School of Education at Durham University, where he was also director of Primary ITT programmes.

Amy Strachan is Senior Lecturer in Primary Science Education at St Mary's University, Twickenham, UK. She has more than 10 years of experience as Head of Science in international, state and independent schools and has produced teacher materials for both the BBC and Oxfam.

The Really Useful Series

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The REALLY USEFUL SCIENCE BOOK

A Framework of Knowledge for Primary Teachers

Fourth Edition

Steve Farrow and Amy Strachan

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SECTION ONE

Introduction

Introduction

THE NATURE AND PURPOSE OF THE BOOK: WHAT THE BOOK AIMS TO DO

This book has been written with primary teachers and teachers-in-training in mind, and its main purpose is to *support and extend teachers' own science knowledge*.

Notwithstanding all the changes that have taken place in primary education since the publication of the previous editions, the main aim of the book remains unchanged – to provide for primary classroom teachers and students, in a single volume, an outline of the key ideas that underpin the main branches of science.

The present, updated edition has been produced for two main reasons: First, the revision covers all changes seen in the National Curriculum (NC) reform in England for Key Stages 1 and 2. Second, the update has allowed for the inclusion of new material. Short chapter summaries in bite-size review pages will highlight opportunities for scientific discussions (views and attitudes), scientific enquiry (skills and investigation suggestions) and application (future developments). 'Teaching idea' boxes throughout the book include useful information linking knowledge to practice. These will include global learning links (e.g. food miles, recycling, technological advancements), common misconceptions (i.e. highlighting areas where there is frequent confusion in understanding) and cross-curricular opportunities (especially in mathematics). There will be short biographies of significant scientists highlighted in the Science National Curriculum (DfE, 2013), stating their importance in the development of our understanding to date. Finally, this edition will feature additional information on scientific enquiry, raising its significance in developing a more secure understanding of scientific phenomena and acquiring an appreciation for the beauty of discovery.

The new edition responds to the latest Teacher Standards used in England from 2012 (DfE, 2011), which replaced the *Professional Standards for Qualified Teacher Status* and the core professional standards published by the former Training and Development Agency for Schools. Teacher Standard 2 states: 'Promote good progress and outcomes by pupils'. This edition will use matrices to demonstrate how the curriculum can support progress of knowledge, understanding and skills in science. Teacher Standard 3 indicates the importance of 'demonstrating good subject and curriculum knowledge'. This book not only aims to support secure knowledge of related areas of science, but will aim to help foster and maintain pupils' interest in science and address common misunderstandings. Teacher Standard 8 requires teachers to 'fulfil wider responsibilities'. The 'In Practice' boxes sharing global learning links will demonstrate how science can support sustainable, environmentally and socially mindful, developments.

Although it is important to acknowledge the content of both schools' and ITT (initial teacher training) professional standards, the key ideas of science remain the key ideas, no matter which 'pieces' of science knowledge happen to be included in the current NC 'mosaic'. The aim is that the content included in this book, and the explanations given, will enable teachers and students to interpret more effectively the Science NC for the children in their charge, through the development of deeper understanding and greater confidence in their own science knowledge. There is now considerable evidence that increased subject knowledge can lead to increased confidence and to changes in the science learning opportunities presented to children – 'Now that I *know* more, I feel I'm a better teacher of science'.

WHAT THE BOOK *DOES NOT* DO

As the book is specifically devoted to the subject knowledge of science, there are two areas of science education that have deliberately not been addressed:

- Experimental and investigative science

Although this edition will highlight the importance of 'working scientifically' and the importance of different methods of scientific enquiry, there is no overt consideration of how different areas of science can be delivered through working-scientifically activities. However, many examples of investigations are provided that relate to the science knowledge under consideration. Wherever appropriate, 'classroom' versions of these investigations are indicated, and teachers may wish to include them in their own schemes of work. For more direct consideration of the implementation of working scientifically, readers are referred to other publications.

- The planning, organization and management of classroom science

The book does not address the issues inherent in the day-to-day provision of science education in primary classrooms. Once again, there are a number of excellent publications available that deal specifically with these issues.

THE STRUCTURE OF THE BOOK

The book contains three main sections, Biology, Chemistry and Physics.

