The environment for secondary school science teachers' continuing professional development in England: policy influencers' and practitioners' perspectives

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Declaration

I, Susan Sissling, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

This study explores the environment for secondary science teachers' continuing professional development (CPD) in England. The rationale is to better understand the situation, in the context of significant on-going investment during the early twenty-first century in CPD programmes for science teachers. Whilst CPD might seem an obvious policy solution to strengthen science education, the premise is not straightforward.

Semi-structured interviews were used to gather perspectives from three groups with different niches in national science CPD systems: policy influencers, from organisations with prominent positions in the science education landscape; leaders of school-based science CPD providers; and science teachers. Their perspectives are the basis for interpreting: the rationale for national CPD programmes; ways in which policy is predicated on or experienced as promoting models of science teaching, learning or curriculum, or of effective CPD; and the influence of the wider education context.

This study found that CPD is seen as a good thing by policy influencers, yet the purpose varies and the nature of CPD and its intended outcomes are unclear or inconsistent. Local CPD providers interpret and implement national programmes with pragmatism grounded in local knowledge and influenced by contractual drivers. Science teachers value, above all else, opportunity through CPD to connect with other science teachers, with immediate relevance to classroom practice and credible facilitators also important. Their participation is influenced by school factors and often associated with public examinations.

The environment for science CPD is fragmented. The rationale and underlying assumptions for policy development, CPD provision and participation vary, and characteristics of CPD which are identified in the literature as important to teacher development are not always evident. The relationship between CPD policy and its

enactment is complex and influenced by: economic and workforce drivers; characteristics of the education landscape, particularly school-led improvement; and pragmatic responses to opportunities and constraints.

Impact statement

This research looks at the environment for continuing professional development (CPD) for secondary science teachers in England from the perspectives of three groups with different niches in the national science CPD landscape: policy influencers, school-led CPD providers and science teachers. Investment by government, support from STEM stakeholders and provision by different types of organisations, including school-led providers, contribute to a wealth of opportunities for science teachers to participate in CPD. My findings suggest that whilst there is widespread consensus about the value of CPD for science teachers, the purpose and process of CPD is envisaged in different ways and that factors identified in the literature as key to maximising the impact of CPD on change in teaching practice often do not characterise teachers' CPD experiences. Schools are crucial to teachers' access to CPD and subsequent changes in practice. My research findings already influence my working practice and I see potential for these to contribute to further change within my own institution and to add more widely to current thinking about science and STEM CPD.

Relevant to local provision of science CPD within nationally-funded programmes, my findings highlight the importance of: minimising possible commercial constraints and influences on CPD focus and pedagogy; balancing local needs with programme requirements; providing opportunities for science teachers to experiment, reflect on new practice and collaborate over time; and recognising schools' influences on teacher development. Whilst the focus of my research was science CPD, these principles could usefully be applied to CPD programmes in other subjects. This is relevant because, in keeping with the current self-improving, school-led system, policies for varied national CPD programmes are enacted locally by schools. Teach Computing, for example, is a current government funded national CPD programme for computing teaching in which schools play a prominent role in local CPD delivery.

Science and STEM education and CPD provider networks are a route to sharing findings, with possible influence on CPD providers' programmes and practice. STEM stakeholder steering and special interest groups provide other opportunities for influence based on my research findings.

Relevant to policy development, I look forward to disseminating my research findings and conclusions formally and informally to facilitate wider impact through working groups, networks and communities of practice that I participate in. By sharing my findings with science and STEM stakeholders, I would hope to contribute to debates about policy development. Some policy influencers interviewed as part of my research indicated that they would be interested to learn about the findings, and I will offer them opportunity for this.

From a methodological perspective, sharing research insights within education research communities might contribute to the way that insights gained through empirical research, in this case about science teacher CPD, can usefully be considered alongside practitioners' perspectives as gathered in this study, so that the reality of their working experiences are captured and reflected. The early career researcher in science education and University of Hertfordshire education research groups are examples of groups that I participate in where this would be appropriate.

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Glossary

ASE	Association for Science Education
BERA	British Educational Research Association
CPD	Continuing professional development
DfE	Department for Education
ECF	Early career framework
EdD	Doctor in Education
EEF	Education Endowment Foundation
HEI	Higher education institution
IoP	Institute of Physics
ITE	Initial teacher education
NCCE	National Centre for Computing Education
NLE	National leader in education
NQT	Newly qualified teacher
PCK	Pedagogical content knowledge
PD	Professional development
PGCE	Post-graduate certificate in education
PISA	Programme for international student assessment
PIXL	Partners in Excellence
RSC	Royal Society of Chemistry
SLE	Subject leader in education
SLP	Science learning partnership
SPN	Stimulating Physics Network
STEM	Science, technology, engineering, mathematics and computing
TIMMS	Trends in international mathematics and science study
UH	University of Hertfordshire

Chapter 1 Introduction

This study explores the environment for secondary school science teachers' continuing professional development (CPD) in England from the perspectives of three groups with different niches in the national science CPD system: policy influencers, from organisations with prominent positions in the science education landscape; leaders of school-based science CPD providers; and science teachers. Policy influencers' perspectives contribute to understanding the rationale and underlying assumptions for national policies for CPD. CPD providers' and teachers' perspectives contribute to understanding how policy is enacted and experienced.

There has been significant, on-going investment of public funds in national programmes of CPD for science teachers during the twenty-first century to address concerns about attainment outcomes in science; low uptake and progression into employment and study pathways by young people; and shortfall of suitably qualified teachers. In a changing educational landscape, I have gained, through local, regional and national roles concerned with CPD for science teachers, first-hand experience of the opportunities presented by national policies or science CPD as well as the dilemmas and considerations involved in influencing, developing and enacting policy. This has led to my interest in taking a broad look at the overall environment for science teacher CPD and in doing so, to explore the interplay of factors that prevail.

This chapter describes the context for secondary science education in England; outlines how my professional experience has led to my research interest; describes the rationale for research; introduces the research questions; and describes the structure of this thesis.

1.1 Science education context

This section discusses ways in which national priorities for science education and changing science curricula, qualification requirements and accountability measures,

set in an evolving wider education policy landscape, provide a context for the current environment for science CPD.

Concerns about standards attained in school science, particularly in comparison to international competitors; the perceived relatively low number of young people choosing to study science after age 16; a predicted shortage of scientists and engineers; and challenges of recruiting and retaining science teachers have led, during this century, to interventions by successive governments, including through programmes of CPD. The House of Lords Science and Technology Select Committee, in 2001, stated the need for CPD for science teachers and was pre-cursor to the formation in 2004 of a national science learning network and national science learning centre. Continuing professional development was seen as key to improving science teaching quality and, in turn, educational outcomes and national prosperity.

Debate about the nature of science education begun in the 1960s (Millar and Osborne, 1998), leading to on-going changes in public policy, the science curriculum and assessment. It has continued throughout the twenty-first century. The UK House of Lords Select Committee on Science and Technology noted in 2001 the dual purposes of engaging all students with science as a preparation for life and preparing some students to continue with science post-16, judging that neither was done well at that time. These dual purposes, polarised as science for citizenship and for the future workforce, have influenced the school science curriculum during the twenty-first century and continue to be unresolved, with the discourse commonly about the purpose and curriculum content rather than its structure (Dillon and Manning 2010; Osborne, 2010; Osborne et al., 2018; Childs and Bard, 2020).

Debate about curriculum pathways in science, in particular whether students should pursue triple (three sciences as separate GCSE subjects) or double or combined science (which includes content from physics, chemistry and biology and is equivalent to two GCSE) reflects the debate about the purpose of school science education. Government policy, supported by funded programmes of CPD, has to date been to encourage triple science as the choice for high attaining students and progression

into subsequent STEM pathways. This illustrates an example of CPD for science teachers as a means of progressing government policy.

Since 1989, science has been a core subject in the national curriculum for England, with five revisions since then, each new version of the national curriculum leading to changes in qualification requirements (syllabuses and assessment frameworks). These are concerned with science curriculum content, which itself develops as scientific research progresses, and the way that the nature of science is perceived (for example, as a process of enquiry or a body of knowledge). Both have implications for the way that science is taught (Donnelly and Jenkins, 2001; Dillon and Manning, 2010; Gilbert, 2010). Emphasis on the processes of science, such as scientific enquiry, imply a more constructivist pedagogical approach, for example, than a curriculum framework in which science is a body of knowledge, to be transmitted by teachers to students.

Different perspectives about the place of practical work in the science curriculum (SCORE, 2008; Millar 2010; Royal Society, 2014; Holman, 2017) illustrate ongoing debate with implications for the content of the science curriculum and how it is taught and learnt. Influential stakeholder organisations lobby for policy and curriculum representations that reflect their standpoints on the purpose and nature of school science.

Formal assessment and accountability measures are influential dimensions of the science education landscape, with implications for science teaching and learning. Accountability operates at individual teacher, school, national and international levels. Science, along with English and mathematics, has featured prominently in secondary school accountability measures such as standard attainment tests (2003 - 2009), Ofsted subject reports (until 2013) and, currently, Progress 8 measures (Department for Education, 2020a). National policy and provision for science CPD responds to trends in national performance data, with improved student outcomes often a key performance indicator for funded CPD programmes.

International data are important too. Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) scores are international indictors of school science performance which inform government policy decisions (Schleicher, 2009). Barber and Mourshed, (2007) suggest that international assessment comparisons such as these have changed how national systems view themselves in relation to each other: success in education is linked with economic potential. In relation to science, this is linked to the need for the country to produce scientists and engineers – economic drivers that have added importance to TIMSS and PISA measures (Jenkins, 2009).

As well as the changing nature of scientific knowledge and the economic significance of the subject (Royal Society, 2014), concerns about recruitment and retention of suitably qualified science teachers also provide a rationale for science CPD. Shortfall in science teachers has continued through the twenty-first century and is predicted to worsen (Allen and Sims, 2017; Sims, 2019; Royal Society, 2020). Recruitment of physics teachers is low compared to other science subjects, and retention of science teachers generally compares unfavourably with many other school subjects (Worth and de Lazzari, 2017).

Science has featured in national initiatives involving subject-specific CPD programmes, such as the national strategies (2001 – 2011) and the specialist schools movement (funded from 2000 – 2011). The national science learning network, established in 2004, comprised of nine regional science learning centres led by higher education institutions (HEIs) and a national centre at the University of York. The aim of the government and Wellcome Trust initiative was to transform science teaching through improved quality and availability of science specific CPD. The structure of the network has changed over time, in part in response to wider educational policies. For example, government commitment to school – led improvement was reflected in the introduction from 2014 of school CPD providers.

At the time of writing, the network dominates the landscape for science CPD in England: with reach reported in 2020 (STEM Learning, 2020) to include every primary and secondary school in England. The network is currently comprised of national

STEM centre (reflecting a shift from science, to embrace a wider subject focus) and school-led science learning partnerships (SLPs), supported by the Department for Education, the Department for Business, Energy and Industrial Strategy, the Wellcome Trust and the Gatsby Charitable Foundation. In addition, industry partners contribute to particular CPD programmes through a charitable fund (Enthuse) which provides bursaries for participation in specific CPD activities. The national network is managed by STEM Learning Limited (formed as a successor to My Science Limited, the original operating company), as part of a portfolio of CPD and curriculum enrichment programmes in science, computing and STEM. Working within the national network and funded by it, the SLPs interpret and enact national policy.

Along-side the national network, other long-standing government funded national science CPD programmes reflect government priorities. The Stimulating Physics Network (SPN), for example, was established in 2009, and provides physics CPD through an infrastructure that is co-ordinated by the Institute of Physics and includes school-based teaching and learning coaches and lead schools. The Triple Science Support Programme has since 2008 supported the policy ambition for more students to follow triple science GCSE; and the Teacher Subject Specialism training programme has for more than 10 years, in different formats, aimed to improve non-specialist and returning teachers' subject knowledge in physics and chemistry.

As well as government funded programmes, there is a wealth of varied CPD provision by a range of stakeholders and commercial organisations. Morgan and Kirby (2016) describe the complex landscape of support for STEM education in the UK. Stakeholders from the public, private and third sectors fulfil varied roles in relation to CPD including influencing policy through their: links with government; investment or potential investment in CPD; status linked to way that science is envisaged; funding for research; or provision of science CPD programmes. Some organisations fulfil multiple roles and many also support programmes more directly focused on students.

Stakeholder organisations' websites and publications provide insight to the basis for the case for CPD for science teachers, in effect representing their policy as text. Key themes are to improve: the supply of specialist science teachers (Institute of Physics,

Royal Society); the supply of scientists and engineers (Gatsby Foundation, Institution of Engineering and Technology, Royal Academy of Engineering); subject teaching and subject knowledge (Gatsby Foundation, Institute of Physics, Royal Society of Chemistry, Wellcome Trust); teacher retention (Wellcome Trust) and science education more generally (STEM Learning, Wellcome Trust). Many websites (Gatsby Foundation, Royal Society, Royal Society of Chemistry, Wellcome Trust) direct teachers to STEM Learning. STEM Learning's vision statement is to achieve a world-leading STEM education for all young people across the UK and focuses on aspects of young people's economic prosperity and employment as outcomes of teachers developing their knowledge and experience.

