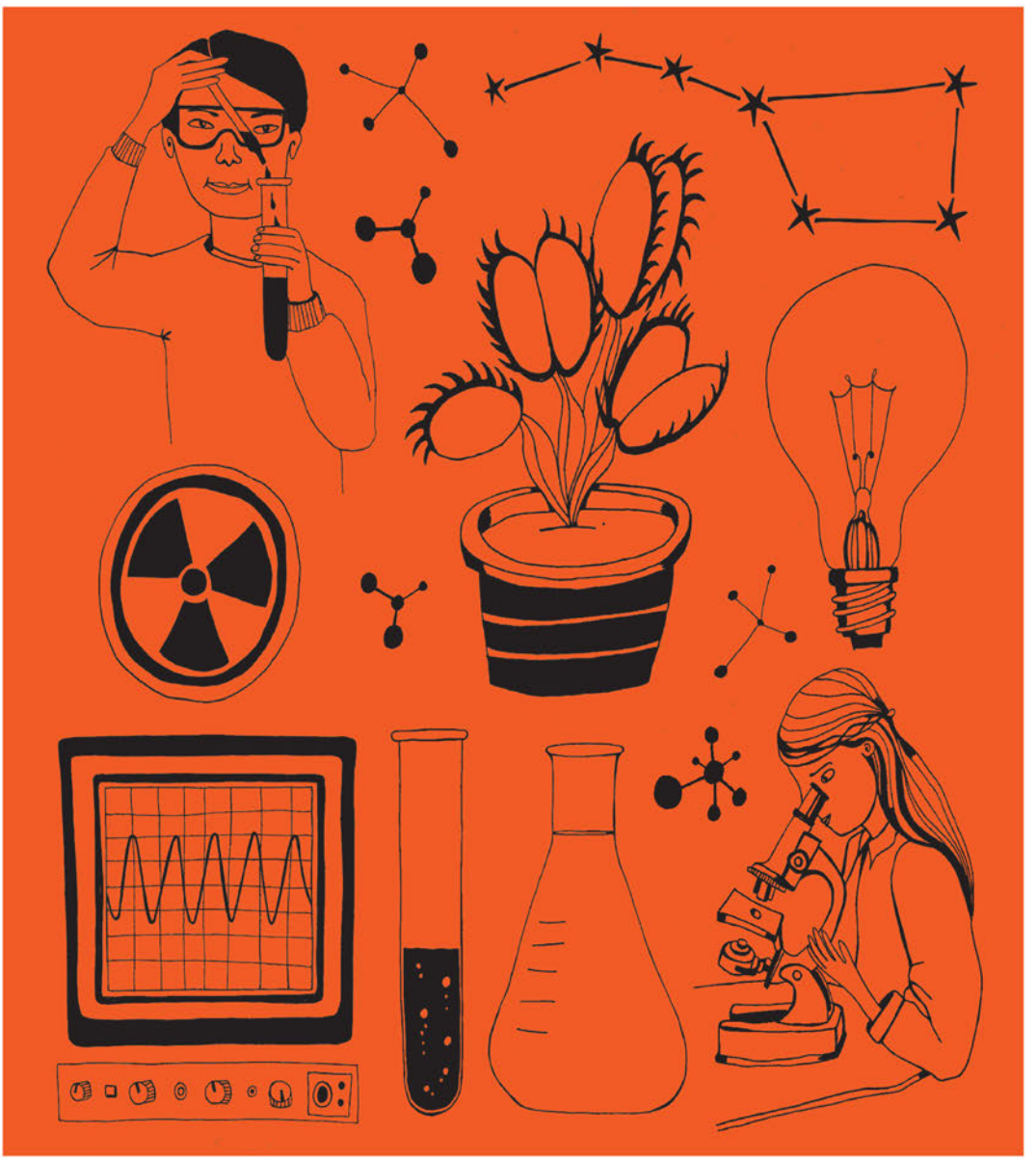
Learning to Teach Science in the Secondary School

A companion to school experience

Edited by **Rob Toplis**

4TH EDITION



LEARNING TO TEACH SCIENCE IN THE SECONDARY SCHOOL

Learning to Teach Science in the Secondary School is an indispensable guide with a fresh approach to the process, practice and reality of teaching and learning science in a busy secondary school. This fourth edition has been fully updated in light of changes to professional knowledge and practice and revisions to the national curriculum.

