Dan Davies, Alan Howe, Christopher Collier, Rebecca Digby, Sarah Earle and Kendra McMahon

Teaching Science and Technology in the Early Years (3–7)

Third Edition

A David Fulton Book

Teaching Science and Technology in the Early Years (3–7)

Teaching Science and Technology in the Early Years (3–7) celebrates young children's amazing capabilities as scientists, designers and technologists. Research-based yet practical and accessible, it demonstrates how scientific designing and making activities are natural to young children, and have the potential for contributing to all aspects of their learning.

By identifying the scientific and technological concepts, skills and activities being developed, the book enables the reader to make more focused diagnostic observations of young children and plan for how they can help move them forward in their learning. This third edition has been thoroughly updated and features:

- fresh insights into young children's learning from neuroscience and 'new-materialist' perspectives;
- a UK-wide perspective on Early Years curricula and how they support the inclusion of science and technology as an entitlement for young children;
- new case studies of successful, evidence-based Early Years practice, alongside new examples of practical planning for learning, and advice on documenting children's learning stories;
- an updated chapter on assessing and documenting children's learning, drawing upon findings from the Teacher Assessment in Primary Science (TAPS) project at Bath Spa University.

Based on the latest research and first-hand experience, this practical and accessible book is essential reading for Early Years and Primary students on undergraduate, PGCE and Masters-level courses.

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

Third edition published 2019
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
52 Vanderbilt Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

First edition published by David Fulton Publishers 2003
Second edition published by Routledge 2014

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Names: Davies, Dan (Daniel John), 1962- editor. | Adaptation of (work): Davies, Dan (Daniel John), 1962- Teaching science, design and technology in the early years.
Title: Teaching science and technology in the early years (3–7) / Dan Davies, Alan Howe, Christopher Collier, Rebecca Digby, Sarah Earle and Kendra McMahon.
Description: Third edition. | New York : Routledge, 2019. | "First edition published by David Fulton Publishers 2003"—T.p. verso. | Includes bibliographical references and index.
Identifiers: LCCN 2018056907 (print) | LCCN 2018058589 (ebook) | ISBN 9780429464812 (Ebook) | ISBN 9781138613034 | ISBN 9781138613034(Hardback) | ISBN 9781138613058(Paperback) | ISBN 9780429464812(eBook)
Subjects: LCSH: Science—Study and teaching (Early childhood)—Great Britain. | Technology—Study and teaching (Early childhood)—Great Britain. | Design—Study and teaching (Early childhood)—Great Britain.
Classification: LCC LB1139.5.S35 (ebook) | LCC LB1139.5.S35 D38 2019 (print) | DDC 372.35/044—dc23
LC record available at https://lccn.loc.gov/2018056907

ISBN: 978-1-138-61303-4 (hbk)
ISBN: 978-1-138-61305-8 (pbk)
ISBN: 978-0-429-46481-2 (ebk)

Typeset in Palatino
by Swales & Willis Ltd, Exeter, Devon, UK

To all past members of the Bath Spa University Primary and Early Years Science Team

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Acknowledgements

Gabriel Lemkow-Tovias of the Discovery, Research and Documentation Centre for Science Education in Early Childhood (Lab 0_6), Manresa, Catalonia.

Children and staff – particularly Selina Barrick and Ruth Burtonshaw – at Dulwich Prep, London.

Children and staff – particularly Bridget Johnson, Sandy Sheppard and Tonie Scott – at Bishop Henderson C of E Primary School, Coleford, Somerset.

Children and staff at The Red Room Pre-school, Chewton Mendip, Somerset.

Children and staff at Bellefield Primary School, Trowbridge, Wiltshire.

Children and staff at Bath Opportunity Pre-School, Bath.

Children and staff at St Michael's Pre-school and toddler group, Winterbourne, Bristol.

Children and staff – particularly Nancy Low – at Victoria Park Primary, Bristol.

Children and staff – particularly Emma Oliver – at Puddleduck Hall Nursery, Gloucester.

Children and staff – particularly Julia Holder and Jae Munroe – at St Phillip's Primary School, Bath.

Children and staff at Trinity Primary School in Taunton.

Children and staff at Moorlands Infants School, Bath.

Children and staff – particularly Amy Skuse – at St Martin's Garden School, Bath.

Children and staff at Twerton Infant School, Bath.