Career-long CPD for science teachers is advocated by stakeholders such as the Royal Society (2014, 2020) and the Royal Academy of Engineering (Morgan and Kirby, 2016). The Wellcome Trust, which has invested more than £45 million in the science learning network since 2003, advocates an entitlement to subject professional development in all subjects and is supporting research into ways that this can best be delivered (Wellcome Trust, 2020). Also embracing all subjects, the Institute of Physics (2020) argues for a national system of subject specific CPD – the rationale includes recruitment and retention of teachers, improvement in teaching quality and improved national economic competitiveness. The argument for CPD in this case is firmly set in current government agendas including levelling up opportunity, tackling ingrained inequality and the advent of a new, technology and innovation driven industrial era.

Stakeholder organisations' differing positions fall broadly into workforce or professional entitlement stances. These are not mutually exclusive, and both are presented as a case for investing in science CPD. The different standpoints are featured with different prominence by two influential organisations. The Gatsby Foundation, for example, focuses on science for national economic prosperity and individual employment prospects in its website education mission statement. CPD is associated with national economic outcomes, with investment in the teaching workforce leading to impact on the wider workforce. The Wellcome Trust takes a

broader view of the value of professional development, whilst still emphasising the importance of CPD to expand teachers' subject knowledge, increasing their desire to stay in teaching and connecting with the wider science community. CPD is seen as an entitlement to support professional growth.

National policy for science teacher CPD is linked with and reflects wider aspects of the education context. Structural reforms in education during the twenty-first century have given schools greater autonomy for improvement, including teacher development programmes, through a system leadership role (Hargreaves, 2012; Woods et al., 2020). The Schools White Paper (Department for Education, 2010) asserts the importance of teaching, with teaching workforce development seen as key to improvement. Developments such as the reform of initial teacher education (ITE), the introduction of teaching schools and the extension of the academies programme, signalled a trajectory from central to school-led improvement, within an environment characterised by centrally prescribed targets and accountabilities. Government policy for school-led improvement, greater school autonomy, new types of schools and new bases for inter-school collaboration has increasingly shifted responsibility for teacher development to schools and remains a key feature of the current environment for science CPD. Relevant to the environment for science CPD, a significant proportion of SLPs within the national science learning network are led by teaching schools, reflecting and reinforcing their role as 'system leaders' as they engage and support schools and teachers with its programmes.

My research explores themes introduced in this section: the basis for policy for science CPD; wider contextual influences on its enactment; and the potential tension between central policy, priorities and programmes for CPD and school-based agendas.

1.2 Professional context

This section describes ways in which my professional experience of the changing context and systems for CPD secondary science teachers has led to my research interest.

I currently lead the University of Hertfordshire (UH) Centre for STEM Education, which was originally established in 2004 as a science learning centre within the national science learning network. Its changing role since then reflects aspects of the development in the national CPD landscape that are described earlier in this chapter. By the time I took up role in 2015 the original network structure of nine science learning centres had been replaced within one in which CPD was delivered by school-led SLPs. The Centre coordinated the activity of SLPs across two of the five operational regions of the national network. From 2016 the regional structure ceased, and STEM Learning subsequently coordinated SLPs. For two years after this, the Centre, by then renamed as the Centre for STEM Education, fulfilled an SLP role as one of its funded strands of work. The transition to a fully school-led national science learning network in 2019 precluded higher education institutions from fulfilling a formal role: although it was subsequently possible to contribute to the CPD programme of a local school-led SLP – which is the current arrangement. The UH Centre for STEM Education will be referred to in full at the start of chapters in which it features, it will subsequently be referred to as the Centre.

A similar pattern of changing roles characterised the Centre's involvement in other government funded CPD programmes. A regional role in the SPN network ceased in 2019, with the emergence of school-led provision and support, and central coordination by the Institute of Physics replacing five HEI regional coordination roles: another example of a CPD infrastructure with central and school-based dimensions.

Investment in CPD for teachers of STEM subjects by government and stakeholder organisations continues. The National Centre for Computing Education (NCCE), for example, was established in January 2019 and comprises a national centre and a network of school-led hubs which provide CPD for computing teachers. Supported by £80 million government funding and with engagement from key stakeholder organisations, there are similarities to the stages in development of the infrastructure for science CPD. In the initial stage of the NCCE, the Centre, along with other HEIs, fulfilled a regional role, enacting national policy through the provision of computing CPD across the east of England. By January 2020, however, HEIs were replaced by a

network of school led computing hubs coordinated by STEM Learning. The Centre continues to contribute as a satellite to a hub, although HEIs are precluded from fulfilling formal roles.

The Centre manages a portfolio of externally funded CPD programmes, operating as a business unit hosted within the UH School of Education. Similarly, school hosted providers such as SLPs or computing hubs rely on funding streams associated with particular CPD policies, also illustrating a model in which funding for national CPD programmes is awarded to coordinating organisations, and in turn, local providers, on a contract basis. In some cases, this is target driven and commercially incentivised, leading to the possibility that measurable, centrally determined outcomes and accountability measures drive local delivery and decisions.

Prior to this role, and relevant to my research interest, I participated in CPD policy development, as a member of national stakeholder steering groups, for example, and policy enactment in local authority, regional and national contexts: thus gained insight to the environment for secondary science teacher CPD from different standpoints. Mediating the implementation of the national key stage 3 science strategy to suit local needs as a local authority science and improvement adviser reflected, on occasions, a situation described by Whitty (2008) in which teacher development provision can be the result of compromise between state and practitioners' professional aspirations. The changing role of local authorities as schools' autonomy increased, led to new ways of working with schools, as local trading arrangements, including for CPD, were introduced.

I gained a different perspective on the environment for science CPD through roles at the Specialist Schools and Academies Trust concerned with facilitating and supporting system leadership by science, technology, engineering and maths and computing colleges. Through these, I observed the interplay between curriculum, CPD, schools' specialism roles and government policy. The opportunity presented by funded policy was enacted by specialist school leaders and practitioners.

My experience in different roles and contexts resonates with the possibility that "… the training available to science teachers has evolved as a result of major changes in education often instigated for predominantly political purposes" (Dillon and Manning, 2010, p.6): hence my interest in looking across the CPD environment from different perspectives.

1.3 Rationale for research and research questions

Possible different purposes for science education are unresolved and influence national priorities, curriculum frameworks and accountability measures. There is every indication that subject-focused CPD for secondary science teachers in England will continue as government and stakeholder policy for the foreseeable future, intended to address on-going concerns about students' attainment, attitudes and choices, and the recruitment and retention of science teachers. Performance and uptake of science and STEM subjects have been stubbornly resistant to change during the twenty-first century, although there has been encouraging progress over the last five years (Engineering UK, 2020). Circumstances of birth (including gender and socio-economic group) remain influential (Sutton Trust, 2019; Archer et al., 2020; Engineering UK, 2020). Despite a variety of initiatives to recruit, retain and retrain science teachers, low recruitment and retention rates compare unfavourably with other school subjects, with regional patterns of teacher shortage and turnover associated with schools' socioeconomic circumstances (Sutton Trust, 2019).

Whilst stakeholder organisations have commissioned research into specific concerns, such as teacher retention, and evaluative studies of specific initiatives, there are few studies which consider the implications of national policies, or which look across the CPD landscape. Teachers' own accounts of their experiences of CPD are infrequently drawn on in literature about the effectiveness of CPD (Pickering, 2007).

Perry et al. (2019) describe, in relation to the quality assurance of CPD, a model of system contexts: the professional and social system (characterised by ideologies, socio-economy, professionality, regulation, professional bodies); within this, CPD systems (comprised of participants, providers, activities, values, purpose); and within

this, CPD quality assurance systems (concerned with purpose, values, defining quality of CPD). Whilst the focus of my study is broader than quality assurance of CPD, and different system contexts will be considered, the interaction of the wider system and context for CPD, which Perry et al. (2019) argue is important, is an area for consideration.

Three key niches in the current environment for national programmes for secondary science teacher CPD are concerned with: policy influence; local CPD provision, which usually is school-led; and CPD participation. By gathering perspectives each niche my research explores the basis for policy, the relationship between policy and CPD provision, how policy is enacted and how the environment for CPD is experienced by science teachers. The research questions which arose from my professional experience and the literature, and which are the basis for exploring the environment for secondary science CPD, are:

1. What is the basis for current policy for continuing professional development of secondary science teachers in England?

2. How is policy for continuing professional development of secondary science teachers in England enacted?

3. How do secondary science teachers experience the environment for continuing professional development?

Directly relevant to my current role, my study can generate new understandings about influences on policy enactment and teachers' experiences. More broadly across the science education community it has potential to generate understandings relevant to policy development and the opportunities, challenges and implications that arise from policy approaches.

Whilst I have chosen to consider the basis for policy and its enactment, and the interrelationships between different players in the environment, the short overview in this chapter suggests the possibility that the environment for science teacher CPD could be explored through different lenses: for example, the changing role of HEIs in teacher CPD; the relationship between CPD and teacher change, recruitment and

retention; or the impact on student outcomes and pathways. It also is important to acknowledge that there is on-going national commitment to and investment in primary science CPD, particularly by stakeholder organisations – which also could be a worthwhile focus. My focus is on the secondary sector, however. To emphasise this, I refer in full, at the start of each chapter, to the environment for secondary science teachers' CPD in England. Subsequently, this is shortened to CPD environment or science CPD, depending on the context.

1.4 Thesis overview

This introductory chapter suggests some significant dimensions of the environment for secondary school science teachers' continuing professional development in England. Professional experience that led to my research interest is described and the research questions are introduced. The next chapter (Chapter 2) draws on literature perspectives from different fields to better understand the environment for secondary science CPD. These informed the research questions and the research approach, although some proved to be more useful than others when interpreting data.

The stance of my research is interpretivist, predicated on the assumption that the environment can be characterised by different perspectives and is likely to be experienced differently by different individuals and groups within it. Thus, people's accounts are the data for my study. Chapter 3 describes the research approach, and the basis on which semi-structured interviews with policy influencers, local CPD providers and teachers were undertaken and interpreted. Data from the three groups of interviewees is presented and analysed in chapters 4, 5 and 6.

Chapter 7 draws on literature to interpret the data and address the research questions. At this stage, theoretical perspectives including: models for situated teacher growth and effective CPD; cycles summarising stages in education policy development and enactment; and the impact of neoliberal and managerial influences on the education landscape were particularly useful in interpreting participants' accounts. The final chapter of the thesis, Chapter 8, outlines conclusions from

research, identifies limitations and suggests implications for practice and further research to better understand the CPD environment.

Chapter 2 Literature review

The previous chapter described dimensions of the environment for CPD for secondary school science teachers in England and outlined my professional experience in the field. In this chapter, to situate my study, I draw on the literature to explore different ways of conceptualising the environment that are relevant to my research focus including: ways that effective science teaching is envisaged; ways that teacher development and effective CPD are understood; and dimensions and possible implications of the wider educational context for secondary science teachers. The final section of the chapter outlines how the literature is drawn on at different stages of the research.

2.1 Effective science teaching

This section explores ways in which effective science teaching is characterised, on the basis that the purpose, process or aims of CPD are likely to be underpinned by perspectives of effective teaching practice.

The knowledge base of science teachers

The notion of good teaching is contested and changing (Connell, 2009; Brindley, 2013; Mamlock-Naaman et al., 2018). This is particularly the case for science teaching, with subject developments, the changing value that society places on science education, national policies and the way that student outcomes are assessed (seen as a proxy measure of teaching success) having significant influence. Sjoberg (2017) reiterates the distorting effect of accountability measures and possible conflict with constructs of good science teaching.

Schulman's (1987) characterisation of subject teaching knowledge is the basis for many subsequent studies and approaches to teacher education and development (Abell, 2008). It proposes categories of knowledge: subject content; general pedagogy; school; how students learn; curriculum; subject pedagogy; and

educational goals, purposes and values and has been adapted and applied to science teaching (Gilbert, 2010). As has already been suggested, content knowledge in science changes as research leads to new scientific knowledge and theories. Other aspects of the knowledge base for science teachers change too (Hargreaves, 1998; Corrigan et al., 2011) – of relevance to CPD policy and provision intended to facilitate more effective teaching.

Gilbert (2010) sees pedagogic knowledge as the general purpose of teaching and learning and suggests that in science these are changeable. For example, the purpose of school science has shifted as a scientific literacy focus has become more prominent.

There is general consensus that pedagogical content knowledge (PCK) is central to the development of subject teaching and that it is concerned with the subject-specific teaching approaches that teachers use to make the subject accessible to students (Schulman,1987; Loughran et al., 2012; Simon et al., 2012). Some authors suggest that rather than being fixed and generic, PCK has personal and contextual dimensions. Loughran et al. (2012) argue that PCK it is an artificial construct, elusive rather than tangible, influenced by personal dimensions such as beliefs, but none the less fundamental to teachers' professional learning. Magnusson et al. (1999) argue that it not possible to separate PCK from subject knowledge, illustrating a limitation of the categorisation of different aspects of subject teaching knowledge. Abell (2008) argues that as well as general science PCK, concerned, for example with teaching scientific enquiry, it is useful also to identify discipline specific PCK that relates to physics, chemistry or biology.

Coe et al. (2014) synthesise research findings to suggest six components of effective teaching, including PCK. They distinguish between knowledge of a subject and how that knowledge is used when teaching. They found that whilst there is a modest relationship between teachers' understanding and students' gains, the proposition that more knowledge leads to better teaching appears too simple to assume. Whilst the premise that student outcomes are a reasonable indicator of better teaching is

open to question, some policies for CPD do appear to be based simply on the provision of more knowledge to science teachers.