Written by experienced practitioners, this popular textbook comprehensively covers the opportunities and challenges of teaching science in the secondary school. It provides guidance on:

- the knowledge and skills you need, and understanding the science department at your school
- development of the science curriculum
- the nature of science and how science works, biology, chemistry, physics, astronomy and earth science
- planning for progression, using schemes of work to support planning, and evaluating lessons
- language in science, practical work, using ICT, science for citizenship, sex and health education and learning outside the classroom
- assessment for learning and external assessment and examinations
- educational research and science teachers

Every unit includes a clear chapter introduction, learning objectives, further reading, lists of useful resources and specially designed tasks – including those to support Master's level work – as well as cross-referencing to essential advice in the core text *Learning to Teach in the Secondary School.*

Learning to Teach Science in the Secondary School is designed to support student teachers through the transition from graduate scientist to practising science teacher, while achieving the highest level of personal and professional development.

Rob Toplis is Senior Lecturer in Secondary Science Education at Brunel University, UK.

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Series Editors: Susan Capel and Marilyn Leask

Designed for all students learning to teach in secondary schools, and particularly those on school-based initial teacher training courses, the books in this series complement *Learning to Teach in the Secondary School* and its companion, *Starting to Teach in the Secondary School*. Each book in the series applies underpinning theory and addresses practical issues to support student teachers in school and in the training institution in learning how to teach a particular subject.

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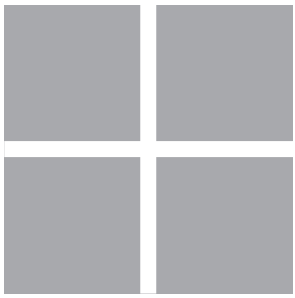

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Rob Toplis

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PREFACE TO THE FOURTH EDITION

As with the previous editions of *Learning to Teach Science in the Secondary School*, this fourth edition is written in conjunction with the generic text, *Learning to Teach in the Secondary School*, 6th edition (Capel, Leask and Turner, 2013), which we assume readers can access. Therefore, we have attempted to avoid repetition of material in the generic text though there may be some inevitable overlap to aid clarity. The suggested tasks, set in boxes, are an integral part of each unit and the intention is that they should be read in conjunction with the text. As with the generic book, these tasks can be done on your own or in collaboration with your mentors in school, your tutor or your fellow student teachers. The tasks frequently provide opportunities to link theory with practice: it is often very difficult to separate theory and practice and very often theory is essential in order to understand and interpret much of the practice and procedures you will encounter as a student teacher. It may be worth highlighting that in a number of texts and journals, the term 'student' is used instead of 'pupil'; that 'trainee teacher', 'trainee', 'beginning teacher' or 'pre-service teacher' may all be used to mean 'student teacher' and that 'school-based tutor' may be used instead of 'mentor'. Although the term 'student' instead of 'pupil' is now becoming commonplace to mean a learner in 11–19 secondary education, there is a risk of confusing 'student' with 'student teacher' and we have therefore kept to the terms 'pupil' and 'student teacher'.

Since the publication of the third edition, there have been a number of important changes in teacher education and in science education. These changes include:

- a new set of Teachers' Standards;
- the introduction of School Direct for school-based teacher education and training;
- changes in the names and status of schools that now include terms such as colleges, academies, 'all-through' schools (from 5–19 years) and free schools;
- changes in assessment and examinations;
- new Ofsted (Office for Standards in Education) inspection frameworks for both schools and teacher education and training;
- changes in the National Curriculum.

Many teacher education and training courses include Master's level work and readers are directed to the relevant sections of the units that address these requirements. Many of the suggested 'Further Reading' lists include references to books and book chapters that will provide appropriate background for Master's level work.