Children and staff at Chandag Infants School, Keynsham.

Children and staff – particularly Di Rhodes and Margaret Harrison – at Newbridge Primary School, Bath.

Children and staff – particularly Judy Cooper – at Broad Chalke C of E First School, Wiltshire.

Children and staff – particularly Sue, Cathy, Andrea and Fleur– at Red Beach Primary School near Auckland, New Zealand.

Children and staff – particularly Joanne Hobson and Danieka Rivers – at Point Chevalier Primary School, Auckland.

Children and staff – particularly Heidi Wood and Liz Evans – at Bathampton Primary School.

Children and staff – particularly Angela Millar – at Oak Tree Day Nursery, Bath.

Children and staff at Ashley Down Infant School, Bristol.

Children and staff – particularly Jocelyn Brown – at Ballycraigy Primary School, Antrim.

Children and staff – particularly Lesa Martin – at Ballyclare Primary School, Northern Ireland.

Children and staff – particularly James Petrucco – at Meadowbrook Primary School, South Gloucestershire.

Children and staff – particularly Patrick O'Brien – at St Philip Evans Catholic Primary School, Cardiff.

Children and staff – particularly Elaine Stockdale – at Tongwynlais Primary School near Cardiff.

Children and staff – particularly Toby Tyler – at Great Moor Infant School, Stockport.

Children and staff – particularly Cat Powell and Garreth Rhodes – at Beacon Rise Primary School, Bristol.

Fen Marshall (formerly headteacher at Hawkesbury Upton Primary School, South Gloucestershire).

Trainee-teacher John Paul Sharman.

The Primary Science Teaching Trust, for funding the 'See the Science' project, from which many of the learning stories are drawn.

PART

1

The principles of teaching science and technology in Early Years settings

CHAPTER

1

Introduction

Alan Howe and Dan Davies

Purpose of this chapter

Through reading this chapter, you should gain:

- an introduction to our philosophy of Early Years education in the age range 3–7;
- an understanding of the ways in which we see science and technology as relevant to the education of young children;
- an appreciation of the structure and contents of this book.

Introduction to the third edition

We first published *Teaching Science and Design and Technology in the Early Years* in 2003, the result of collaboration between Early Years practitioners and tutors at what was then Bath Spa University College, following this with a second edition in 2014. We wrote not out of a desire to see design and technology (D&T) and science 'taught' to young children, but from a concern for a holistic approach to Early Years provision, which includes the sometimes-overlooked elements of scientific, design-related and technological development. The 2014 edition reflected a growing awareness of the importance of 'sustained shared thinking' (Siraj-Blatchford and Sylva 2004) and documentation of 'learning stories' (Carr and Lee 2012), whilst this third edition re-emphasises the importance of children's encounters with objects in their environment (Jones 2013) from a 'new materialist' perspective (Barad 2008) and draws further from the implications of neuroscience for Early Years practice (Sinclaire-Harding, Vuillier and Whitebread 2018). This new edition also draws upon our recent research; whilst the second edition included a number of case studies (learning stories) from our Early Years 'See the Science' project (2012–13), we have added new examples from *Teacher Assessment in Primary Science* (TAPS 2013–18), which reflect curriculum change across the UK. In England, the *Early Years Foundation Stage* (EYFS 0–5) has been updated (Department for Education 2017) to include 'Understanding of the World' and 'Expressive Arts and Design' as 'Specific Areas of Learning', whilst the statutory expectations on practitioners to assess children's attainment of Early Learning Goals (ELGs) through the EYFS Profile (Standards and Testing Agency 2017a) includes criteria for ELG 14 ('the world') ELG 15 ('technology') ELG 16 ('exploring and using media and materials') and ELG 17 'being imaginative'. At Key Stage 1 (age 5–7) the *National Curriculum for England* has removed attainment levels, replacing these with 'expected standards' for science at age 7 (Standards and Testing Agency 2017b), against which teachers are expected to make judgements. Interestingly, whilst both English and mathematics assessment requirements include criteria for 'working towards the expected standard' and 'working at greater depth within the expected standard', teachers' judgements on the threshold for children's science attainment are expected to be simply binary. Our examples from the TAPS project – particularly in Chapter 5 – are designed to help practitioners summarise the assessment evidence they have collected primarily to inform planning, feed back to children and support their learning, in order to make this binary judgement in a valid and reliable way.