Drawing on research, some recent publications to promote good practice in science teaching propose classroom approaches which science teachers might implement. The *Improving Secondary Science Guidance report* (Holman and Yeomans, 2019) is research-informed, although the underpinning evidence is not always expanded or explored. The report includes seven recommendations designed to be actionable by science teachers for their teaching to be effective, each with underpinning recommendations, so that there are 23 in total. A similar style is reflected in *Good Practical Science* (Holman, 2017), which includes benchmarks with 37 detailed criteria, and the *Science Capital Teaching Approach* (Godec et al., 2017), a CPD resource which includes 'three pillars' for practice, each including lists of actions to implement the approach, with 21 actions in total.

These guidance reports, which are all research-informed and more accessible to science teachers than the original research on which they are based, characterise effective science teaching through the provision of checklists for good practice, suggesting a technical view of teaching. This runs counter to commentators who argue against a mechanistic approach (Abell, 2007; Van Driel et al., 2012). There are many examples of recent CPD, offered by a variety of providers, which are directly linked to the reports, in some cases narrowly focused on specific criteria.

Science teachers' beliefs and identities

Coe et al. (2014) argue that the belief system that accompanies teachers' knowledge has more impact than teachers' knowledge than on student outcomes. Ellis (2007) and Van Driel et al. (2012) also emphasise the link between knowledge, beliefs and practice, explaining that teacher knowledge is embedded in personal and professional contexts, thus arguing that teacher knowledge cannot be easily codified or reduced to mechanistic, technical characteristics. Abell (2013) also takes the stance that knowledge residing within teachers (rather than their knowledge about

teaching) is important – with the implication for teacher development that cultural and political dimensions which influence their beliefs are important.

Teachers from an early stage hold beliefs about the subject, nature of teaching and student learning which are important to their subject identity (Sachs, 2001; Gilbert, 2010; Brooks, 2016) and generally considered to be multi-layered, fluid and influenced by situated and social aspects of practice (Beijaard et al., 2004; Noonan, 2019). Ball and Goodison (1985) describe how, over time, subject specialism for many secondary teachers plays a crucial role in identity which Sachs (2001) explains as being more than disciplinary knowledge: rather, a way of thinking about the world that makes the discipline 'come alive'. Brooks (2016) also concludes that subject identity develops over time and is context-specific, arguing that it is an important influence on teachers' response to reforms in education.

Subject identity, then, is an interesting proposition to consider in relation to CPD for science teachers who often are described as though they constitute an uncomplicated or homogeneous group with shared identity. In reality, they bring different subject knowledge starting points (biology, physics and chemistry, for example) to teaching but might share identity across these – for example, in relation to the nature of science, which might influence their response to changes in the science curriculum, as well as national programmes for science CPD, which themselves are reforms. Developing subject knowledge is the basis for much CPD for science teachers, however the literature suggests that consideration of their beliefs and identities is important too (Woolhouse and Cochrane, 2010; Brooks, 2016; Noonan, 2019). It is noticeable that initial teacher education, rather than CPD, is often the context in the literature for consideration of identity in teacher development.

Links to my research

CPD is often seen as a policy solution to address science curriculum change, concerns about patterns of student participation and attainment in science and workforce characteristics. Literature perspectives suggest that the knowledge base of science

teachers and constructs of effective science teaching are changeable rather than fixed. My research explores how these prevail in the environment for CPD.

2.2 Perspectives on science teacher development

Investment in science teacher CPD by government and support by STEM stakeholders in the twenty-first century is predicated on the belief that CPD will lead to improvement in standards and participation in science (Sutton Trust, 2011; Fletcher-Wood and Zuccollo, 2020). However, with the exception of subject-specific CPD, which usually is associated with acquiring knowledge to teach outside a specialist subject area, explanations of what is meant by CPD or how it leads to improvement are often not clear. This section considers perspectives in the literature on teacher development and effective CPD.

The nature of teacher development

In the field of science education, as more widely, terms such as 'teacher professional development', 'continuing professional development', 'teacher learning' and 'teacher development' are used interchangeably both in the literature and in everyday practice, reflecting the 'conceptual vagueness' described by Fraser et al. (2007). There is general consensus that, however it is defined, investing in teacher development is worthwhile. The assumption that it leads to a sought set of outcomes, for example increased student attainment or more positive attitudes to science, in many cases is not evidenced. Nonetheless, a simple cause-and-effect link between CPD and improvement appears to underpin investment in and support for CPD for science teachers by government and other key stakeholders.

The notion of teacher development is contested and can be used to refer to individual learning and growth (Fraser et al., 2007), something provided to teachers (Porrit et al., 2017) or a collective element of school improvement (Fullan, 2001). Each construct is relevant to the environment for science teacher CPD.

Whilst sometimes used interchangeably, many writers differentiate between teacher learning, an individual process, and teacher development, which is seen as situated

and social, with the new knowledge acquired in learning a precursor to a teacher's development. Individual development is variously described as teacher change (Simon and Campbell, 2012), teacher development (Bell and Gilbert, 1994) or professional learning (Fraser et al., 2007). Fraser et al. (2007) provide a useful working distinction, explaining that professional learning results in new professional knowledge, skills, attitudes, beliefs or actions as a result of deliberate, intuitive, individual or social processes. They conceptualise professional development as referring to broader changes over time and introduce another consideration – that teacher professionalism shifts as professional development occurs.

Different factors are proposed as key to facilitating teachers' learning including purpose, conceptual inputs and time (Hoban 2002), motivation to want to change, understanding of the theoretical basis of curriculum materials and desired teaching approach and appreciation of the perceived benefits for students (Adey, 2004). Mullholland and Wallace (2008) suggest metaphors for individual science teacher learning, with the teacher positioned in different ways: as a consumer or acquirer of knowledge (computer database metaphor); as an independent artisan (craft-based metaphor), building practice-based knowledge and skills through cognitive apprenticeship; or as a social practitioner who acquires knowledge specific to a particular community context (complexity metaphor).

The complexity metaphor encompasses the notion that whilst learning is generally portrayed as an individual process, it is not a simple linear or cognitive process. Rather, it is influenced by situated factors including social systems (Hoban, 2002; Borko, 2004; Fraser et al. 2007; Wallace and Loughran, 2012; Simon and Campbell, 2012).

The nature of teacher development is described in different ways, which in many cases reflect the way that teaching is conceptualised. Much research envisages teacher development as a process in context rather than the acquisition of skills, as might underpin a technical view of teaching (Pickering, 2007; Pachler, 2007). Propositions of the knowledge base for science teachers were described in Section 2.1, and these provide a starting point for envisaging science teacher development

as change in the different knowledge categories. Fraser et al. (2007), for example, envisage teacher change as being the result of transactions between teachers' knowledge, experience, beliefs and professional actions. Loughran et al. (2012) identify PCK as central to this.

Broader perspectives on teacher development extend beyond specific subjects, to include, for example, development in functional aspects or attitudinal development (Evans, 2014). Hargreaves (1998) describes intellectual (relating to the subject taught), emotional (social) and organisational (relating to choices about practice) aspects of teachers work, arguing against seeing teaching as a craft characterised by a set of skills or knowledge that can be easily changed, a perspective which, he argues, implies reduced agency and professionalism. Possible implications of CPD for science teachers' professionalism are considered in Section 2.4.

The importance of social aspects and reflection are key themes in the literature about teacher development (Wenger, 1998; Fullan, 2001). Learning as part of social practice constructed through membership of a community, underpinned by shared aims, within which there is exchange and reflection about successful practice, is identified as promoting teacher development (Lave and Wenger, 1991; Schulman and Schulman, 2004; Stewart, 2014).

Models for teacher development

Bell and Gilbert (1994) identify three intertwined domains – personal, professional and social – of teacher learning or development (terms that they use interchangeably). A three-year study of science teacher development led to the proposal that within these three areas, there are three loosely defined stages in development. Their research suggested an overlapping and interdependent matrix for science teacher development, with change in one area dependant on change in another, with metacognition, reflection and support important in facilitating development. Within the development process, teachers reconceptualised what it meant to be a science teacher as they implemented a new curriculum framework with embedded constructivist approaches to student learning. Subsequent research

indicates that unless teachers want to change, and value how a particular change is beneficial to them and their students, they will not alter their perceptions of themselves as teachers or change their practice (Cordingley et al., 2015; Kennedy et al., 2016).

Simon and Campbell (2012) embrace the model proposed by Bell and Gilbert (1994) and conceptualise teacher development as a complex combination of the individual teacher's knowledge growth (learning), the professional teacher practising in a particular setting and the social teacher working collaboratively with others in that setting. Hewson (2013) provides another framework for professional development in which science teaching is organised into four key areas, each a strand of development: teaching activity; professional activity; the teacher as an adult learner; and subject knowledge and epistemologies. She reiterates the complexity of science teacher development pathways and the influence of students, schools, the curriculum, and social, education and political factors.

Clarke and Hollingsworth's (2002) interconnected model of professional growth encompasses the possibility of external and policy influences. In it, as with Bell and Gilbert's (1994) model, teachers are portrayed as active learners rather than passive recipients of transmitted content, skills or expertise: teacher agency is built into the process of change. Clarke and Hollingsworth (2002) draw on research to identify four interconnected domains of change: the personal domain (knowledge, beliefs and attitudes); the domain of practice (professional experimentation); the external domain (external sources of information or stimulus); and the domain of consequence (the salient outcomes or changes). Processes of enactment and reflection mediate and interlink changes in the domains. This model is relevant to my study which focused on the external domain, with CPD for science teachers an example of an external stimulus for change.

In summary, whilst there is lack of consistency about how individual teacher learning and development are envisaged, the literature consistently highlights the importance of situated dimensions, including social aspects. Teachers' beliefs, motivation to change and agency are also key. Perspectives on the conditions for teacher

development are a helpful starting point for understanding the basis of interventions such as CPD.

2.3 How is CPD considered in the literature?

The focus of my research is planned, deliberate interventions (Fraser 2007) with the intention to facilitate changes in science teachers' practice, variously in policy documents and the literature referred to as continuing professional development (CPD) and professional development (PD). In this context professional development can mean provision (of interventions) rather than the outcome of teacher learning and change as considered in Section 2.2. The nature of PD and CPD interventions, including national programmes for science, vary widely, yet are almost unquestionably considered to be the basis for fostering improvements (Kennedy, 2016).

A variety of different approaches to conceptualising effective CPD are proposed in the literature. Fraser et al. (2007) propose a triple lens, based on models proposed by Bell and Gilbert (1994), Clarke and Hollingsworth (2002) and quadrats of formal, planned, informal and incidental professional learning to better understand CPD programmes. They suggest that approaches based on collaborative enquiry can support teachers in restructuring their knowledge. Kennedy (2014) maps a framework for looking at CPD comparatively in which nine models of CPD based on their key characteristics are analysed in terms of their potential for professional autonomy – with transmission models least likely to develop autonomy and transformative models most likely.

Meta-reviews of the vast array of research on effective CPD suggest consensus about the characteristics of effective professional development (Timperley et al., 2007; Stoll et al., 2012; Cordingley et al., 2015, 2018; Darling-Hammond et al., 2017; Wellcome Trust, 2018). These inform policy, for example, the government standard for professional development (DfE, 2016). Necessarily condensed and two-dimensional lists of characteristics generated though meta-reviews and summarised in the standard don't reflect the complex, situated and individual nature of teacher learning

and development that is highlighted in research and described in Section 2.2, nor do they address or encompass policy influences on individuals or organisations. Two recent reports suggest caution in interpreting and applying the generally agreed characteristics identified in the literature. Sims and Fletcher-Wood (2021) suggest the importance of taking into consideration links between aspects of CPD and elements of teacher learning. Fletcher-Wood and Zuccollo (2020) note that few reviews consider quantifiable aspects of the impact of CPD on student outcomes.

Characteristics of effective CPD are generally agreed to be: focus on improving student outcomes; underpinned by robust evidence and expertise; collaboration and expert challenge; and sustained over time (DfE, 2016). Ellis (2007) warns against professional recipes and advocates complex conceptualisation of teacher development. Summary lists of characteristics of effective CPD belie the complexity, described by Simon and Campbell (2012), of planning CPD that takes account of the conditions and mediating factors that promote teacher learning in a system where professional developers are subject to external demands and teaching standards define expectations of teachers, as is the case for science education. Relevant to my study, Simon and Campbell (2012) ask whether external courses are likely to change practice or beliefs, even if beneficial in assisting some aspects of teaching. Kennedy (2016) suggests that the focus on design features of CPD, which are not necessarily associated with effectiveness (Desimone, 2009), is a consequence of different perspectives on good teaching and teacher learning, meaning there are likely to be different approaches to how CPD can improve teaching.

Frameworks for designing effective CPD that take a wider perspective than a list of inputs reflect different conceptions of teacher development. Kennedy (2007) proposes CPD approaches based on collaborative enquiry to support teachers reconstructing their own knowledge. Loucks-Horsley et al. (2010) propose a framework for designing CPD in mathematics and science which considers: teachers' knowledge and beliefs about effective CPD and adult learning; teachers' unique contexts; critical issues that might influence teachers' practice; and strategies which align with CPD goals.

Effectiveness of CPD

CPD inputs or checklists for good practice cannot on their own be a measure of effectiveness if teacher development is seen as an individual and situated process, although they might provide a useful basis for planning and quality assurance (Perry et al., 2019). The literature concerned with the outcomes and impact of CPD, which can be considered at individual, school and system level, also provides insight to the basis for national programmes of science CPD.

