

Summary Report: Subject Knowledge in Secondary Science Initial Teacher Training

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Background

The Wellcome Trust acknowledges that its aims to achieve extraordinary improvements in human and animal health can only be realised if there is both a sustainable supply of high-quality scientists and a wider population that can embrace, challenge and respond to the innovation and development brought about by science and technology. Central to the Trust's education strategy is a belief that quality of education depends on the skills and professionalism of teachers and the teaching and learning they encourage.

With this in mind, in December 2009, the Wellcome Trust commissioned a team led by Dr Roger Lock at the University of Birmingham to carry out a study of the development of subject expertise during one-year postgraduate training courses for secondary science teachers.¹ The research was devised to provide insight into the acquisition of subject knowledge that takes place alongside the acquisition of more general teaching skills. Subject expertise and teaching quality are strongly correlated, so understanding how teachers learn the content of the subject they will be teaching will improve the acquisition of this knowledge and should lead to a better science education for all pupils. The research findings from the study were summarised in a briefing document, 'Subject knowledge and pedagogy in science teacher training',² written by Professor Sir John Holman.

¹ Lock R et al. Acquisition of Science Subject Knowledge and Pedagogy in Initial Teacher Training. University of Birmingham 2011 (www.wellcome.ac.uk/About-us/Publications/Reports/Education/WTVM053203.htm).

² Holman JS. Subject knowledge and pedagogy in science teacher training. Wellcome Trust 2011 (www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtvm053188.pdf).

Summary of findings from the Wellcome Trust-commissioned research study

- Science teachers often teach outside their subject specialism,³ which makes the acquisition of sound subject knowledge particularly important.
- The diversity of subject specialist backgrounds presents a major challenge in bringing all trainees to a level where they can teach across the national curriculum for science.
- Training a science teacher involves developing: (i) subject knowledge; (ii) the skills and methods needed to teach specific science topics, known as topic-specific pedagogy (TSP); and (iii) general pedagogy, the teaching craft skills applicable across all subjects.
- Science subject knowledge is acquired directly, as well as through learning TSP; this acquisition usually takes place within a training institution and is less likely to take place formally in the teaching practice school. The time assigned to subject knowledge varies dramatically between training institutions.
- Although it is a central pillar of national curriculum science, understanding the methods and processes of science – often referred to as ‘how science works’ – is not identifiable as a major component of initial teacher training (ITT).
- Trainees tend to focus on areas of subject knowledge weakness only when they are required to teach those areas. They employ textbooks for pure subject knowledge, while drawing on the support of experienced teachers and college tutors for TSP.
- Trainee science teachers anticipate that they will continue to need professional development during their newly qualified teacher (NQT) year, with a focus on generic pedagogy, such as assessment and behaviour management, but with physics knowledge acquisition featuring strongly as a subject-specific need.

Below, we set out the expert views of several invited policymakers and teacher training practitioners who participated in a seminar devised to discuss and further modify the findings and observations arising from Lock’s report. A brief description of the seminar, its presentations and a list of participants are included in the Annex.

³ The majority of science teachers consider themselves ‘specialists’ in biology, chemistry or physics, as opposed to ‘science’.

Additional key points from the seminar

- The Government is reasserting the place of subject knowledge in schools, and it is timely to consider how subject specialist teachers are trained and supported.
- There remains a need for greater emphasis on subject knowledge, notably TSP.
- The proposed reforms in ITT will rely on defining a new relationship between higher education institutions (HEIs) and schools, with a likely shift in balance between the respective institutions.
- The science curriculum in its entirety is too extensive for individuals to master in one year of training.

Given that teachers tend to apply the 'point of use' approach in seeking subject knowledge just before teaching it, a coaching model should be developed that will draw on science subject expertise located within schools to provide support when it is of greatest use. Robust selection and a system of rigorous quality assurance would need to be in place. There would also need to be a mechanism to provide coaching for schools that did not have a 'coaching teacher' in place for a specific subject.

Overall recommendations

The report made several recommendations, which were elaborated upon and added to at the seminar, as described below.

1. The breadth of science topics covered in school curricula is extensive and covers the three major disciplines (physics, chemistry and biology), as well as other areas of science such as earth science, astronomy and behavioural science. Therefore, science teachers in their early careers need more focused subject support to help them acquire greater knowledge and understanding, which will enable them to teach better with confidence.