Whilst in England the changes to the Key Stage 1 programme of study in science emphasise the 'biological' topics of plants and humans as animals – together with brief references to materials and seasonal changes – there have also been curriculum developments in other countries of the UK which justify the continued inclusion of 'physics' topics such as electricity, forces, light and sound within this third edition and point to a new emphasis on curriculum continuity between the early and later years. In Wales the *Foundation Phase Framework* (3–7) has been updated (Welsh Government 2015), including changes to 'Knowledge and Understanding of the World', 'Creative Development' and 'Physical Development' to include sections on 'Myself and Other Living Things/Non-living Things, Light, Sound and Changes to Materials'. The new *Successful Futures* 3–16 curriculum (Donaldson 2015) being developed by schools for implementation from 2019 includes 'Science and Technology' – comprising science, design & technology and computing – as one of its six 'Areas of Learning and Experience'. In Scotland the 3–18 *Curriculum for Excellence* includes within its 'Sciences area experiences and outcomes' (Education Scotland 2013) a range of topics not included for the 3–7 age range in England and Wales, including 'Biodiversity and Interdependence'; 'Energy Sources and Sustainability'; 'Processes of the Planet' (Change of State in Water); Space; Forces; Electricity; 'Vibrations and Waves' (Light and Sound); and 'Topical Science'. In Northern Ireland, the *Foundation Stage* (4–6) 'Areas of Learning' strands extend up into Key Stage 2 (CCEA 2014), including 'The World Around Us' (interdependence, movement and energy – light and sound, forces, electricity, change over time – materials, weather, growth) and 'The Arts' (art and design). Thus, there is support across UK curricular authorities for our inclusion of a wide range of scientific and technological processes and concepts as relevant to young children as part of their continuum of educational experience from birth to 18.

So why a book about science and technology in the early years? Although controversy rages over whether children in Early Years settings should be moving icons around on touchscreens rather than interacting directly with natural materials, we cannot avoid the observation that those growing up in Western affluence are part of the 'iPad generation' – displaying the natural affinity with advanced technology that led Prensky (2001) to describe them as 'digital natives'. Although we do not want our use of 'technology' in this book to be seen as synonymous with 'ICT' (information and communication technology) or 'hi-tech' – it must include children designing and making real things from real materials – we nevertheless feel that to include the phrase 'science and technology' in the title is more holistic and relevant to children's lives than 'science and design and technology', for the reasons we have outlined earlier. As with the second edition, we have structured the book into two parts. The first half deals with the big questions about children's learning, the role of talk, narrative, documentation and planning in relation to Early Years science and technology. It also includes a chapter specifically devoted to outdoor learning, reflecting the influence of 'Forest Schools' (Knight 2011) and recognition of the importance of the outdoor environment in children's learning. The second half of the book provides practical advice and examples for enhancing scientific and technological learning through thematic approaches, as a companion volume to our primary text, *Science 5–11: A Guide for Teachers*. The inclusion of this section in the book raises two questions: why are we including children aged 5–7 in our definition of 'Early Years'? Doesn't the inclusion of specific science topics belie our commitment to holism in young children's learning? In answer to the first of these questions, we clarify the age range of children for which the approaches suggested in the book are appropriate in the next section. In answer to the second question, we suggest that the contents of Part Two are used flexibly. Certainly, a Year 1 topic on 'what things are made of' could be taught by looking at Chapter 9. However, a Nursery or Reception class practitioner could also use Chapter 9 as a resource of ideas for intervening in children's sand or water play. In other words, the presence of what might be seen as science-specific chapters in Part Two of this book does not imply that it should be taught as a subject in the Early Years.

What do we mean by the Early Years?

In this book we are using the phrase 'Early Years' to refer to children aged between 3 and 7 (i.e. from the start of Nursery education to the end of Key Stage 1 in England). Although this is out of line with the curriculum structure in England – the EYFS covers the age range 0 to 5 – it does correspond exactly with the Foundation Phase in Wales (Welsh Government 2015) and reflects the play-based kindergarten for 6-year-olds in Finland, arguably Europe's most effective education system (Sahlberg 2014). We have taken this decision for two main reasons:

1 At the age of 3, many children in England and Wales have their first taste of an educational setting outside the home; it is at this point that we can begin to share our understandings and offer advice for enriching children's scientific and technological experiences. Some would argue that the Early Years start from birth, or even conception. We would certainly agree that children have experiences before the age of 3 that relate to science and technology, such as bathtime, exploring the tactile properties of toys or changing the shape of playdough, but the opportunities for adults to intervene in this process are more limited.