Guskey's (2000) indictors of CPD impact are predicated on a linear view of teacher development and are the basis of much subsequent work on effectiveness of CPD. They underpin approaches to evaluating the impact of many current CPD programmes. Guskey envisages participants' reactions and learning, organisational support and change, participants' use of new knowledge and student outcomes as a hierarchy of impact. The model doesn't readily embrace complex wider contextual and human aspects, such as identity and beliefs, which were suggested earlier in this section as important aspects of teacher development.

Hewson (2007) notes that whilst the ultimate aim of CPD is to improve student learning, the link is complicated and difficult to untangle as student outcomes are influenced by many factors. Different perspectives are proposed in the literature. King and Nomico (2018), for example, suggest that it might be more socially just to measure developments in critical teacher agency than students' exam scores as an indicator of effectiveness of professional developments. They argue that Guskey's classification highlights teacher mastery and the role of organisational factors, whereas agency considers autonomy, reflexivity and purpose, which are not addressed in traditional CPD evaluation. Teachers' perspectives on their experiences of CPD in their working lives provide another way of considering outcomes: a gap in many studies (Fraser et al., 2007; Timperley et al., 2007; Webster-Wright et al., 2009; Taylor, 2014). Perry et al. (2019) found that indicators of CPD effectiveness are not always clear to CPD participants.

The approaches outlined so far in this section consider CPD impact at individual teacher level. Two recent meta-reviews of research draw on varied studies and synthesise research into the impact of CPD more broadly. Cordingley et al. (2018) found that subject-specific CPD, defined as intended to enhance teachers' understanding of subjects, how students learn in the subject and how to teach, the subject is more effective in terms of student outcomes than generic, pedagogic CPD. Fletcher-Wood and Zuccollo (2020) note the difficulty in comparing the impact of programmes of CPD that use different indicators of impact. However, they cautiously suggest evidence from a study of 53 professional development interventions of some impact on student learning and teacher retention, concluding that teacher professional development is a promising approach to improving teaching quality and student outcomes.

Perhaps reflecting the possible links between school science, CPD and national prosperity as outlined in Chapter 1, evaluation reports of some national science CPD programmes also take a system-level perspective on outcomes. This is the case, for example, with recent evaluations of the impact of national science learning centre CPD programmes on teaching, teacher retention and outcomes for young people (Allen and Sims, 2017; STEM Learning, 2020).

Links to my research

Section 2.3 has mapped out broad areas of the literature that are relevant to my study and suggests that a key consideration is the way that individual, social and situated aspects of teacher development are addressed in CPD. Much research into science CPD is concerned with specific interventions, often associated with a specific pedagogical approach or curriculum project, such as cognitive acceleration in science education or argumentation in science, rather than about policy or teachers' experience more generally as is the case in my study.

My research explores the ways that professional learning is envisaged and the assumptions that prevail in national CPD programmes and how situated and process aspects of CPD are addressed and experienced based on science teachers' accounts,

thus using two different lens on the landscape, which Kennedy (2016) suggests need not be at the expense of each other.

2.4 The wider educational environment for CPD for secondary science teachers

The introduction and changing shape of national programmes for science teacher CPD coincides with significant changes in the wider educational context. Economic imperatives arising from globalisation (Bottery and Wright, 2000; Brant and Panjwani, 2015) and neoliberal policies during the twenty-first century have influenced teacher accountabilities, market influences on schools and diversification of educational provision. Commitment to school-led improvement (Whitty, 2008) is an associated area of significant change in the education landscape relevant to this study.

This section draws on literature to suggest possible ways of understanding the implications of wider contextual influences on the environment for CPD for science teachers.

Neoliberal and managerial education policies

Consideration of contextual, political and power relationship influences is absent from much of the literature about teacher development and effective CPD. The relation of education policy to the needs of the state and the economy (Ball, 2015) is pertinent to understanding the environment for science teacher CPD, given the economic importance of science education.

The increasing influence during the twenty-first century of neoliberal and managerial policies in education characterises the landscape for CPD for secondary science teachers. As described in Section 1.1, science education is frequently linked with ambition for national economic performance. This drives the perceived need for CPD for science teachers as well as the way that it is envisaged, including performance indicators and measures of success, which are often concerned with quantitative, value-for-money considerations (Apple, 2018).

Neoliberal characteristics of the education environment in England in the twenty-first century include: economic rationalisation of schooling; privatisation of schools, for

example the emergence of academies and free schools; marketisation; competition between schools; closer links between schools and the economy; students perceived as consumers; and parental choice (Bottery and Wright, 2000; Apple, 2005; Brant and Panjwani, 2015; McGregor, 2018).

Whilst neoliberal policy leads to a weaker state and economic rationalisation, with market mechanisms prevailing, Macgregor (2018) describes an apparent contradiction between weak central control and strong centrally determined accountability dimensions, focused on standards, managerial accountabilities, testing, and regulated content and pedagogy. Two illustrations of how a strong state with traditional values might impact on science education are the national strategies, a national CPD programme (2004 – 2011) that promoted a particular pedagogy for science, and government commitment to increase uptake of triple science, including through an incentivised CPD programme which began in 2007 and is on-going. Science education, then, features within a neoliberal environment, and is visible in accountability measures, as a subject of national economic importance.

The political nature of the education environment shapes the way that teachers and teaching are viewed. Much of the literature on neoliberalism positions students as consumers (Bottery and Wright, 2000; Apple 2005; Connell, 2009) who are seen as needing to gain, through schooling, skills and dispositions to compete efficiently and effectively within a global economy or, in some cases, as problems in need of solutions (McGregor, 2018). In this construction, where democracy is seen as an economic concept, teachers are producers, contributing to a workforce in line with government ambition.

The way that teachers and teaching are positioned in the education environment has implications for the way that teacher development and CPD are envisaged. Connell et al. (2009) suggest that a scenario in which teacher education is concerned with the making of a workforce, as is suggested in some policies for CPD, doesn't embrace collective responsibility or teacher agency, as teacher performance is dependent on what others (students, schools) do. They argue that it is important that CPD builds a resilient occupational culture in which social identity develops, and ideas and practice

are shared. In relation to science CPD, a workforce might refer to the teachers (for example, CPD to train physics teachers) or students – where CPD is envisaged as key to more students becoming scientists or engineers.

As well as teachers being envisaged as producers in a supply chain, ultimately of scientists and engineers, with students the consumers, they might themselves be thought of as consumers of CPD. They too need to acquire particular skills to contribute effectively. Apple (2005) sees this neoliberal scenario, in which policies link the education system to the economy, with resources allocated to supporting reform, as deskilling to teachers. National programmes of science CPD could be perceived in this light, implemented as a solution to national challenges. In the same way that some groups of students are seen as problematic, for example because they are disengaged (McGregor, 2018), science teachers might be portrayed as in need of more subject knowledge: as the problem rather than the solution (Donnelly and Jenkins, 2001).

Fensham (2008) appears to take a different stance in recommending that policy makers should consider the policy implications (financial and structural) and benefits of establishing professional development provision in science and technology as an essential component of the careers of all science teachers, predicting rapid improvement in teaching and learning, morale of science teachers and retention. However, the proposal is predicated on the basis that initial teacher education is insufficient to lead to dynamic science teaching: thus, another deficit perspective. Donnelly and Jenkins (2001) accept limitations in science teachers' knowledge base, again related to initial teacher education, and ask what the balance should be between two overarching dimensions of their professionalism: policy and the experiential nature of teaching. They suggest a shift in policy stance to a position in which science teachers should be seen as a solution to improvement in science education.

Sachs (2001) describes the context of managerial professionalism that is recognisable in science education through the emerging focus during the twenty-first century on national and international science accountability outcomes and the wider context in

which science education operates (the focus on national economic competitiveness). Donnelly and Jenkins (2001) describe how central science curriculum and assessment policies and the way that change is determined detract from teachers' professionalism. Whitty (2008) describes the scenario in which professional development which emphasises or is underpinned by accountability and effectiveness as steering at a distance. Control over schools' outcomes is not relinquished, and whilst there is some policy direction about what is taught in science, most decisions are made at school (rather than individual teacher) level. In this scenario, national policy for CPD might provide steer.

Within the current science CPD environment, national policy is for CPD provision to be devolved to networks of school – led providers, yet many of the measures for this are set centrally, and the accountabilities are managerial. Along-side this, other education policies and managerial aspects of schools, including resourcing and institutional priorities, influence participation in CPD.

Marketisation of CPD

Within the landscape described above, school-led CPD can be seen as an economic and policy solution that is incentivised and outsourced, in the same way as schooling itself (McGregor, 2018). In this understanding, CPD is commodified, and schools are consumers. Marketisation drives the perceived need for CPD as well as the way that it is envisaged, including performance indicators, measures of success and accountability, which are often not concerned with the desired long-term outcome (improved learning, for example) but quantitative, 'value-for-money' considerations (Apple, 2018).

As well as the basis for CPD, the operation of national programmes for CPD reflects neoliberal values: market forces prevail in the award of contracts by competitive tender, with best-value considerations and measures of success. The endpoint for CPD is aligned with the agenda, but so is the means of securing it, in an overtly economic model of provision: CPD has become increasingly commodified within the education environment.

Watson and Michael (2015) provide an example of the trend of increasing commercialisation of CPD. They observe that CPD in Scotland, where there is annual entitlement to 35 hours of CPD for each teacher in a maintained school, is often associated with the acquisition of skills and mastery. Associated with a suite of standards, which provide an organising instrument for CPD, Watson and Michael (2015) suggest that policy for CPD responds to different interpretations of the term 'professional', with courses rebranded as professional development opportunities. They differentiate between CPD, which is provided to or for teachers, and professional learning, which is associated with individual growth.

More generally, Watson and Michael (2015) explain that marketisation of CPD is often associated with professional accreditation and standards and is concerned with institutional change and outcomes for students rather than being driven by individual teacher agency. This scenario has implications for teachers' professionalisation.

Science teachers' professionalism

Teachers' professionalisation features in different strands of literature relevant to the landscape for CPD for science teachers. The nature of teachers' professionalism is contested (Crook, 2008; Sachs, 2001, 2015; Perry et al., 2019) but is broadly considered to be concerned with specialist expertise, demonstrated by particular qualifications, autonomy that results from this, and a public service role. Neo-liberal and managerial policies, including accountability reforms associated with the standards agenda, can be de-skilling and deprofessionalising (Sachs, 2001; Connell, 2009; Brooks, 2016; Apple 2005, 2018; McGregor 2018). Government interventions, including CPD, can reflect notions of best practice in teaching, set out in centrally prescribed criteria which reduce control by individuals and across teachers (Hargreaves, 1994).

The government focus on science education, including investment in CPD and curriculum interventions, has implications for science teachers' professionalism (Bottery and Wright, 2000; Bishop and Denleg, 2006; Pachler, 2007). In a scenario in which science education is linked to economic success, science teaching might be

considered as the object of reform: a practice to be changed in pursuit of improved outcomes. CPD can become a vehicle for national ambition, not necessarily aligned with the needs of individual science teachers or the wider community (Fraser et al., 2007), detracting from professional agency and democratic professionalism in which practice is shared and developed within a community. Rather, CPD for the state might be envisaged as focusing on a technical, measurable perspective of teaching within a market context, and a managerial view of professionalism (Kennedy, 2007).

Notwithstanding the position that delivery models for national programmes of CPD themselves are marketized, with success measured by managerial accountabilities, the focus and content of CPD interfaces with aspects of science teachers' professionalism. As explained earlier in this chapter, perspectives on the role of science teachers change. The emphasis on accountability militates against democratic professionalisation and can lead to restricted professionalism (Bottery and Wright, 2000; Sachs, 2001; Whitty, 2008).

Bottery and Wright (2000) differentiate between being a good teacher and the development of independent professional practice – which contributes to the autonomous strand of professionalism. It is interesting that these authors argue for the involvement of higher education institutions (HEIs) in supporting teachers with critical enquiry and extended professional development. Yet, as described in Chapter 1, universities are increasingly excluded by government from the national science and STEM CPD initiatives as school-led initiatives are favoured.

The literature on the influence of neoliberal and managerial drivers on the education landscape is particularly relevant to science education. It suggests the possible impact on science teacher professionalism of national programmes of science CPD linked to the accountability agenda and marketisation of CPD. At the same time, national programmes of CPD undoubtedly present opportunities for science teachers, although Perry et al. (2019) point out that teaching differs from other professions, which have an obligation to participate in ongoing training and development frameworks that are independent of government, and more autonomous, in tune with democratic professionalism.

Taking a policy perspective on CPD for secondary science teachers

National programmes for science teacher CPD are influenced by the relationship of education policy to the needs of the state and the economy (Ball, 2015). Political and power relationship influences, which are an area of exploration in this study, are not considered in much of the literature about effective CPD.

There is general consensus about the value of CPD for science teachers, reflected in stakeholders' and government policy statements, stated support and investment. Teachers are both policy subjects and policy actors (Ball et al., 2011). They think about and interpret policies in different ways and in different roles. Local science CPD providers, a key niche in the environment for CPD for secondary science teachers, interpret policy for science CPD from a different standpoint to science CPD participants – who themselves do not comprise a homogenous group, as is often implied. Within schools, policy is translated by leaders and at departmental level as well as by individual teachers.