At the beginning of each section, the Key Ideas are listed and are subsequently expanded in the following text. Concepts relating to the Key Ideas are presented as 'Concepts to support Key Stage 1' (or Key Stage 2, or both). The expectation is that the ideas presented will assist in teachers' understanding of the science involved and, hence, will support their own teaching of the various components of the Key Stage 1 and 2 programmes of study. Where concepts are presented that are not Key Stage 1 or 2 requirements for children, but may be helpful in terms of teachers' understanding of science, this distinction is made clear in the text.

At the end of each main section, there is a *National Curriculum progress matrix* demonstrating how the ideas build on each other. This allows the reader to relate each component of the programmes of study for Key Stages 1 and 2 to the Key Ideas and concepts presented and described in the book and may be useful as a quick reference guide for those seeking help with particular, specific aspects of NC-related science knowledge.

It is important to recognize that the book does not set out to provide material that can be used in the classroom in an unmodified form. It is not a book for children, but the hope is that it will be of value to teachers and students in supporting and extending their knowledge of science, so that what they provide in the way of science learning experiences for children will be grounded in a broader, more secure knowledge base and a deeper understanding of the subject knowledge context of the Science NC.

THE LANGUAGE OF SCIENCE

Throughout the book, the aim is to express scientific ideas in the most straightforward language possible, using examples from everyday experience. In each case, and at the appropriate place, the scientific terminology appropriate to the particular idea presented has been included in the explanation.

Where complex concepts are involved, scientific terminology becomes necessary for the accurate expression of ideas, as, in such cases, oversimplification could lead to distortion, omission and/or a potentially misleading explanation, and every effort has been made to avoid this. As highlighted in the NC (DfE, 2013), it is important for pupils to 'develop their scientific vocabulary and articulate scientific concepts clearly and precisely'.

It is hoped, therefore, that the self-avowed non-specialist will not be daunted, nor will those with a science background feel patronized, by the use of the language chosen (simple or scientific) for the expression and explanation of ideas.

Using accurate scientific language is essential for the development of children's scientific literacy. The progression of scientific vocabulary, consistent with the NC programmes of study, is therefore identified at the end of each section of this book. Development of scientific language will allow children to share their emerging scientific ideas with increasing confidence.

THE PROVISIONAL NATURE OF SCIENCE KNOWLEDGE

It is important to stress that science does *not* provide us, once and for all, with the *right* answers. What it can provide is a series of provisional explanations based on theory, observation and verification by experiment or investigation. In some cases, these explanations offer a degree of predictability so high that they can be generalized into 'laws' – the laws of motion, for example. In everyday terms, the laws of motion first propounded by Sir Isaac Newton can still offer us a useful explanation of the forces acting on moving objects – it is these laws that are described and explained in the subsection of this book that deals with forces.

Further theorization and experimentation, however, may bring new discoveries that increase our understanding of the way the world works and cause modifications to the explanations offered by science. Early in the last century, the 'frontiers' of Newtonian physics were extended by the theory of relativity proposed by Albert Einstein, and Einsteinian physics may well be supplanted in future by the attempt to provide a 'unified theory' that can explain the behaviour of all matter.

Scientific knowledge, then, is provisional and gives rise to current explanations of the nature of things – explanations that may only remain valid until further knowledge allows us to modify and improve them. In the writing of this book, every effort has been made to present the current, accepted thinking in science. Where alternative explanations or controversies exist (as with global warming, or 'cold' nuclear fusion, for example), these have been acknowledged and included. It is important, too, that we convey the nature of science through our teaching, together with the understanding that we do not have all the answers.

WORKING SCIENTIFICALLY

The NC (DfE, 2013) specifies that pupils should be taught to use practical scientific methods, processes and skills, through the teaching of the programme of study content. This is referred to as working scientifically and aims to develop children's independence in answering their own questions in science. It is essential that children learn about the nature, processes and methods of science. By working like scientists, children will develop the skills to answer the questions they raise. Not only does practical, hands-on learning aid the development of scientific skills, but it aims to nurture curiosity about the world and beyond.