For Government, teaching schools, HEIs, professional bodies, Science Learning Centres

2. There needs to be an explicit acknowledgement from school senior leaders, subject teachers, HEIs and trainees that new entrants to science teaching

seldom have an extensive knowledge of all areas of the curriculum. In recognising this reality, new teachers would feel better able to admit areas of weakness and to seek the necessary support to address deficits.

For Government, school senior leaders, HEIs, subject leaders

3. ITT should be considered formally as the first stage of a continuous process of professional development extending across the early years of teaching and beyond. The emphasis would be expected to change over a teacher's career, from the acquisition of broad skills and knowledge to keeping knowledge up to date and developing advanced professional expertise.

For Government, HEIs, school senior leaders, Science Learning Centres

4. While intensifying the drive to recruit more physics and chemistry specialist teachers, specifically designed continuing professional development (CPD) courses should continue to be provided and promoted for science teachers teaching outside of their original subject specialism.

For Government, professional bodies, Science Learning Centres, other CPD providers

5. A single, authoritative collection of resources should be produced to provide accurate science subject knowledge for trainee teachers and NQTs, for all science topics in the national curriculum. These resources will focus on the powerful analogies, illustrations, examples, explanations and demonstrations that experienced teachers use to promote clear conceptual understanding and dispel common misconceptions. The collection could be hosted and validated by a national organisation, such as the Association for Science Education or the National STEM Centre, and professional bodies.

For Government, professional bodies, HEIs

6. The coverage of science subject knowledge in training courses is variable, especially in the school-based component of training. With ITT policy placing an increasing emphasis on school-based training, it is important that the following mechanisms are put in place:

- defining a small common core of topics, drawn from all disciplines, that are so fundamental to science that all trainees cover them in depth, regardless of their specialism

For the Teaching Agency, ITT providers, professional bodies

- assigning to selected specialist science teachers a formally recognised role as subject mentors, or coaches, to support the development of subject knowledge and topic-specific pedagogy at trainees' point of need.

For Government, HEIs, teaching schools, The National College, school leaders

Annex

Subject Knowledge in Secondary Science Initial Teacher Training seminar

29 November 2011, The Wellcome Trust

Summary of the seminar

In welcoming participants, the Wellcome Trust's Head of Education and Learning, Dr Hilary Leever, set a context for this work, linking students' enthusiasm for – and performance in – science with the subject knowledge of their teachers. Her predecessor, Professor Derek Bell, who chaired the event, indicated how the day's presentations would address the following questions:

- How and when do teachers gain their subject knowledge and expertise?
- What are the implications of proposed changes to initial teacher education for subject knowledge acquisition?

Participants were asked to contribute and discuss these issues throughout the day. They were also asked to consider:

- In what ways should the development of subject knowledge and expertise be strengthened at all stages of a science teacher's career?
- What practical steps can be taken to meet these ends by key players over the next three years?

Finally, the Wellcome Trust Senior Fellow for Education, Professor Sir John Holman, reflected on the day's discussions, drawing out some recommendations for action (which are incorporated in the overall recommendations in the seminar report).

The place of subject knowledge in science teacher education

Professor John Leach, Pro-Vice-Chancellor, University of Hull

“Let’s not get into auditing knowledge for large cohorts of PGCE students. It’s all about pedagogical content knowledge.”

Professor John Leach

The science content covered by the national curriculum is extensive, and very few science graduates or postgraduate trainees are familiar with all its wide-ranging topics. As a former science education lecturer and researcher, John Leach asked whether it was realistic to expect PGCE courses to make up the gaps in trainees’ subject specialist knowledge. He also suggested that most trainees were not prepared to own up to these knowledge deficiencies. Although previous attempts have been made to put together a national curriculum of content that science educators should know, the mechanism proved unwieldy: auditing what teachers should know is not the same as establishing a mechanism to ensure they know it.

Professor Leach highlighted two particular themes in relation to science teachers’ acquisition of subject knowledge. First, increasing teachers’ specialist knowledge requires some form of subject CPD, which school senior leaders do not currently see as a priority. Head teachers feel more comfortable supporting professional development that links to generic school performance or the implementation of government policy. Persuading senior leaders of the value of investing in teachers’ subject specialist knowledge will require robust evidence that subject CPD has led to measurable changes in teacher confidence, teacher performance and pupil attainment. Drawing on a paper he coauthored in 2005,⁴ John Leach characterised successful subject CPD as being central to teachers’ core activity, collegial in its nature and approach, fostering the accumulation, articulation and communication of professional knowledge, and embedded in the culture of the individual school.