Policy implementation is portrayed in the literature as complex and situated rather than linear. According to Bourdieusian analysis (Hardy and Lingard, 2008), policy doesn't directly affect practice in schools, which is local, situated and emergent, as the policy field interacts with the field of teachers' work. In this scenario, CPD is seen as being mediated by cross-field effects – a possibility also suggested, from a different standpoint, in Clarke and Hollingsworth's (2002) interconnected model of professional growth. Ball (2015) suggests that policy enactment is a much richer term than policy implementation, as it allows for different policy actors, in schools, interpreting policy in different ways depending on local factors and individuals' perspective and values.

Literature perspectives raise questions about how science teachers are positioned and how policies are enacted. Recognising early in the development of the national science learning network that teachers might feel de-professionalised rather than empowered by the centrally directed science learning network, Bishop and Denleg (2006) proposed the possibility that it might change the landscape and re-

professionalise teachers. Teachers' experiences of national policy for science CPD, either as participants or in provision of local programmes, are central to this study.

Links to my research

The relationship between policy and implementation as experienced by science teachers will not be considered as simple or linear in my research. The literature suggests the possibility that policy for CPD is aligned with neoliberal and managerial agendas. Policy, however, is enacted at different points in the science education environment, including CPD provision and participation. On-going financial support for science CPD indicates a policy commitment to CPD provision which is directly enacted through commercial contracts – at both national and local levels. Participation in CPD is influenced by school and individual teacher factors – adding further layers of complexity.

2.5 Research questions

To situate my research, this chapter explores different ways of conceptualising the CPD environment for secondary science teachers. The literature on effective science teaching, teacher development and effective CPD, and the implications of education policies for science and STEM education and school-led improvement provide different lenses for considering the CPD landscape. In most cases, these fields are considered separately. However, features of the current landscape, for example the role of schools as science CPD providers within national programmes, in many cases on a commercial basis, illustrate ways that they are interwoven and led to my interest in exploring the implications of this. Rather than exploring the CPD environment from a narrowly focused starting point or with a particular theoretical model in mind, the aim was to take a more holistic approach by drawing on perspectives from people within niches concerned with science CPD policy, school-led science CPD delivery within national CPD programmes, and science CPD participants to address the broad research questions:

1. What is the basis for current policy for continuing professional development of secondary science teachers in England?

2. How is policy for continuing professional development of secondary science teachers in England enacted?

3. How do secondary science teachers experience the environment for continuing professional development?

As research progressed, an increasingly rich and complex picture of the CPD environment emerged from participants' perspectives. Some of the theoretical perspectives that are introduced in this chapter became more useful than others in interpreting data. Constructs of effective science teaching and effective CPD were included in the initial literature review, and followed up in interview questions, on the basis that I had anticipated that they would be an area of shared interest across the three groups of participants. Their absence from some interviewees' accounts was noticeable and in itself, an interesting finding. As research proceeded and my thinking developed, theoretical perspectives that emerged as more relevant to the research data were concerned with models for situated professional development, theories of policy development and marketisation associated with neoliberalism. Thus, Bell and Gilbert's (1994) model of personal, teacher development as professional, personal and social development; Clarke and Hollingsworth's (2002) model of teacher professional growth; and Ball's (1993) policy cycle model which are introduced in this chapter, are drawn on in more detail in Chapter 7, where they are applied to interpret data.

The next chapter describes the research methodology.

Chapter 3 Methodology

Chapter 2 explored literature perspectives on different dimensions of the environment for secondary school science teachers' CPD in England, to situate my study and introduce my research questions. The first part of this chapter describes how my research approach is matched to my research questions and literature perspectives. The rest of the chapter discusses: how data were collected; ethical considerations; insider aspects of research; adjustments made in response to the COVID-19 'lockdown' which commenced during the field work phase; and my approach to data analysis.

3.1 Research approach

My research is predicated on the belief that people's experiences, understandings, perspectives and social interactions are a valid means of characterising the environment for secondary science teachers' CPD. When planning my research, I matched the epistemology, theoretical perspective, methodology and methods for the study to the research questions and underlying assumptions (Crotty, 1998). I envisaged the environment as complex, multi-layered and socially constructed, characterised by different perspectives rather than a single or absolute entity. The epistemological stance of my research is interpretivist, resting on my assumption that the environment is likely to be experienced and understood differently by different individuals and groups within it. In line with this stance, people's accounts, experiences and beliefs are the data for my study.

In an interpretivist paradigm, data is seen as socially constructed: beliefs and meanings held by the researcher and the subject, and the interaction between them, are germane to the emergent understandings. My study involved interpreting data about peoples' different realities (Crotty, 1998), as the basis for suggesting underlying meanings (Denscombe, 2010; Cohen et al., 2011; Robson, 2011) and generating

deeper perspectives, theoretical insights and working hypotheses (Denscombe, 2010; Robson, 2011).

Circumstances changed as the COVID-19 pandemic prevailed during my research, highlighting the temporary nature of knowledge and understanding generated through research. This reflected another feature of the interpretivist epistemology: that social phenomena and their meanings continually change.

The methodology for finding out about the experiences and perspectives of occupants of three key niches in the landscape (policy influencers, CPD providers and CPD participants) was qualitative: an approach which was matched to the aims of a small scale, exploratory study. Semi-structured interviews were the tools for gathering data from different position holders, as well as being a flexible and responsive means to explore individuals' experiences and perceptions. Audio-interviews were transcribed and analysed using themes drawn from the data. I brought my own understandings and experience to the research process and was mindful throughout to recognise the impact of these.

3.2 Data collection

Sample

Three key niches within the national science CPD landscape are concerned with CPD policy, provision and participation. In the context of nationally funded CPD programmes, the focus of this study, much provision is local, led by schools or colleges. As explained above, the basis for the research approach is to learn about the CPD environment from the perspective of occupants of these three niches. The potential population for each of these groups is vast: a wide variety of stakeholder organisations influence policy; there are more than 50 SLPs within the national STEM Learning network, which is just one of the national networks concerned with science CPD; and any science teacher in England might contribute perspectives on CPD.

Reflecting the constructivist ontology, the study is based on a small sample: participants' perspectives provide the basis of considering the environment from

different standpoints and, by doing so, generating new understandings. My original aim was to recruit 6 - 8 policy makers and 12 – 16 practitioners, including 3 or 4 teachers who lead local CPD provision and other teachers who would contribute as CPD participants, on the basis that this sample would provide sufficiently rich and varied data to construct an understanding of the CPD environment. The starting points for recruiting research participants were knowledge of the field, professional contacts and advice from colleagues and research supervisors. Table 3.1 provides an overview of the groups of research participants. Individuals within each group are described in more detail later in the thesis, and page numbers for this are shown in the table.

Table 3.1 Research participant groups

Group	Overview of sample	Sample size
Policy influencers	Senior post-holders, with roles related to education or CPD policy in stakeholder organisations that influence national policy, provide national programmes of CPD or both. The organisations are concerned with different subjects and fulfil different roles. See page 65 for information about individuals within this group.	6
Local CPD providers	Teachers who lead school or college provision within national CPD programmes. Within the school-led system and national CPD initiatives, providers such as these institutions are seen as well-positioned to meet local needs. The three provider organisations are located across the east of England. See page 83 for information about individuals within this group.	3

CPD participants	Science teachers from schools across London, central and east England with a mix of characteristics including: mixed; single-sex; high performing; within government-designated opportunity areas; high free-school-meals population; and within or leading teaching school alliances and multi-academy trusts. The teachers had between 2 and > 20 years teaching experience. Some held posts of responsibility, including head of chemistry, head of biology and head of key stage 3 science. The teachers were drawn from 6 schools, which were not the local CPD provider schools in the study. The teachers were not selected on the basis of participation in CPD provided by the local providers in the study. Rather, they were suggested or approached because they had participated in CPD, irrespective of the provider. See page 102 for information about individuals within this group	7

Recruitment of participants

The sample of six policy influencers and ten teachers, including three who led local CPD provision, was purposive (Cohen et al., 2011; Robson, 2011). To recruit policy influencers, I approached people with whom I was professionally acquainted and who held senior roles concerned with education policy or teacher development in eight national stakeholder organisations with a history of involvement in secondary science

teacher CPD. The organisations had different characteristics, roles and subject foci. Four people agreed to take part in the research themselves, and two brokered introductions to colleagues, suggesting their roles were better matched to the research focus.

Three leaders of well-established, local CPD provider institutions (two schools and one college) with different characteristics, located across the east of England, with whom I also was professionally acquainted, agreed to participate.

Recruiting teacher participants was more challenging: I was less well networked with this group and was keen to involve teachers whose CPD experience was wider than my own institution. Unsuccessful early attempts led me to revise the wording of my invite note, for example by referring to CPD rather than CPD policy, and reducing the suggested duration of the interviews, before contacting senior school leaders to ask for their assistance. They were known to me through work in other fields, for example computing education, and either brokered email introductions to individuals or forwarded my note to their schools' science departments. This led to positive responses, although before the interviews took place, field work was paused in response to the developing impact of the COVID – 19 pandemic. It resumed when government and research protocols permitted. Some teachers subsequently withdrew, citing workload and family circumstances, so the recruitment process continued. Seven teachers eventually agreed to participate.

Method

Data were collected through individual semi-structured interviews in line with the aim to gather individuals' perspectives and experiences of the CPD environment. These offered scope to respond flexibly and explore individual participants' comments and accounts by changing the order of questions or following up responses with additional questions in response to emerging areas of interest (Robson, 2011). Semi-structured interviews were better matched to the aims of the study than research tools such as focus groups and surveys, even though both offered the possibility, in theory, of a larger sample size. Each, however, would have

presented practical challenges (for example, low response rate to surveys and logistics of convening focus groups) and could have constrained participants' responses, through the lack of opportunity to respond presented by surveys and the impact of group dynamics in the case of focus groups.

Interviews were originally planned to be in person, but as is explained later in this section, some were carried out remotely. Participation was based on informed consent (Cohen et al., 2011). I invited potential participants by e-mail – using my UCL rather than my professional e-mail account to underline the role in which the research was being undertaken. The invite note (Appendix 1) explained the focus and process of my research, and that I was undertaking it as part of an EdD rather than as part of my professional role. It explained the principles for participation: voluntary, anonymous; with the possibility of withdrawal at any stage; and that, with participants' permission, interviews would be audio-recorded. These protocols were also stated in the participant consent form (Appendix 2), which interviewees signed to indicate their understanding and agreement.

Protocols for research during the pandemic meant that in-person interviews were not possible with one of the policy influencers, the local providers and teachers. Skype, Microsoft Teams and Zoom were all used for remote interviews. The participant consent form was revised to reflect this change (Appendix 3).

I envisaged that interviews would be conversational rather than question and answer. Before audio-recording of in person and remote interviews started, I set the scene, explained the research protocol and offered participants the opportunity to ask questions. I clearly indicated when recording commenced and ended. Interview schedules for the three groups of interviewees (Appendices 4-6) provided a framework and prompts for key areas to address during interviews: these were covered flexibly in response to the course that interviews took. During interviews I checked my understanding of interviewees' responses and clarified their views by revisiting their comments and responses. I sought to establish validity during interviews through feedback to participants and by rephrasing and summarising their responses for clarification and to check my understanding (Cohen et al., 2011).

By the time most interviews with teachers took place, remote communication was becoming a familiar way of working for research participants and me. None the less, there were differences between the in-person and remote interviews. Briggs (1986) and Mishler (1991) characterise interviews as forms of social discourse influenced by the questions asked and answered and the way that this happens. Briggs also identifies features of the context, including physical aspects, as influential. Janghorban et al. (2014) and Lo Iacono et al. (2016) conclude that Skype works well as an alternative to face-to-face interviews. They identify limitations to do with making eye contact, establishing rapport and reading body language. I recognised these challenges during remote interviews. Acknowledging the unusual circumstances seemed to put interviewees at ease, as did flexibility when there were unexpected interruptions, for example, as their children called for their attention.

I was alert to possible implications of changing interview mode. For example, when transcribing remote interviews and during data analysis I noticed changes to my questions and interview style. I said more in remote than in in-person interviews, particularly as they proceeded, and it appeared that during the final third of each remote interview, I increasingly asked complex, multi-faceted questions and was less clear and concise than in in-person interviews. This might have been because it was more difficult to establish a 'connection' during remote interviews, although my acquaintance with most policy influencers and local leaders and the focus of my current role on CPD strategy rather than teaching might have meant that I was better able to elicit and respond to their responses than to the teachers'.

The interruption to my field work at the early stage of the pandemic provided a time for reflection about emerging themes from interviews. This also might have contributed to some differences in questioning in remote interviews. Themes from interviews with policy influencers and local leaders were not reflected in what the teachers said – another possible reason for the multiple questions which might have been searching for some common ground. Teachers were interviewed at a time when their circumstances were significantly removed from their usual working conditions, so it is also possible that CPD was distant from their thoughts.

It would be misleading to imply that face-to-face interviews were comfortable and remote ones less so. The final face-to-face interview, at the start of the COVID-19 pandemic, when protocols to reduce spread of infection were already implemented, took place in a small meeting room. The interviewee wasn't at all well and coughed throughout. She hadn't wanted to let me down by postponing. My discomfort might well have impacted on the interview.