Throughout this book, the famous scientists that are highlighted illustrate the common approaches to research and scientific methods and processes. It is important that children understand that they can be the scientists of the future, caring for and improving the planet on which we live. Exposing children to a variety of scientists, from those who work in laboratories to those who work out in the field, will demonstrate that ordinary people work in collaboration to make outstanding contributions to science.

Scientists use a range of enquiry approaches to answer their scientific questions. If these are modelled to children, they will help them to answer their own investigations, using the best approach to obtain relevant and accurate evidence. Critical thinking skills will also ensure that young people challenge ideas of other scientists, considering the reliability of evidence and alternative points of view.

Teachers must highlight the nature of science and celebrate uncertainty. It is fundamental that our future scientists realize that nobody has the answer to every question. Scientific enquiries may provide some answers, but should also generate further questions. The presence of a question box or question wall in classrooms can encourage the skill of raising questions and answering them in collaboration.

To provide some guidance on how these working-scientifically skills can be developed through the key stages, a progression of skills has been mapped out in a table format. This can be found in Table 1.1. Based on the NC Science programme of study guidance, the skills have been broken down into five key areas:

1 *thinking scientifically*: developing the ability to ask pertinent scientific questions and to have a perception of how they may be answered;
2 *planning scientifically*: considering the overarching plan of action to answer the question, the relevant variables and drawing on prior knowledge and experience to predict what might happen;
3 *working-scientifically approach*: beginning to develop a repertoire of key scientific enquiry approaches and to understand how they may be used to answer different scientific questions;
4 *observing, measuring and recording*: developing the refined skills to put the thinking and planning into action in a systematic way;
5 *communicating and reviewing*: ensuring that findings are shared, scientific enquiry is evaluated, and further exploration is considered.

PROGRESSION OF SCIENTIFIC VOCABULARY FOR WORKING SCIENTIFICALLY

The table below provides a useful progression of vocabulary that will support pupils to work scientifically and use appropriate equipment and skills (based on when the words are introduced in the NC programmes of study).

Year 1	Questions, answers, equipment, gather, measure, record, results, sort, group, test, explore, observe, compare, describe, similar/similarities, different/differences Egg timers, ruler, tape measure, metre stick, beaker, pipette, syringe
Year 2	Pictogram, tally chart, block diagram, Venn diagram, table, chart, order, observe changes over time, notice patterns, link, secondary sources Hand lenses, stopwatch
Year 3	Types of scientific enquiry, changes, identify, classify, order, comparative tests, fair tests, careful, accurate, observations, evidence, present, data/evidence/results, keys, bar charts, conclusions, prediction, support/not support Thermometers, data loggers, magnifying glass, microscope
Year 4	Increase, decrease, secondary sources, appearance
Years 5 & 6	Opinion/fact, variables, independent variable, dependent variable, controlled variable, accuracy, precision, degree of trust, classification keys, scatter graphs, line graphs, causal relationships, support/refute

Table 1.1 Mapping progression of working-scientifically skills

Early Years	Key Stage 1, (Years 1 and 2)	Lower Key Stage 2 (Years 3 and 4)	Upper Key Stage 2 (Years 5 and 6)	Deeper Learning / KS3
THINKING SCIENTIFICALLY				
Playing and exploring. Creating and thinking critically (having own ideas and making links)	Explore the world around them and raising own questions.	Exploring, talking about, testing and developing ideas about everyday phenomena and the relationships between living things and familiar environments. Develop ideas about functions, relationships and interactions. Ask own questions about what they observe.	Exploring and talking about ideas. Asking own questions about scientific phenomena. Analysing functions, relationships and interactions more systematically. Use science experiences to explore ideas and raise different kinds of questions.	Ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience.
PLANNING SCIENTIFICALLY				
Mostly whole-class planning		Facilitated independent and group planning	Independent and group planning	
Respond to teacher's questions	With help, plan and perform simple tests	Begin to make own decisions about the most appropriate type of scientific enquiry they might use to answer questions	Select and plan the most appropriate type of scientific enquiry to use to answer scientific questions;	Select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables