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ACKNOWLEDGEMENTS

When Jenny Frost, the editor of the previous editions of this book, approached me to take on the role of editor for this fourth edition, I was both flattered and rather daunted. How can anyone follow on from the direction that Jenny had set out for the book? I once commented to one of the contributors that this is really Jenny's book, I am just looking after it.

I am grateful to all the previous authors who remained on the team and were able to bring their Units up-to-date with the sometimes radical changes in both the school science curriculum and in science teacher education. I am also grateful to those new authors whom I approached and who enthusiastically agreed to contribute. I would like to thank those contributors with whom I had a very professional dialogue about terminology and meanings. These discussions have, I hope, added to the clarity of ideas in the Units and to our own thinking as science teacher educators.

Together with the contributors, I would like to express my thanks for permission to reproduce or use materials from the following individuals and organisations. These include, from the third edition, Cengage Learning Services Ltd for the reproduction of Figure 1.2.1; Caroline Allen for her drawing of a scientist in Unit 3.1; Nick O'Brien, Satomi Saki and Jamie Styles for ideas and drawings which appear in Unit 5.3; and the pupils and student teacher who appear in the photographs in Unit 5.6. In addition, I would like to thank Herschel Grammar School for permission to reproduce the pro-forma example in Figure 4.3.4 and Brunel University for the pro-forma example, Figure 4.3.5 and the lesson evaluation pro-forma in Figure 4.4.6.

Marcus Grace (Unit 5.4) would like to acknowledge the advice and helpful discussions with Jackie Smith, Personal Development Learning Coordinator and Careers Coordinator at The Mountbatten School, and with Maxine Farmer, Citizenship Coordinator at Hounsdown School.

I would like to express particular thanks to Helen Pritt, Sarah Tuckwell and Natasha Ellis-Knight of Routledge for their advice and support, to Kat Troth for editing some of my sections and asking awkward but important questions, and to Jenny Frost herself for her advice and for easing the transition to my editorship.

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ABBREVIATIONS

AAIA	Association for Achievement and Improvement through Assessments
ACCAC	Qualification Curriculum and Assessment Authority for Wales
ACT	Professional Association for Citizenship Teaching
AfL	Assessment for Learning
AIDS	Auto Immune Deficiency Syndrome
A-level	Advanced level (GCE)
APP	Assessing Pupil Progress
AQA	Assessment and Qualifications Alliance
ARG	Assessment Reform Group
AS level	Advanced Subsidiary level (GCE)
ASE	Association for Science Education
AST	Advanced Skills Teacher
BEI	British Education Index
BTEC	Business and Technical Education Council
CASE	Cognitive Acceleration in Science Education
CAU	Centre Assessed Unit
CCTV	close circuit television
CLEAPSS	Consortium of Local Education Authorities for the Provision of Science Services
CLISP	Children's Learning in Science Project
CPD	Continuing Professional Development
DARTS	Directed Activities Related to Texts
DCSF	Department for Children, Schools and Families
DfE	Department for Education
DfEE	Department for Education and Employment
DfES	Department for Education and Skills
DNA	deoxyribonucleic acid
DoH	Department of Health
EAL	English as an Additional Language
ECM	Every Child Matters
EBD	Emotional and Behavioural Difficulties
EPPI	Evidence for Policy and Practice Information and Coordinating Centre
ESTA	Earth Science Teachers Association