The second theme draws on the work of Lee Shulman in describing the four pillars of a teacher’s professional knowledge:

⁴ Leach JT et al. The continuing professional development of science teachers: a discussion paper. *Sch Sci Rev* 2005;87(318):105–111.

- knowledge of subject matter
- pedagogical content knowledge (PCK)
- knowledge of the curriculum
- knowledge of other content, learners and educational aims and general pedagogical knowledge.

It is through a teacher's pedagogical content knowledge that their unique professional expertise is to be found, in the most powerful analogies, illustrations, examples, explanations and demonstrations. According to Leach, if you have a well-developed PCK, "you know the questions to ask".

Science subject knowledge in initial teacher training

Dr Roger Lock and Dr Allan Soares, University of Birmingham

Roger Lock described substantial variability in how ITT secondary science courses address subject knowledge. His research⁵ uncovered a broad spectrum of approaches, from "we don't do anything about subject knowledge" to "we have a dedicated session dealing with it". However, PGCE science courses that do address trainees' knowledge focus on topic-specific PCK.

Echoing John Leach's remarks, Lock and colleagues' research findings gave a clear sense that trainees and newly qualified teachers are expected to be largely responsible for their subject knowledge. Trainees said that much of the subject-specific training took place in HEIs, as opposed to teaching practice, and that school mentors have a more generic support role. Once more, the levels of support in school varied greatly, both in terms of formal mentoring and through informal contact with class teachers.

Class teachers were identified as being a major source of subject knowledge and expertise for trainees. With schools taking on more responsibility for training teachers, Roger Lock and coauthor Allan Soares proposed formalising this highly valued support by establishing a cadre of class teachers as coaches to provide support in the initial, induction and early career period. Their findings also showed

⁵ Lock R et al. Acquisition of Science Subject Knowledge and Pedagogy in Initial Teacher Training. 2011 (www.wellcome.ac.uk/About-us/Publications/Reports/Education/).

that trainees make most use of subject knowledge at the point of need (when they are about to teach a specific topic).

Class teachers, trained and paid as coaches, would be well placed to provide bespoke subject support for teachers *in situ* in their early careers. In providing training and quality assurance, such coaching provision could draw on the expertise within HEIs, the Science Learning Centres and professional bodies and would foster a model of partnership for other types of subject CPD. A subject coaching approach would undoubtedly provide participating teacher coaches with their own CPD experience.

The implications of proposed changes to initial teacher education for subject knowledge acquisition

Liz Francis, Director of Workforce Strategy, Standards and Qualifications at the Training and Development Agency

“We know that teachers learn best from other professionals and that an ‘open classroom’ culture is vital; observing teaching and being observed, having the opportunity to plan, prepare, reflect and teach with other teachers.”⁶

The Government’s programme of educational reform has prompted a national debate about the role of subject knowledge. According to Liz Francis, proposed changes to the way in which teachers are trained have arisen from a commitment to raising teacher quality and providing greater autonomy. The ITT implementation plan has recognised that the quality of an individual teacher was the single most important determinant in a child’s educational progress and that the crucial factor that defines countries with the most successful schools was the quality of those in the teaching profession.

The New Teachers’ Standards that are due to be implemented from September 2012 arose from an independent review carried out by top head teachers and teachers. From this date, to achieve qualified teacher status, all trainees will be required “to demonstrate good subject and curriculum knowledge”, by:

⁶ The Importance of Teaching: The Schools White Paper, 2010

- having a secure knowledge of the relevant subject(s) and curriculum areas, fostering and maintaining pupils' interest in the subject, and addressing misunderstandings
- demonstrating a critical understanding of developments in the subject and curriculum areas, and promoting the value of scholarship
- demonstrating an understanding of and taking responsibility for promoting high standards of literacy, articulacy and the correct use of standard of English, whatever the teacher's specialist subject.

The Government plans to raise status and standards further through the greater involvement of schools in the process of training teachers (including recruitment, selection and training). Individual schools or groups of schools will offer provision along a continuum of involvement, ranging from active partnership through to the establishing of university training schools.