2 At the upper end of our age range we believe that children between the ages of 5 and 7 need the kinds of exploratory, contextualised, meaningful activities characteristic of good practice in Nursery and Reception classes. They are, in our opinion, still in their Early Years. For some, the Early Years come to an end when children enter compulsory education; play is put behind them and the 'serious learning' begins. Indeed, there are signs that Key Stage 1 in England has become more formal in recent years, with increasing use of whole-class teaching; the introduction of compulsory teaching of systematic synthetic phonics (Rose 2006) and an associated 'phonics screening check' at the end of Year 1 (Department for Education 2011). Yet in several countries – Sweden for example – children do not begin statutory schooling until they are 7 (i.e. at the end of Key Stage 1), and in others (USA, Australia) the years from 5 to 7 are described as kindergarten – 'children's garden' – implying an educational ethos more akin to that of Nursery education in the UK. In Piagetian terms, children in these age groups are working within a 'pre-operational' phase of cognitive development and, even if we accept that they are capable of more abstract thinking within meaningful contexts (Donaldson 1978), it can be argued that a child of 7 has more in common with a 3-year-old than an 11-year-old.

We therefore strongly reject the equating of Early Years with the EYFS in England and support a more international interpretation of the phrase. Excellent Early Years practice should continue throughout Key Stage 1 and beyond. Characteristics of such practice include a concern for the 'whole child'; the fostering of independence through self-directed activities; attention to issues of inclusion; and the primacy of narrative and verbal interaction in the interventions that adults make in children's learning. While government directives on the teaching of reading may have had a formalising influence on many Year 1 classrooms in England, we do not believe that this need extend to the whole curriculum. Science and technology, by their very natures, require exploration, interaction and discussion to be learned effectively. As we argue in Chapter 2, children (and adults) need to retain their capacity for play to be good scientists and technologists!

Why science in Early Years practice?

> Science begins with children's very first acts of exploration.
>
> (de Boo 2000: 1)

Science is not a 'subject' in the EYFS curriculum for England. Indeed, until comparatively recently (the 1980s) the term did not feature in Primary education at all and is still absent from the elementary curricula of many countries. This is not to say that science was not, or is not, happening in nurseries, infant classes, playgroups and childminders' and children's homes. Many activities in which young children spontaneously engage are intrinsically scientific, or can be made to be so: blowing bubbles, playing with sand and water, looking at flowers or spiders' webs etc. There are, however, major problems of definition and recognition. As practitioners, our definitions of science are often too narrow, resulting in difficulties recognising where it is going on in our settings.

The images we have of science in the world beyond the classroom will inevitably affect our attitude towards children's scientific activity, and will in turn be transmitted to the children with whom we work (Harlen 2000). A multiplicity of meanings surround the word 'science' in general use:

> Science . . . can mean organised knowledge about natural phenomena ('Einstein's theory of relativity was a major contribution to science'), or the thought processes which generate such knowledge ('Discovering the structure of DNA was a triumph of modern science') or as a rubric for a set of disciplines ('Psychology as a science is a century old'); it can also refer to social systems and fields of work and study.
>
> (Gardner 1994: 2)

If, from our own educational experience, we see science as a factual body of knowledge about the world, concerned with laws and formulae and 'discovered' through complex experiments, we will find it difficult to recognise the scientific significance of 4-year-olds pushing each other around on wheeled toys. If, on the other hand, we regard scientific knowledge as shifting and tentative – inherently rooted in the 'here and now' of everyday things and events – Early Years science will appear as a natural component of young children's learning and development. Fortunately, many practitioners in England tend to take the latter view; Johnston and Hayed's international study (1995: 8) found that English primary teachers were more likely to subscribe to a 'process-based' model than other nationalities:

> This emphasis may, in part, be due to the English teachers' interpretation of the question 'What do you think science involves?' as 'What do you think school/primary science involves?'