EVC	Educational Visits Coordinator
EVS	Electronic Voting System
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
GP	General Practitioner
G & T	Gifted and Talented
GTC	General Teaching Council
GTP	Graduate Teacher Programme
GUM	Genito-urinary Medicine
HEI	Higher Education Institution
HIV	Human Immunodeficiency Virus
HoD	Head of Department
HoS	Head of Science
IB	International Baccalaureate
IDEAS	Ideas, Evidence and Argument in Science project
IEP	Individual Educational Plan
IoB	Institute of Biology
IoP	Institute of Physics
ISA	Investigative Skills Assignment
IT	Information Technology
ITE	Initial Teacher Education
ITT	Initial Teacher Training
IWB	interactive white board
KS	Key Stage
LA	Local Authority
LRS	Learner Response System
LSA	Learning Support Assistant
LSD	lysergic acid diethylamide
MA	Master of Arts
MA	Management Allowances
MedFASH	Medical Foundation for Aids and Sexual Health
MI	Multiple Intelligences
NHSS	National Healthy School Status
NQT	Newly Qualified Teacher
Ofqual	Office of Qualifications and Examinations Regulation
PACKS	Procedural and Conceptual Knowledge in Science project
PCK	pedagogical content knowledge
PDP	Professional Development Portfolio
PHSE	Personal Health and Social Education
PLTS	Personal Learning and Thinking Skills
PSA	Practical Skills Assessment
PSHE	Personal, Social and Health Education
PSMSC	Personal, Social, Moral, Spiritual and Cultural
QCA	Qualifications and Curriculum Authority
QCDA	Qualifications and Curriculum Development Agency
QTS	Qualified Teacher Status
RSC	Royal Society of Chemistry
SASP	Science Additional Specialism Programme

SATs	Standard Assessment Tasks
SCITT	School Centred Initial Teacher Training
SEN	Special Educational Needs
SEP	Science Enhancement Programme
SLT	Senior Leadership Team
SMT	Senior Management Team
SoW	Scheme of Work
SRE	Sex and Relationship Education
STEM	Science, Technology, Engineering and Mathematics
STI	sexually transmitted infection
TDA	Training and Development Agency for Schools
TGAT	Task Group on Assessment and Testing
TIMSS	Third International Mathematics and Science Survey
TLR1	First Teaching and Learning Responsibility
TLR2	Second Teaching and Learning Responsibility
TLRP	Teaching and Learning Responsibility Payment
TTA	Teacher Training Agency
VAK	Visual, Auditory, Kinaesthetic

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1 BECOMING A SCIENCE TEACHER

INTRODUCTION

Becoming a science teacher involves a diverse range of different tasks covering a wide range of skills, knowledge and understanding. No day is the same and very often no hour is the same. This is by its very nature a function of dealing with human beings. The humans you are dealing with on a daily basis are not just ordinary humans; they are teenagers and have all the features that go with an age group who are going through some of the most important changes of their lives. As a secondary science teacher you are in a privileged position to witness and even to some small extent, to be part of those changes. Therefore, the skills of a beginning or student science teacher are not those that just involve science knowledge and skills but are those of an individual who may, at various times, be a counsellor, careers officer, adviser, psychologist, carer and actor, to name but a few. After all, that is probably why you decided to be a teacher. At this point it might be useful to read the first unit, Unit 1.1, 'What do teachers do?' by Andrew Green and Marilyn Leask from the companion volume, *Learning to Teach in the Secondary School* (Capel *et al.*, 2013).

The units in this section provide an early introduction to starting out as a student science teacher. It provides some background about starting points and some of the skills and knowledge you may bring with you that can enhance pupils' experiences. It provides the backdrop to developing as an individual who is deeply involved with science *learning* – in Keith Taber's words, a 'learning doctor' (Taber, 2001, p. 53) – and with a proactive approach to managing your own learning and professional development as a science teacher. It also gives an overview about the ways in which schools and science departments are structured and some of the different jobs that science teachers undertake. In essence, this first section is about an induction into a community of practice that relies not only on science knowledge, but also on a variety of skills required when dealing with people. And the people in secondary schools are a diverse but extremely interesting lot!

REFERENCES

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UNIT

1.1

LEARNING TO BE A SCIENCE TEACHER

Rob Toplis

INTRODUCTION

Science education can be a rather tricky business. Not only do you need to know the science itself, to 'know your stuff', you also need to know a lot about education, that is teaching and learning, and know quite a lot about people. There is a myth – and one that is unfortunately still prevalent in the minds of some people with little experience inside schools – that science is something that can somehow be imparted to pupils, that science knowledge can be transmitted directly from the teacher to the pupil by some unseen conduit, a kind of learning cable from one stock of knowledge to an empty vessel at the pupil end. The mere act of telling someone can somehow convey all the information needed. Nothing could be further from the truth.