Immediately after each interview I completed a contact summary form (Miles, Huberman and Saldana, 2014) (Appendix 7) to capture my overall impressions and first thoughts about the main concepts, unexpected aspects and areas to follow up. These provide insight to my early concerns that my research questions were not being addressed during interviews, and that there appeared to be mismatch between areas of interest identified in my literature review and data gathered from interviews. I decided on reflection not to change the interview framework or approach, as patterns were emerging within and between groups, and because of the uncertain but changing context.

I chose to transcribe audio-recordings of the interviews personally. I interacted with the research data as I listened carefully to the recordings and considered small sections of responses, revisiting them to ensure an accurate record. I completed a second contact summary form after transcribing each interview, noting my reflections and overall patterns in the interview which might otherwise be obscured by the detail of word-by-word transcripts.

I returned transcripts to interviewees within 10 working days of interviews, so that they were relatively fresh in our minds. Transcribing interviews throughout the data collection phase (rather than doing so at the end of the fieldwork) was part of the on-going process of interaction with data. Interviewees were sent the full transcript electronically and asked to let me know within ten working days if they wished to suggest any changes. None did so.

Throughout the research process, I maintained a research journal to record thoughts, feelings, ideas to follow up as I endeavoured to maintain a reflexive approach (Usher

and Scott, 1996). This also helped to monitor the possibility of bias at every stage of research including choice of participants, during interviews and data interpretation.

3.3 Ethics

Research was planned and carried out in line with BERA (2018) ethical guidelines and most recent UCL data protection protocols (Appendix 8). Initial ethical approval was granted in October 2019. Proposed procedures were subsequently revised to take account of changes to the data collection method during the pandemic and these were approved in April 2020. Throughout, I sought to put participants at ease and to minimise discomfort that might have arisen from being interviewed (whether face to face or remotely) or audio-recorded, for example by offering choice about interview venues or on-line platforms and reassurance about the value of their responses. This was particularly the case when they questioned whether they were making useful or sensible comments or apologised for not being clear or not making sense. Literature about interviewing techniques refers to the potential discomfort of interviewees (Robson, 2011). In some cases, I was aware of my own discomfort when interviewing people whom I knew professionally. In one early interview the situation felt awkward rather than comfortable, for example, reminding me of the importance of avoiding assumptions based on whether I knew people prior to field work.

I minimised risks of identification by storing interview recordings, electronic documents and hard copy material securely and not using participants' names in relation to these (for example, when labelling documents), as described in the ethics approval form.

Policy-influencing organisations occupy a long-standing role in landscape for secondary science teachers' CPD. I was concerned that to have credibility when reporting, it might be important to be able to indicate the type of organisations (for example learned societies or CPD funders) that would feature in the study and interviewees' roles within them. Thus, I offered the possibility to policy influencers that they could participate either as an organisational representative or as an individual who works in the field. All but one chose the latter, yet their organisations

were central to their accounts. I therefore faced something of a dilemma about how to interpret and draw on their comments when interpreting data and reporting research findings whist still maintaining individual and organisational anonymity. The interviewees could be considered as 'policy influencers' through organisational power and influence, rather than individual action or attributes, yet they didn't participate as organisational representatives.

The informed consent form offered anonymity for individuals and organisations. It became clear at an early stage that it would be more straightforward to anonymise schools and teachers than policy influencers and organisations. There are many fewer influential stakeholder organisations than schools, and each has distinct characteristics which, if described in much detail, could mean that identification might be possible. Describing a teacher as head of biology from a mixed comprehensive school in a rural area of East England, with particular characteristics would provide far fewer clues to identity than characterising a stakeholder organisation or an interviewee's unique role title. Some policy influencers referred to CPD programmes that could only be linked with one stakeholder organisation: the challenge was to draw on their contributions and at the same time maintain anonymity. On reflection, this was, perhaps, an early indication that uncovering the basis for policy for science CPD would not be straightforward.

The dilemma presented by the need to both anonymise and describe individuals from policy-influencing organisations meant that it was more difficult to give individuals from policy influencing organisations than teachers 'voice' through the research – an interesting scenario, as literature more often points out the vulnerability of those with less power (teachers, in this instance). Here, the possibility arose that those with more power, the policy influencers, might be the more difficult group to protect.

3.4 Insider research

The process of data collection described above follows recommended steps and ethical protocols for qualitative research of this kind (Cohen et al., 2011; Robson, 2011). As fieldwork got underway, dilemmas emerged that illustrated ways that the

complex and tangled nature of research (Loxley and Seery, 2008) is influenced by organisational and individual relationships.

Research was undertaken as an insider. I am part of a broad community of science education (Lave and Wenger, 1991) and the CPD field within this and have credibility, access to potential interviewees, and could bring information to the interviews based on professional experience (Robson, 2011). Maintaining objectivity during conversational interviews was not always easy when I knew people. For example: when different interviewees made assumptions about my views on an aspect of policy of CPD; invited me to express an opinion that reflected their views; or referred to my contributions to a meeting that we had both attended about science CPD policy. Possible implications for future working relationships were a factor too. Policy influencing organisations might, for example, provide funding for Centre of STEM Education projects. The Centre might be perceived by local leaders to have influence or funding relevant to their future, even though this isn't the case.

Entries in my research journal describe dilemmas, opportunities and challenges of insider research. I noted some nervousness about approaching acquaintances to participate and was concerned that professional links might influence their participation, particularly when responses such as: "*Glad to help you out*" and "*Of course, no problem*" suggested the advantage that my insider position afforded. In some cases, the influence of a professional relationship was indirect – for example when invitee policy influencers or school leaders suggested alternatives and vouched for me in introductory emails to colleagues. I reflected on whether their colleagues would otherwise have agreed to participate.

I had imagined that a rapport might be easier to establish during interviews with people I knew, than those that I didn't. I was interested to notice when reviewing interview recordings that, perhaps over – compensating for this, during interviews with people that I wasn't acquainted with, particularly early on, I spoke more than during those with people that I knew. Some interviewees, particularly policy influencers, implied that they knew my views on some of the areas covered, as was

evidenced by invitations to agree with an opinion or comments such as: “As we both know ...” and “You and I have both …”.

Malone (2003) argues whilst that research in home territory might imply the possibility of openness, safety and trust, as it is undertaken in a place where people can be themselves, it can involve risks to confidentiality and anonymity. This was the case when an interviewee spoke unguardedly to tape, having said “I wouldn’t want this on record” and revealed information that could be damaging to him and by association to his organisation. Another policy influencer, during recording, having said “Don’t quote me on this …” went on to critically judge a contribution by a named senior civil servant at a recent talk that she had attended.

One interviewee was surprised to receive a word-by-word transcription. Another sought further clarification about use of the transcript, possibly nervous about what he had said and considering backtracking. I had thought during the interview that he had been less than cautious, perhaps because he knew me. Another dilemma rooted in trust occurred when an interviewee asked for his interview transcript to be sent to his personal assistant, who manages his emails. Notwithstanding my research protocols about anonymity, I was aware of the potential risk of a written record of an interview which included some frank revelations about named government officials, so applied discretion and provided a short summary rather than a direct transcription of the relevant section of the interview, with names removed.

My understanding of the field might well have contributed to the depth and richness of interviews. Possibly, it enabled informal conversations too. Many interviewees, particularly acquaintances, made comments relevant to the research which extended or clarified their responses after recording had ended. I noted in interview contact summary forms when this was the case.

As my research proceeded, I recognised Malone’s (2003) assertion that the inductive, emergent nature of qualitative design precludes researchers being able to predict where the study will take them. I was aware that whilst I shared with stakeholder participants focus my initial interest in CPD policy, my research questions and

research focus subsequently broadened. Some dilemmas seemed to be magnified by researching 'at home' (Malone, 2003). In reflecting on what 'home' might mean for me, I recognised that 'insider' is a more complex position than might at first seem to be the case.

Loxley and Seery (2008) argue that the insider-outsider distinction is not straightforward. They differentiate between institutional insideness and insideness that is characterised by shared technical expertise. In relation to the three research participant groups, my 'insider' status stems from the social setting (Sikes and Potts, 2008) of broad shared technical expertise, vocabulary and understanding of the landscape of science teaching, curriculum and CPD. At the same time, by undertaking research, to some extent, I positioned myself as an outsider looking into the ecosystem of science CPD.

3.5 Data Analysis

A standard approach in analysing interview data is to assign codes to sections of texts and then to look for patterns and themes which become the basis for organising codes into categories or displaying data so as to interpret the data and draw conclusions (Cohen et al., 2011; Robson 2011; Miles and Huberman, 2014). The sections of texts which are the coding units might be words, phrases or paragraphs. The need to make decisions about how to analyse data, including the basis for coding, is an example of the way that data analysis and interpretation are intertwined rather than separate stages in the research process.

As an experienced professional in the field, bringing knowledge and understanding, an approach involving initial coding based on small units such as words or phrases, then building up into themes seemed artificial. Alert to the possibility of losing the overall sense of interviews as might have been the case with such an atomistic approach, I found that by relistening to interviews and rereading transcripts for a sense of the whole, I was able to identify four broad domains within which to organise and analyse data: the landscape for CPD; the nature of CPD; organisations' involvement in CPD; and science teaching and curriculum.

The domains are connected to, but don't replicate my research questions. The landscape for CPD, for example, is relevant to the basis for policy and ways that it is enacted and experienced: the areas of interest behind the three research questions. This early stage of data analysis was both data-driven and theory-driven (Boyatziz, 1998). The domains arose from interview recordings, transcripts and summary forms and relevant fields of the literature. The landscape for CPD domain, for example, encompasses theoretical perspectives reviewed in Section 2.4, concerned with neoliberal and managerial education policies and science teachers' professionalism; the nature of CPD domain connects with perspectives on teacher development and how CPD is considered in literature (Sections 2.2 and 2.3); and the science teaching and curriculum domain connects with the literature on effective science teaching (Section 2.1).

From an early stage of interview transcription, I built up data displays: initially in the four domains and as analysis proceeded displays were of sub-sets of data within them. These mapped different descriptors of content and possible links between them, as illustrated in Figure 3.1 and included as Appendix 9. These helped me to progressively analyse the rich interview data that I had gathered and to identify patterns. Some of the descriptors with more spokes from them became themes as analysis proceed and some of those linked to them became codes – although this was not a deliberate approach.

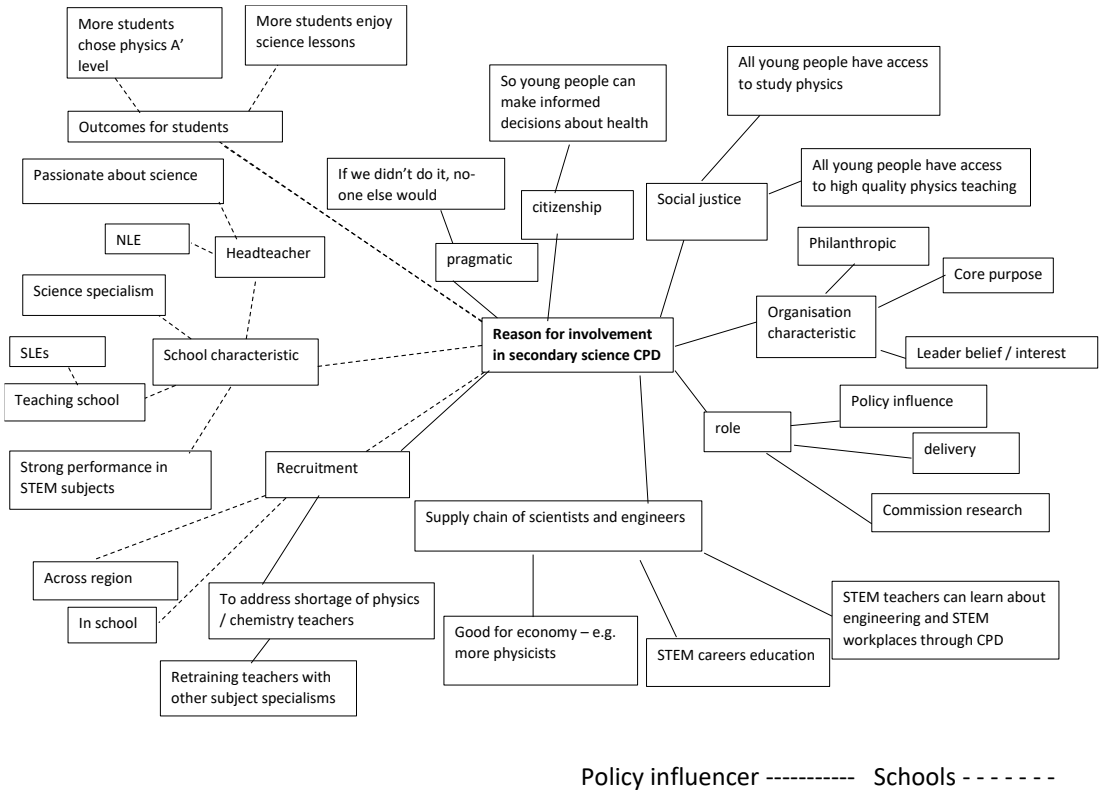

Figure 3.1: Data display: organisations' reasons for involvement in secondary science CPD

Having transcribed interviews, I highlighted parts of text (sentences or statements, for example), using a different colour for each domain. Some parts fell into more than one domain. Within the highlighted sections I identified smaller units of text which more specifically indicated meanings and were the basis for coding the transcripts. I added notes and questions as I read and re-read the transcripts – an iterative process through which codes were refined, new ones added, sub-codes identified, and some parts of transcripts were redesignated. I built up a list of codes within each domain (Appendix 10). The process was iterative and interpretive as new codes were added and interviewees' comments recoded. Some codes were deductive or latent (Braun and Clarke, 2006) – arising from theoretical concepts from the literature. For example, when I coded a phase as linked to professionalism when an interviewee referred to an entitlement to CPD for all teachers, or when I labelled comments as concerned with marketisation – a term that interviewees didn't themselves use. Other codes arose directly from data, when teachers' early career phase was mentioned, for example. Appendix 11 shows an example of a coded interview transcript.