Scientific processes (exploration, observation, asking questions, trying things out) are certainly very important aspects of Early Years science. Indeed, we could argue that the younger the child, the greater the emphasis that needs to be placed on the procedural ('doing') aspect, in comparison with the conceptual ('understanding') components of scientific learning. Not that we would wish to separate these elements; for young children doing is intimately bound up with knowing, and both depend fundamentally upon the development of scientific attitudes. Children's emotional disposition towards learning, and their responses to natural phenomena, can serve as the starting points for developing the attitudes of curiosity, open-mindedness and respect for evidence.

Why technology in Early Years practice?

Our definition of technology education reflects its widespread international usage to include both what was previously referred to as ICT in the National Curriculum for England (now 'computing') and activities in which children design and make things – still called design and technology (D&T) in many countries. Young children can engage with coding and computational thinking (Bers 2018) as when giving instructions to a programmable toy such as a Beebot or solving an online maze. However, it is in designing and making that their creativity is made concrete. D&T is an educational invention; it does not exist outside school settings, though it relates in some ways to the tasks performed by different types of professional designers, technologists and engineers. Although the term was in use before 1988, it was the UK National Curriculum Design and Technology Working Group who in their visionary Interim Report (1988: 2) gave it an educational rationale:

> Our use of design and technology as a unitary concept, to be spoken in one breath as it were . . . is intended to emphasise the intimate connection between the two activities as well as to imply a concept which is broader than either design or technology individually and the whole of which we believe is educationally important.

Design and technology – spoken as a singular rather than plural term – is a holistic activity, involving thinking and doing, action and reflection. In this respect it parallels many approaches to Early Years education, including 'HighScope' (Schweinhart et al. 1993) with its emphasis upon the 'plan-do-review' cycle to develop intentionality in children's play. We believe that purposeful making – giving new arrangements to materials, textures, colours, shapes – is central to young children's quests to bring pattern and order to their physical environments. From their earliest manipulations of blocks, food or soft toys, children show themselves to be born designers. They learn to talk about what they are doing – Piaget's 'egocentric' commentary – and to empathise with the needs and wants of others, real or imagined (e.g. 'I'm making a bag for teddy'). The problem for practitioners (as with science) is to unpick our own preconceptions about 'technology' and 'design' so we can begin to recognise the D&T happening under our noses.

Research into primary teachers' beliefs about technology (Jarvis and Rennie 1996) has noted – as in the case of science – the strong influence of models from the school curriculum. Teachers in the study typically cited modern mechanical and electrical products such as computers, telephones and vehicles as 'examples' of technology, with little mention of 'low-tech' examples such as pencils or cups. Food or textiles rarely featured. Design is in some ways even more problematic for non-specialist primary practitioners, who may regard it as a mysterious language couched in the jargon of 'form' and 'function' from which the general public is largely excluded (Davies 1996). Designers tend to be viewed as 'trendy', 'creative' people concerned with style rather than substance, adding labels to products that increase their value in the market place. The ability to draw well is assumed to be part of the activity, which may further alienate teachers who lack confidence in their own drawing skills. It is important that we expand these limited conceptions to embrace the creativity of children's experiences with materials. Young children 'think' with their hands; their learning is profoundly kinaesthetic and the abstraction of 'drawing before you make' may be irrelevant to Early Years practice. We want children to have a rich experience of handling designed artefacts from many cultures, and opportunities to fashion objects of beauty for themselves or others, discussing the decisions they are making as they do so.

Why science and technology together?

As noted, the word 'science' does not appear in the Statutory Framework for the EYFS (Department for Education 2017), while 'technology' and 'design and technology' both make a single appearance; the former within the Specific Area of 'Understanding of the World', the latter under 'Expressive arts and design'. Hence there is no implied relationship between science and technology in the EYFS, since there is no science! However, in other curricula such as the new 3–16 *Successful Futures* in Wales (Donaldson 2015: 50), science and technology are explicitly linked within a single 'Area of Learning and Experience': 'Science and technology are closely linked, each depending upon the other. Science involves acquiring knowledge through observation and experimentation, and technology applies scientific knowledge in practical ways.'

In previous writing (Howe et al. 2001) we have identified a number of ways in which the relationship between technology and science in the Primary curriculum might be conceptualised. One alternative – perhaps attractive in the context of Early Years education – is that we might view the two areas as indistinguishable. In a topic on 'ourselves', for example, choosing fabrics to keep us warm might draw upon science and technology as strands of learning within the broader realm of understanding, emotional and social skills being developed. In practice, however, this model can often imply a hierarchy in which science plays the dominant role (Ritchie 2001) and any designing or making activities can be seen as an opportunity for children to 'apply' scientific principles they have learned earlier, as implied by the earlier quote from *Successful Futures*. This is an approach that in our view can be developmentally inappropriate if it implies a progression from the abstract to the concrete, whereas we know from experience and research that young children need to begin with concrete experiences.