There will be a central role for teaching schools: the first cohort of 100 will come on stream in September 2011, and it is expected that 500 will be training teachers by 2014. Each teaching school will enter into a strategic partnership with at least one HEI. It is anticipated that directly engaging with ITT will contribute to overall school improvement.

The Government has established the National Scholarship Fund for Teachers, which it is hoped will encourage teachers to pursue knowledge to Master's level and share learning, knowledge and expertise across the school system. The first scholarships, awarded in December 2011, were limited to mathematics, science, English and special educational needs.

Discussion

How might subject knowledge and expertise be strengthened during initial training induction and mid-career?

There needs to be a wider acceptance that subject specialist trainees are not subject experts, especially in their early careers. Trainees should feel more comfortable admitting gaps in their knowledge in certain topics, as the first stage in attempting to acquire greater knowledge and understanding.

There was broad support for making better use of the knowledge and expertise of class teachers as coaches or subject mentors. This prompted questions on how such a scheme might be configured to offer incentives to participants and ensure high-quality coaching. In addition, the question was raised of how this approach would dovetail with – or be subsumed under – the proposed specialist leaders of education initiative, in which highly skilled middle and senior leaders will provide specific support to individuals or teams in other schools.

HEIs are good places to help trainees identify misconceptions. With schools taking on greater responsibility for training, how well placed will they be to identify and challenge these common conceptual errors? Within the proposed partnership between universities and schools, this could be an area in which HEI tutors continue to take a lead.

Dialogue among science subject specialists was highly valued as a potential source of improving teachers' knowledge and understanding. There was support for promoting discussion among subject teachers around case notes, much as lawyers and clinicians carry out much of their professional development. Protected funding that comes to schools for NQT support could be put to good use in providing opportunities for this type of collegial professional development.

Attendees

Katerina Antonatos	Southfields Community College	Roger Lock	Formerly University of Birmingham
Tony Ashmore	National Education Trust	Brian Marsh	University of Brighton
Maureen Baker	EM Centre for Learning	Jane McNicholl	University of Oxford
Hannah Belben	Ringwood School	Robin Millar	University of York
Derek Bell	College of Teachers	David Mitchell	IOE
Paul Betteridge	Department for Education	Jim Moreland	St Mary's University College
Katy Bloom	National Science Learning Centre	Rhys Morgan	The Royal Academy of Engineering
Gavin Boulby	University of Greenwich	Gaynor Nelder	University of Chester
Sarah Boyse	Altrincham Grammar School for Girls	James Noble Rogers	UCET
Susan Cannan	University of Bedfordshire	Christine Otter	University of York
Jasmin Chapman	University College Plymouth St Mark & St John	John Oversby	University of Reading
James de Winter	Faculty of Education, University of Cambridge	John Perry	Keele University
Marie-Claude Dupuis	ACME	Ashlee Perry	Bradford College University Centre
Jane Fieldsend	University of Reading, Institute of Education	Dana Ross-Wawrzynski	Altrincham Grammar School for Girls Trust
Peter Finegold	Isinglass Consultancy Ltd	Damian Royal	Waldegrave School for Girls
Liz Francis	Training and Development Agency for Schools	Douglass Scorer	University of Reading
Jenni French	Gatsby Charitable Foundation	Linda Scott	University of Worcester
Caro Garrett	University of Southampton	Jean Scrase	Nuffield Foundation
Charles Golabek	Cass School of Education and Communities	Keith Simpson	
Irena Grounds	St Mary's University College	Emma Snowden	Goldsmiths, University of London
Keith Hicks	University of Roehampton	Allan Soares	Formerly University of Birmingham
Leigh Hoath	Bradford College	Pete Sorenson	University of Nottingham
John Holman	Wellcome Trust	Stephen Stanton	Department of Education
Gren Ireson	Nottingham Trent University	Libby Steele	Royal Society
Susan Jones	Bangor University	Caroline Still	University of East Anglia
Julie Jordan	Centre for Science Education	Stephen Tomkins	Homerton College
Chris King	PGCE Science Team, Keele University	Rob Toplis	Brunel University
Rachel Lambert-Forsyth	Society of Biology	Charles Tracy	Institute of Physics
John Leach	The University of Hull	Adrian Warhurst	Newman University College
Hilary Leever	Wellcome Trust	James Williams	University of Sussex
		David Wood	MMU