The process of coding wasn't clear-cut. I interpreted meaning and from an early stage recognised that multiple interpretations were possible (Cohen et al., 2011). To illustrate my approach, Table 3.1 (page 58) shows examples of codes associated with the broader category, organisations' involvement in CPD. Within the domain of organisational involvement in CPD, most data were either concerned with how organisations were involved or why. Within the 'why' category, workforce development was a rationale for some organisations. Within this, the variety of reasons included: recruitment; retention; to increase numbers of teachers in a particular subject; to support early career teachers; or to improve subject leadership. In some cases, it was possible to assign finer grained sub-codes, for example by identifying the subject concerned: most often physics and in some instances, chemistry. Samples of interviewees' comments, and how they were coded, are shown in Table 3.2.

Table 3.1 Examples of codes for why organisations are involved in science CPD

Involvement in science CPD: Organisation (O) Why (W) OW			
Code		Subcode	
workforce development	wf	recruitment	rec
		entitlement	ent
		subject teaching	sub
student	stud	equity	eq
		career pathway	car
		attainment	att
		physics	phys
		chemistry	chem
		citizenship	cit
leaders' passion / interest	lead		
national economy	ec		
opportunistic	opp		
Position in landscape	pos	school	sch

		stakeholder	st

Table 3.2 Examples of coded teacher comments about why organisations are involved in science CPD

Interviewee comment	Code
"As the organisation grew its stature increased, it started to get a sense of its position as a powerful body. It was opportunistic. It didn't have a tradition of supporting education but …"	OW opp pos
"Traditionally (name of organisation) has been fixed on having young people consider science as a career to become scientists".	OW stud car
"There isn't a balance between the sciences so we're interested in the role of professional development in creating physics and chemistry teachers or teaching non specialists to teach their non-specialist subjects better".	OW wf rec phys chem
"It fitted nicely with the work we were doing as a teaching school alliance".	OW pos sch

Once each transcript was annotated with codes and comments, the next stage of analysis was to look across the data sets for groups of interviewees in a process of progressive focusing (Cohen et al., 2011), noting: similarities and differences, the presence and absence of codes, areas where codes were clustered, and the extent to which the broad domains were addressed. I was alert to the possibility of the potential influence of early analysis on the course of further interviews and of data analysis being self-fulfilling or confirmatory of beliefs that I brought to the research and endeavoured to remain open to unexpected research outcomes.

This chapter describes the underpinning rationale for field work and practical approaches for data gathering and initial analysis. In the following three chapters, to address my research questions in line with my chosen research approach (Cohen et al., 2011), I present and analyse data about each group of interviewees separately, including direct quotations to foreground participants' perspectives and voices. In line with the interpretive stance of my research, the aim was to capture and interpret different perspectives and realities. The broad areas embraced by the domains,

including organisations' roles, how CPD is envisaged and the CPD and education context, are the basis for presenting participants' perspectives in the next three chapters. The emphasis and specific areas addressed are different for different groups, reflecting their standpoints and positions in the CPD environment.

Chapter 4 Policy influencers' perspectives

This chapter presents my analysis of policy influencers' perspectives on the environment for secondary school science teachers' CPD in England, including stakeholder organisations' roles and rationales for involvement and ways that CPD is envisaged.

4.1 Interviewees

Table 4.1: policy influencer identifiers and brief description of their organisations

Individual identifier	Stakeholder organisation
S1	Influences policy. Commissions research. Facilitates a school network focused on science, maths, computing.
S2	Influences policy. Funds research including a current pilot about CPD entitlement, including subject-specific CPD.
S3	Influences policy. Key focus – recruitment and retention of physics teachers. Commissions and disseminates research.
S4	Influences policy. Provides national programmes of subject-specific CPD, including government-funded.
S5	Influences policy. Provides national programmes of subject-specific CPD.
S6	Influences policy. Provides national CPD programmes, including government-, industry- and school-funded, and influences policy.

All the interviewees held senior roles when interviewed, such as head of education, education policy or professional development in stakeholder organisations that engage with national CPD policy, provision or both. The six organisations influence

government policy including through direct engagement with civil servants and in some cases ministers, and more generally through the different, but specific niches that they occupy within the science education landscape.

The challenge of offering participants anonymity while at the same time conveying a sense of role and organisational contextual is described in Chapter 3. Only one interviewee was happy to present organisational perspectives and for him and the organisation to be identified. So as not to appear to foreground this individual and organisation over others, all are anonymised in this account.

Whilst they indicated that they were talking as individuals, interviewees frequently referred to their organisational perspectives using phrases such as: "*We are developing …"; "Our role is ..."; and "We are interested in …".* Inclusive language such as this conveyed organisational ownership and positions, and provided warrant for my analysis of organisational perspectives, albeit not acknowledged during interviews as formal organisational policy. In a couple of cases interviewees indicated that they thought their views were in line with organisational policy; others were less clear that their organisations had overarching policy on science CPD, even though the organisations occupied an influencing role in the landscape and supported the case for CPD.

Interviewees who had been teachers drew on this experience. In most cases this related to their experience of teaching outside their specialist science subject. S1 trained to teach psychology but found himself teaching subjects he didn't feel confident about. S5 explained that:

> *I'm a classic example. I was a biology teacher, but biology is the only science A level I have, yet I was teaching chemistry and physics content to GCSE and I was teaching applied science up to A level which includes snippets of chemistry and physics A level stuff. Which was ridiculous and I'm sure I taught it very badly. I had to rely on other people to help me with it the night before, which is not a sustainable situation*.

Some interviewees drew on their experience of teacher development. S1 explained that he knew from his experience of teaching and department leadership that:

> *… it doesn't matter how good the course is, or how good or bad the curriculum, if you don't have teachers of calibre and resilience and wider knowledge, you can't make up for that by having a good scheme of work.*

4.2 Stakeholder organisations' roles

The stakeholder organisations fulfil different roles in relation to CPD for secondary science teachers which interviewees described as: commissioning and disseminating research; advising government; making conversations happen with other stakeholders and government; steering; being a trusted voice; being the go-to organisation for advice and support; delivering national programmes of CPD; designing CPD; facilitating and supporting subject-focused teacher networks; and quality assurance of CPD. In some cases, the focus is subject-specific (chemistry or physics), whilst in others it is more broadly across STEM subjects. The different roles are not mutually exclusive, and CPD is part of a wider interest in STEM education for all the organisations.

Organisations' roles have changed over time and continue to do so. For example, S4 described his organisation's plans to reduce involvement in CPD delivery to focus on policy influence and provision of support for delivery organisations. However, to support credibility, S4 recognises the need to have "*some skin in the game*", so his organisation will continue to have some of its own people running sessions in schools to gain first-hand experience. S5's organisation is also reviewing its role in CPD provision, considering working with other organisations or focusing on quality assurance. Reflecting the increasingly school-led landscape, organisations 4 and 6 currently coordinate school-led networks to deliver CPD programmes which previously were more centralised.

Organisations' basis for influencing policy comes from different strengths and positions. S4 and S6 described the advantages of holding large-scale national contracts for CPD delivery, involving direct contact with teachers and first-hand experience of the school context. This adds credibility to their policy advice. Financial security influences organisations' roles: S2 explained that her organisation can take risk, for example, in commissioning research. As an international STEM employer,

with a role in public health, and having made significant financial investment in science CPD it has developed influence accordingly. Other organisations have long-established credibility through their positions in the science landscape, with education part of an extended role. S1's organisation was seen by one of the interviewees as having particular credibility with government and thus able to connect directly with ministers. S6 described ways in which his organisation influences other stakeholders.

Organisations have different rationales for involvement in the science CPD landscape. In some cases, it is clearly linked to the core purpose of the organisation. For example, organisations 4 and 5 are concerned with a particular science subjects, and organisation 6 is commissioned to deliver CPD. Organisations 2 and 3 are charitable trusts – they engage with science education part of their philanthropic missions, related either to the core work of the organisation or particular interest of the head of the organisation. Social justice is a key driver in each case.

The needs of future citizens are a rationale for some organisations. S1, describing developments such as genetic technology and neuroscience, saw CPD as addressing concerns about: "*How do we bring the citizenry of the next generation of people who will have to live some societal implications of this?*" The rationale for S2's organisation is that:

> *All young people have access to excellent science education so they can make informed decisions about their health … We also want to ensure that there is a throughput of people who are interested in science as a career.*

The pipeline of future scientists and engineers is a key rationale for other organisations' involvement in science CPD. Physics was more often mentioned than chemistry as the target subject. Biology was not mentioned by any of the stakeholders. S3 explained that her organisation was committed to extending opportunities for more young people to study physics. S2 made a social justice argument, suggesting that independent and possibly grammar schools are more likely to be well staffed with physics teachers than state schools. S4, describing a problem with basic subject knowledge and confidence of people teaching physics outside their

subject specialism was pragmatic about the reason for involvement in CPD: "*If we didn't do it, no-one else would*". As well as improving the quality of physics teaching, including training non-specialists, "*Retention and keeping good physics teachers in the profession"* is a key aim for S4.

In some cases, the rationale for organisational involvement, role and interest is less obvious. S1 explained that an organisation he previously had worked for which now has a key role in the science education and science CPD landscape. The organisation:

> *… didn't have a tradition of supporting education … but it was opportunistic … its stature increased and it started to get a sense of its own position as a powerful body … it started to act beyond its own direct mission.*

It was not always clear during interviews where particular areas of organisational focus arose from, or why particular research about science education or CPD was commissioned. In one organisation, personal interest of its leader had direct influence.

The stakeholder organisations are large and, in all but one, science CPD, and science education more generally, are strands of focus rather than the main concern. It was clear that different areas of focus were not always connected within organisations. S2 explained that funding for a high-profile science CPD delivery initiative is not linked to other science CPD projects in her organisation, although all support the dual purposes of citizenship and the pipeline of scientists: *"The various strand of work including teacher professional development and education research are separate*". S3 also described separate and disconnected projects concerned with science CPD.

4.3 Policy influence

Interviewees described examples of ways in which they influence government policy, providing insight into their perceptions and experiences of how government works. Government was not portrayed as currently having a clear agenda for science education, with the exception, possibly, of commitment to encourage more students to follow triple science courses at GCSE and to recruit more physics teachers. S3 explained that government programmes run independently and separately. S6 was

concerned that this: *"… doesn't help with the holistic view of what we want STEM education to look like"*.

The current policy position contrasted with descriptions of previous, stronger central agendas, described by S1 when he suggested that: "… *government over the last ten years has seen itself as having specific job to do ... the intention is to bring the standard up so that everybody gets a basic education*". He explained that: "*CPD in many cases has been about delivery of government agendas. So, it's about how can the training of teachers or CPD enable us to deliver".* He described: "… *government dogmas about transfer of knowledge to young people, with emphasis on assessment and accountability, and mostly of accountability of teachers".*

Interviewees described the importance of presenting economic arguments to influence policy. For example, the cost of training and losing teachers, value for money, and the efficiency of the system. S2's organisation is undertaking a cost-benefit analysis of teachers having an entitlement for CPD, taking a national perspective and calculating the impact of allocating to teachers ring-fenced funding for their own professional development – with impact measured in terms of retention across the workforce. S1 takes a value for money perspective on investment by major funders in CPD over recent years, comparing investment in CPD to investment by an engineering company in maintaining equipment.

S4 also saw CPD as an investment, illustrating how CPD and teacher training and retention were commodified for the purpose of policy influence:

> *If you invest, these numbers are open to discussion, but it's of the order in £50,000 in training a teacher and they leave after three years, that is a very expensive recruitment process. So, providing them with, let's say, £4,000 worth of professional learning in that time, if that then would even keep one in ten in the profession, to make it worthwhile. That's the case we'd make.*

He outlined economic factors that underpin a rationale for CPD:

> *The current government, what they, the two big levers for them, one is a high functioning economy, of course, so I think you have to make the link between students being better educated will result in a higher functioning economy, and then the link between students being better educated and having better teachers or higher quality teachers, and then the link between higher quality*

> *teachers and CPD and that link is partly about making them better directly and also retention. If you keep them in for longer, they have a longer time to become better. So, there are four steps in the argument, but that's one lever you can pull. The other is, and this is science-specific, but there we are, is the 2.4% GDP commitment for research. You've got to have people to spend it on, you need some researchers, so you've got to have people going through university in the fundamental disciplinary sciences to do some research later. Then all the links are the same as before really. And then finally, I think in that there's implicit retention angle, so there's a cost-benefit. Now from our point of view, you and I, we think it's about people's well-being and we also think that education is about youngsters becoming better thinkers and having a fulfilling life as a result, however, if you're a government … of course it's money.*

S1 described his perception that policy makers, including civil servant and ministers, over time have seen teachers as: "… *only a valuable resource to be in front of students and in classrooms".* In a previous role he had proposed that teachers might be entitled to professional development time to spend time in industry to learn about workplace settings. He explained that: "*Responses, even if supportive of the value of teachers spending time in industry, were not in agreement with teachers doing so during term time and were concerned with achieving government targets".*

Different approaches to influencing policy were described. S3 described the importance of 'big data' to policy making, in this instance about the importance of measuring and recording subject expertise across the workforce: "*If you've got big data it makes you able to make decisions more clearly*". She explained that: "*Policy work is most effective when we can identify a very clear problem and offer a clear solution".* Whilst the approach was: "*Trying to work with government, trying to talk to them and shape their ideas"* (S3), the turn-over of civil servants led to a pragmatic response:

> *If you say a word to DfE enough, they think that's a thing, and because they change over so much … that will be passed on to the next person. They won't know where it came from, but it will be in their heads.* S5

S4 described his organisation's credibility with civil servants and explained that they: "… *bash ideas around with them and hope we can influence policy by feeding up through discussions that happen at different levels*".