Table 1.1 *continued*

Early Years	Key Stage 1 (Years 1 and 2)	Lower Key Stage 2 (Years 3 and 4)	Upper Key Stage 2 (Years 5 and 6)	Deeper Learning / KS3
WORKING-SCIENTIFICALLY APPROACH (pattern-seeking, observing over time, grouping and classifying, comparative and fair testing, scientific research)				
	Experience different types of scientific enquiries, including practical activities. Begin to recognise ways in which they might answer scientific questions.	Make some decisions about which types of scientific enquiry are likely to be the best ways of answering questions, including observing changes over time, noticing patterns, grouping and classifying things, carrying out simple compara-tive and fair tests and finding things out using secondary sources of information.	Select the most appropriate ways to answer science questions using different types of scientific enquiry, including observing changes over different periods of time, noticing patterns, grouping and classifying things, carrying out comparative and fair tests and finding things out using a wide range of secondary sources of information.	Use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety.
OBSERVING, MEASURING AND RECORDING				
Look closely at similarities, differences, patterns and change.	Use simple measurements and equipment (for example, hand lenses, egg timers) to gather data, carry out simple tests and record simple data.	Begin to look for naturally occurring patterns and relationships and decide what data to collect to identify them. With support, make decisions about what observations to make, how long to make them for and the type of simple equipment that might be used. Begin to use new equipment, such as data loggers, appropriately. Collect data from own observations and measure-ments, using notes, simple tables and standard units.	Make own decisions about what observations to make, what measurements to use and how long to make them for, and whether to repeat them. Choose the most appropriate equipment to make measure-ments and explain how to use it accurately. Decide how to record data from a choice of familiar approaches. Look for different causal relation-ships in data and identify evidence that refutes or supports their ideas.	Understand and use SI (International system) units. Use and derive simple equations and carry out appropriate calculations. Undertake basic data analysis including simple statistical techniques

Table 1.1 *continued*

Early Years	Key Stage 1 (Years 1 and 2)	Lower Key Stage 2 (Years 3 and 4)	Upper Key Stage 2 (Years 5 and 6)	Deeper Learning / KS3
		Help to make decisions about how to record and analyse data. Record findings using simple scientific language, drawings, labelled diagrams, keys, bar charts, and tables.		
COMMUNICATING AND REVIEWING				
	With help, record and communicate findings in a range of ways and begin to use simple scientific language. Talk about what has been found out and how it was found out.	Look for changes, patterns, similarities and differences in data in order to draw simple conclusions and answer questions. With support, identify new questions arising from the data, making predictions for new values within or beyond the data collected, and find ways of improving what has already been done. Recognise when and how secondary sources might help to answer questions that cannot be answered through practical investigations. Use relevant scientific language to discuss ideas and communicate findings in ways that are appropriate for different audiences.	Draw conclusions based on data and observations. Use evidence to justify ideas, and use scientific knowledge and understanding to explain findings. Use results to identify when further tests and observations might be needed. Recognise which secondary sources will be most useful to research ideas and begin to separate opinion from fact. Use relevant scientific language and illustrations to discuss, communicate and justify scientific ideas and talk about how scientific ideas have developed over time.	Interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions Present reasoned explanations, including explaining data in relation to predictions and hypotheses Evaluate data, showing awareness of potential sources of random and systematic error. Identify further questions arising from their results.

Figure 1.1 An image of working scientifically

A NOTE ON UNITS

Throughout the book, the attempt has been made to express units in the most easily understandable form. So, for example, the units of density have been cited as *grams per cubic centimetre* and have been expressed in terms of g/cm^3, rather than in terms of the more conventional $g\ cm^{-3}$. Similarly, *acceleration* is expressed in terms of *metres per second per second*, written as m/s^2, rather than as $m\ s^{-2}$.

FURTHER READING

Supporting teaching, planning and assessment

ASE. (2010) *The Language of Measurement: Terminology Used in School Science Investigations*. Hatfield, UK: Association of Science Education.

Cooke, V. and Howard, C. (2014) *Practical Ideas for Teaching Primary Science*. Northwich, UK: Critical Publishing.

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Davies, D., Collier, C., Earle, S., Howe, A. and McMahon, K. (2014) *Approaches to Science Assessment in English Primary Schools: Interim Findings from the Teacher Assessment in Primary Science (TAPS) Project*. Bristol, UK: Primary Science Teaching Trust.