OBJECTIVES

By the end of this unit, you should:

- be aware that science teaching and learning is a complex process;
- know that your own enquiry skills are needed to develop knowledge about science education;
- understand some of the requirements for Master's level work.

WHAT DO SCIENCE TEACHERS NEED TO KNOW?

Starting points: what do you know already?

Beginning or student teachers come from a wide variety of starting points in terms of their academic experience, social and cultural experiences and work experiences. Added to this are their values, attitudes and beliefs about science, what it is and how it should be taught.

Academic experiences may be varied. They may include a first degree from a fairly narrow area or one with a mixture of different modules; they may include a higher degree

in an even narrower area with research based on one specialist topic. Examples may be a biology student teacher with a first degree in genetics but with little or no ecology; a physics student teacher with a degree in electrical engineering but with little content in astrophysics, or a chemistry student with a degree in medicinal chemistry but little inorganic chemistry. In these examples, further subject knowledge enhancement would be required before being able to confidently teach all aspects of the specialist science.

An individual's social and cultural experiences can often be a valuable addition to the daily interactions with teenage pupils. Personal experiences and interests, memberships of groups, travel experiences and hobbies can contribute to the positive professional relationships that occur between teachers and pupils. At one level, involvement in the clubs and societies in schools not only helps forge these positive interactions but helps the informal education of pupils: the hidden curriculum. At another level, the richness of a diversity of backgrounds and cultures can add to the overall pupil experience in school.

A student teacher's prior work experience can provide opportunities that will enrich their science teaching, whether it be through new ideas to teaching science, approaches to organising the classroom, dealing with individuals – the so-called 'life skills' – or simply some of the anecdotes from work that can be used to illustrate ideas in the science laboratory. However, it is important to point out that schools and classrooms are very complex social situations and often work very differently to the workplace; it may not always be possible to simply transfer practices from the context of work to the context of school.

You will, inevitably, arrive with a number of very different views, values, beliefs and attitudes. Some of these may be based on your own education; some will be based on your views of the world, your experiences and even the ways you view learning. When you begin teacher education and training, a number of these will alter, and may even be in conflict with new experiences and change as a result. It is important to be open-minded. As you observe, reflect on and evaluate your previous ideas and current experiences, you may start to develop a personal philosophy about science teaching and learning, and your role in this.

Task 1.1.1 **Starting out**

Make a list of some of your skills and beliefs about science teaching and learning. These might include: subject knowledge; 'transferable' skills such as organisation, time management and creativity; 'people skills' such as empathy, diplomacy, enthusiasm, and beliefs, attitudes and values that might address the question, 'why do I want to teach science?'

Then look at this list and consider how you can enhance these skills, and how you hope to address some of these areas during your teacher training and education.

An outline of some of the different roles of teachers can be found in Unit 1.1 of the companion volume to this book, *Learning to Teach in the Secondary School* (Capel *et al.*, 2013).

Subject knowledge, content knowledge and pedagogy

There has been a certain amount of debate about the nature of subject knowledge. Teachers need to know *what* to teach, the content knowledge necessary. They also need to know *how* to teach this knowledge, the pedagogy involved. Shulman (1986) has contributed to our understanding about subject knowledge and has proposed the term *pedagogical content knowledge*, or PCK, to refer to the practical knowledge used by teachers in classrooms. This practical knowledge is, understandably, complex as it involves the knowledge that specialist teachers possess that includes pupil misconceptions, examples, analogies and models. Added to this are the illustrations, conceptual difficulties and connections with other aspects of learning such as assessment and the curriculum (Berry, 2012). If we take the example of teaching a very simple topic such as the forces on a cyclist pedalling at a constant speed along a flat road, the teacher will need to know a number of important facts. They will need to know the content knowledge about the forces acting on the cyclist such as friction, forward motion, gravity and Newton's Laws. They will also need to know pupils' misconceptions or alternative frameworks about forces and motion, how force arrows can be drawn, balanced forces, some possible simple demonstrations or observations about Newton's Laws, other possible examples that can add to pupils' understanding, 'what if' questions and even the kinds of questions that may arise in assessment tests or examinations. The PCK involved in this apparently straightforward example on forces and motion is rather more complex than it immediately appears and the teacher needs to draw on a wide range of knowledge to deal with this.