As currently represented in the National Curriculum in England (Department for Education 2013), the differences between science and technology are more clearly accentuated than their similarities. Indeed, D&T has arguably more in common with art and design than it does with science. This is an example of what Gardner (1994) called a demarcationist model, leading to the establishment of two distinct subjects, with only very limited links between them. This too seems to us an inappropriate approach for Early Years practice; by treating science and technology entirely separately practitioners risk missing out on opportunities for contextualising scientific learning through D&T activities. The development of specific knowledge in particular contexts – so-called 'situated cognition' (McCormick et al. 1995) – is central to our understanding of young children's learning, and underpins what Gardner (1994) terms a materialist model of the interaction between science and technology. The materialist approach elevates technology to a leading role in the relationship, encouraging practitioners to 'scaffold' children's development of science concepts through the hands-on, familiar contexts provided by evaluating products and solving design problems during making.

While there are clear educational benefits to be gained by framing the Early Years science and technology curriculum in this way, we would favour an approach that maintains a more 'even' balance between the two disciplines, such as that implied by Gardner's interactionist model (1994) in which they are regarded as distinct yet mutually supportive: 'When the two sets of ideas are brought together they immediately begin to spark off imaginative approaches because they support and complement one another' (Baynes 1992: 35). However, this model begs the following question: 'which elements do science and technology share, and how much of each should be left in a discrete form?' For young children, while a developing understanding of their surroundings and 'how the world works' transcends any subject boundaries, it is in the processes informing this understanding that similarities emerge. For example, children exploring fabrics in order to find out about their texture and structure may be said to be operating in a scientific mode, while a similar process of exploration undertaken in order to choose materials for a teddy's coat would involve more technological thinking. While appreciating the similarities and differences between processes used in science and technology it is important in an interactionist approach to seek ways in which they can 'feed into' one another. For example, the imaging and modelling skills that children develop during designing and making activities (Baynes 1992) can support them in developing scientific models and pictures to help understanding of areas such as simple electrical circuits.

But how do science and technology differ? One useful way of looking at the differences between them is to consider the purposes for which we engage in them as activities. As scientists, young children are seeking to understand the world (and beyond) as it exists. They are trying out new ideas (e.g. 'light objects float') to see how useful they are in explaining the phenomena they observe. The product of scientific enquiry is a body of 'tested' knowledge and understanding for the enquirer. By contrast, when acting as technologists, children are seeking to change the world (or elements of it) to serve a particular purpose. For example, they might be trying to make a boat that will sail across the water tray. Testing materials for their suitability may appear to be exactly the same as the scientific activity discussed here. However, the purpose in the child's mind is different, since he or she is now working towards making something that hasn't existed before. The product of technological activity is therefore a 'thing' – a changed reality that may take many forms and may also include the development of understanding on the part of the technologist. Both disciplines are driven by human wants and needs: in the case of science it is the desire for understanding; whereas for technology it is some improvement in our physical environment. On most occasions, for both children and adults, the motivations may be somewhat mixed, but it is useful for us as educators to recognise the scientific and technological strands within human endeavour.

The contents of other chapters

This book is organised into two parts. Part One (Chapters 1 to 6) outlines the principles of teaching science and technology in Early Years settings, while Part Two (Chapters 7 to 12) provides specific guidance on thematic science and technology topics. Chapter 13 rounds off the book by looking forward to children's transition to science in the primary school and beyond.

In Chapter 2, Janet Rose, Lone Hattingh and Karen McInnes explore the theoretical understandings of learning underpinning Early Years science and technology. They review some of the recent research into the human brain that sheds light on the ways in which children's scientific and technological aptitudes might unfold. They explore the implications of cognitivist learning theories such as social constructivism for these areas, including the importance of symbolic representation and the pedagogies of play in the development of scientific and technological thinking. Finally, they move on to considering appropriate multimodal teaching and learning approaches informed by socio-cultural and new materialist theories.

In Chapter 3, Kendra McMahon and Janet Rose emphasise the importance of narrative; an essential feature in the education of young children and a mode