Task 1.1.2 **Simple photosynthesis**

List the items of PCK needed to teach a simple outline of photosynthesis, involving the production of carbohydrate and oxygen from carbon dioxide and water, using light energy.

Curriculum knowledge

Subject knowledge is not the only form of knowledge a teacher needs. They also need to know *what* needs to be taught, i.e. curriculum knowledge. This is further complicated by the frequency of curriculum change but change is inevitable as the curriculum is revised in response to changes in policy and evolving ideas about what kind of science needs to be taught to all pupils in the secondary age range. Curriculum change is not just something to hit the news in England; it occurs throughout the world as governments and international educators react to the need for both a scientific and technological workforce while at the same time enhancing the scientific literacy of twenty-first-century populations who need to be better informed about some of the major scientific, ethical and environmental issues facing them.

One of the biggest curriculum changes in more recent years has been the arrival of and changes to the General Certificate of Secondary Education (GCSE) with a shift towards what pupils can do, rather than what they can remember for a final examination – and recent shifts back again. The second major curriculum change is the National Curriculum and its revisions.

The National Curriculum arrived in 1989, resulting from a mixture of historical events, initiatives and a not inconsiderable degree of political influence. Although the biological, chemical and physical science content was familiar, AT1, later to be called Sc1, covered experimental and investigative work and was the first time investigations in school science were now part of a statutory curriculum. With Sc1, pupils were required to predict, carry out, analyse and evaluate investigative work in science. This type of practical work in science was a noticeable departure from the 'recipe-following' form of practical work that was being carried out across the country, designed to illustrate scientific phenomena and explanations.

Since 1989 there have been five versions of the National Curriculum in 1991, 1995, 2000, 2004 with another in 2013. What does this indicate? Changing criteria for the science curriculum? Different political agendas? Or the realisation that previous versions of the curriculum were in need of change? Two earlier areas of the National Curriculum were open to general criticism as far as teachers were concerned: its manageability in practice and its assessment. A third criticism relates to scientific literacy and the question: 'Who is the science curriculum for?' A rapid level of curriculum reform in the early days led to 'mass reading activities' (Wellington, 1994, pp. 3–4) where teachers attempted to interpret the new requirements, a difficulty for a group of professionals more used to *controlling* aspects of the curriculum (certainly below the examination years) than *delivering* a centralised and prescribed format over which they had no influence. Teachers then had to write complex schemes of work to accommodate all of these factors – and have been doing so ever since. The later versions of the National Curriculum attempted to address some of the problems and simplify them by relying more on the professional judgement of teachers in their interpretation and implementation.

In response to criticisms that the curriculum was prescriptive and assessment-driven in nature; that there was an overload of factual content, little contemporary science, and coursework that was restricted to a few tried and tested investigations that were divorced from day-to-day science teaching, the 2004 version of the National Curriculum introduced 'How Science Works' with its emphasis on evidence, investigative science, communication, and applications and implications. These now form the 'working scientifically' part of the latest version of the National Curriculum.

More recently, there have been continuing international concerns about school science education, including a reduction in the numbers of pupils studying the physical sciences beyond the age of 16, gender differences, and pupils' attitudes and motivation for studying science. The Relevance of Science Education (ROSE) study of pupils' attitudes to science shows that in over 20 countries, pupils' response to the statement: 'I like school science better than other subjects' is increasingly negative the more developed the country (Osborne and Dillon, 2008, p. 13), that science is 'important but not for me' (Jenkins and Nelson, 2005, p. 41). Against this backdrop has been the most recent version of the National Curriculum with greater emphasis on content knowledge. It remains to be seen if this initiative is able to reverse some of the trends in attitudes to school science and can engage *all* pupils in further study and for greater scientific literacy.

LEARNING SCIENCE

The science teacher needs to have some understanding about theories of learning. A biologist would not expect to understand many aspects of the subject without Darwin's theory of evolution by natural selection; a chemistry teacher would be expected to know