Whilst the stakeholder organisations each have particular interests, interviewees described ways that they work together to maximise their influence on government. In some cases, organisations take a strategic view that extends more widely than science. S2's organisation urges government to mandate a requirement for career-long entitlement to CPD for teachers of all subjects, not just science. S5 described a coalition, between stakeholders that includes other subject associations, unions and the Chartered College of Teaching, which focuses on subject-specific CPD:

> *We're working with other stakeholder organisations on a set of slides that demonstrates the importance of specialism, why specialism is important. Not just in teachers, the importance of biology, chemistry and physics as separate subjects. In terms of teachers, we talk a lot about the unbroken chain of specialists and why it's better for young people and better for teachers.*

S3 explained that her organisation is working as group with DfE and other stakeholders on accrediting subject knowledge. S4's organisation is lobbying government for investment on the scale of the national strategy in subject-specific CPD. S5 described how: "*We try to use a common language when we talk to the DfE, so they're used to hearing the same message and it's no surprise to them"*.

General entitlement perspectives on CPD, which appeared to be more prevalent when stakeholders came together, contrasted with arguments that attributed a specific purpose, often workforce related, to CPD. For example: "*In every meeting we have with government we talk about the importance of professional development in terms of retention"* (S3).

4.4 How is CPD is envisaged?

Interviewees consistently asserted the need for and importance of science CPD; however, the purpose was envisaged differently and the nature of CPD and its process were often unclear.

Purpose of CPD

Training teachers to teach outside their subject specialism was described as a key purpose, with more clarity than any other construct of CPD. The rationale could be

workforce related – in effect to recruit more physics and chemistry teachers by training teachers with expertise in other subjects to teach them. In most cases, this was presented as addressing a deficit: "*Biologists can't teach physics well"* (S3) and thus envisaged as a mastery process which would provide teachers with the knowledge and pedagogical content knowledge to become competent teach physics or chemistry. S3 later described CPD as:

> *Equipping non-specialists to teach their non-specialist subject better. At the heart of it, it's about subject specificity. What we are about is creating teachers who are able to teach physics and chemistry better.*

S4 echoed this mastery purpose, seeing CPD as: "*Giving the tools for teaching physics"* and getting non-specialists to: "*think about physics in a physicsy way"*. S5 referred to subject CPD as: *"a deep dive to explore the subject more, so they become proper subject experts who can then pass it on".*

The perspective that CPD supports subject teaching mastery is reflected in the exploration of possible policy by three organisations to badge or accredit subject teaching mastery which would demonstrate capability to teach specific curriculum components. This proposal was presented as addressing workforce characteristics, with CPD a solution through which more teachers would become competent to teach chemistry and physics. Mastery could be measured at individual (how many and which badges), school (whether there is appropriate, badged capability across the science teachers) and workforce (through national statistical returns about numbers of teachers with particular badges) levels.

S5 explained that a teacher might:

> *… be able to get the subject badges in all of the chemistry units from key stage 3 to key stage 5 and actually you did a bit of biology as well, so you can tick off all of the key stage 3 ones and half of the key stage 4 ones, but actually your physics is a bit dodgy so you've just got some of the key stage 4 physics ones.*

S4 drew on examples in other workplaces to justify his organisations' support for badging:

> *It's used quite a lot in catering. You wouldn't say this person's a chef so let's get them making the sweets, puddings or cakes today. You would look and see that they are a pastry chef, that'd got qualifications in that area. The same with IT, you wouldn't say this person's an IT person, they can write a bit of code in Pearl. You'd check that they can write in Pearl at a granular level. There's no reason we can't do that. At the moment there's this thing that says QTS, in science teaching, therefore they can teach mitosis to a year 10 class. And that clearly is flawed.*

He explained that there would be a test as part of the badging, frustrated that: "*At the moment, with science PGCE, you wouldn't know whether they know that living things are made of cells"* and anticipating that the proposed system would provide more fine-grained evidence of teachers' capabilities:

> *People being able to demonstrate their capabilities is important and that requires some form of assessment and it is strange that schools are geared up for assessing students but slightly rail against assessing people who work in them whereas in accountancy, medicine, law, people are assessed all the time.*

In similar vein, S6 described a new initiative in which teachers who participate in CPD will secure STEM certificates and digital badges. His organisation will signpost units of CPD that block together, to give accreditation, to support teachers in different phases of their professional learning journey to be, for example, an outstanding educator or leader of science. Suites of courses will help them to address issues that they might have in a particular area.

The implications of accrediting and assessing CPD and resultant capability for teachers' professionalism are significant. S4 recognised the possibility that the focus on CPD as a recruitment tool, by addressing shortcomings across the workforce and locating them in individual performance and capabilities in subjects, has wider implications:

> *Actually, I think we've been complicit in generating a deficit model of CPD which worries us. What has been lost from the system is that if you are a person with physics experience teaching physics, you still benefit from subject-specific CPD. You can still get better at your physics and you can still get better at teaching physics. It would be good to get it (CPD) back as a positive thing that is both an entitlement but also that gets people better constantly.*

Thus, S4 suggests the possibility that CPD can benefit experienced teachers within their subject. CPD envisaged as supporting subject mastery was in marked contrast

to CPD envisaged as individually focused, continuous and an entitlement. S1 described an underpinning vision for his involvement in establishing a national programme of CPD provision for science teachers as being about professionalisation rather than compensatory provision. He presented a different perspective on subject-specific CPD: "*People don't just teach curriculum, they teach the subject they love".* Based on his own experience, he saw subject-specific CPD as enhancing:

> *I was fortunate enough to have done my early teaching in a context where I was released from the school for a couple of days a year on average to find out about biology. That's what I wanted, was interested in. That was my identify as a biologist and that's where I derived my professional interest.*

Acknowledging the pace of scientific research and development, S1 also suggested that there are: "… *different challenges and needs for STEM subjects compared to other disciplines because they're far less moving"*. He holds clear views about science teachers' professional development and professionalism and ways that they could be supported through entitlement to CPD, and individual choice. S6 also took an individually focused perspective when describing the importance of targeting CPD more specifically as part of teachers' learning journey and career development.

S2 explained that her work involves: *"… ensuring that all science teachers have access to high quality, regular, effective professional development*". Her organisation sees CPD as an entitlement, key to underpinning commitment for all young people to have excellent science education. S5 also referred to CPD as an entitlement, describing career-long, high quality, ring-fenced CPD which her organisation would like to be mandatory. In recognising that: *"Entitlement implies a degree of autonomy for teachers"*, S5 identified a dilemma of juxtaposing mastery and entitlement constructs. Whilst recognising the importance of teacher agency in choosing CPD, S5 explained that: "*It's a balance between supply and demand and the needs of the school".* S1 described how in Scotland CPD is an entitlement and seen as valuable rather than imposed, suggesting that wider cultural factors across the teaching profession are important. S5 suggested that messaging is important, to convey that CPD is supportive and not taking away teachers' autonomy.

The nature of CPD

Whilst strongly advocating CPD as a good thing for the workforce or for individuals, interviewees didn't convey clear or formulated perspectives when asked whether their organisations were promoting a particular model of effective CPD. S6 explained: "*I think it's anything where there's engagement with a teacher that leads to an improved outcome for young people*". He suggested that sharing good practice that brings about an impact on a student was key, and could be light touch, such as through a network meeting or more formal consultancy or in-school support. S5 suggested that CPD should be designed differently for different purposes including CPD responding to specific circumstances, for example, a new examination syllabus.

S2 also recognised a variety of ways by which people can develop expertise including from reading, talking to colleagues, looking at some research and supporting staff. She is interested in developing a culture of professional learning in schools rather than being: "… *concerned with the minutia of best practice. There's a myriad of ways this can be achieved. I don't think there's one position"*. S4 explained that from a policy point of view CPD can be any aspect of professional learning including reading a book, being in a network or working with people in school. Two interviewees referred to the DfE standard for teacher professional development as characterising effective CPD practice; however, none of the examples of CPD described during interviews appeared to meet it.

Whilst CPD was often envisaged as supporting subject science teacher retention, interviewees didn't convey a clear sense of what type of CPD would achieve this. S3 explained that: "*CPD helps retention because teachers feel valued*". S5 suggested that reasons causing teachers to leave the profession weren't necessarily subject-specific – although that aspect is what her organisation is interested in. She pondered what CPD designed to support retention might look like. S3 is concerned with retention of physics and chemistry teachers – but extends recommendations to include biology, taking a pragmatic approach and judging this most likely to influence policy. S1 suggested that concerns about teacher attrition were being considered from the wrong perspective: "… *how much or little can we invest in the knowledge and skills*

and pedagogical skills of teachers to … simply stop them from leaving", rather than a more considered perspective on career-long professional learning and development.

As well as being key to retention, S5 saw CPD as important to: "… *students' achievement and attainment and the general quality of subject education*". S6 referred to a world class education system and S2 also made connections between CPD and quality of education. However, young people were largely absent from the interviewees' accounts.

Whist suggesting there could be a range of forms of CPD, S4 was clear that: *"Anyone providing it needs to be trained*" and to have their own CPD. His organisation has set up networks and professional practice groups to provide continual learning and help presenters to engage with research. Particularly relevant to the emerging circumstances when the interviews were conducted, S6 referred to on-line CPD, both stand-alone, as a means of sharing practice, and as part of blended CPD that also included face-to-face elements.

Curriculum, teaching and learning links

When asked whether a particular view of the science curriculum underpins CPD, some interviewees saw the curriculum as a separate concern to CPD. S5 explained: *"That's something we haven't considered*", taking the position that: "*Teacher CPD should happen; what we haven't got is any particular position that says CPD should focus on these particular pedagogical approaches*".

Links between curriculum and CPD are closer in other organisations. S4 responded: "*Yes. We're close to having a view on that. It is developed in parallel. The next step is to translate it into a framework for educating teachers".* S6 referred to the importance of CPD drawing on research summarised in publications such as *Good Career Guidance* (Holman, 2014), *Good Practical Science* (Holman, 2017) and *Improving Secondary Science: guidance report* (Holman and Yeomans, 2019). He also saw a role for CPD in steering the curriculum away from the restricted view that practical work comprises just activities included in examination syllabuses.

Whilst advocating CPD as an entitlement, S2's organisation doesn't have a particular view of effective science teaching. She explained that: "*CPD would be based on evidence that exists in teaching and learning in science, but as an organisation we're not looking at that. Our interest is in ensuring access to high quality CPD".*

When asked if CPD is underpinned by a particular view of effective science teaching, S3 responded: "*That's tricky because I don't think there's an accepted definition. It's more about accreditation, you could do some subject knowledge testing"*. S4 also didn't have a particular view: "*Good physics teaching … I suppose so, but I don't know how to describe it".* S6 referred to EEF research on improving secondary science and other recent research on benchmarks for effective science teaching and described a competency model perspective: "*We've got a list of what we think good science teaching looks like and the CPD is underpinned by that".* S6 described the approach as: *"… keen to distil research in a way that teachers can pick up and use without having to understand a whole research paper".*

4.5 The wider context

The role of school leaders in supporting CPD for science teachers was recognised by some policy influencers when they described factors that impact on participation in subject CPD. Some other aspects of the complexity of school contexts and the education landscape weren't reflected in policy considerations.

S5 explained that her organisation is talking to government about teacher deployment according to expertise, describing inequalities with young people more likely to be taught by a subject specialist in affluent areas. Her organisation's policy proposal is that each student should be taught by a subject expert throughout their education meaning: "*Someone with the appropriate subject knowledge for the curriculum and classes they're teaching*". This was framed as a policy ask for school leaders.

S2 noted financial constraints might lead to schools drawing on expertise from within their staff and networks rather than externally for CPD. Whilst acknowledging the

potential value, she also asked: "*Where is the disruption coming from?"*. She described concerns that CPD tends to slip off schools' agendas – for example in the face of an Ofsted inspection or structural needs, but recognised the importance of supportive school leaders in enabling teachers to access CPD, noting that where this isn't the case: "*… they are a significant barrier to participation".* S3 suggested schools should be judged on the quality of their teachers, but that: "*There's no real incentive for them, in terms of league tables, to say that their teacher did all those courses"*.

S6 described how school leaders can see CPD as a pragmatic solution to operational aspects of provision such as curriculum planning and timetabling:

> *I think it is a sticking plaster approach and a lot of it is down to the curriculum design and the offer that schools want to give, so using a music teacher as an example, a music teacher may now just be the one teacher in the school that is delivering music. They might not have a full timetable. They haven't got enough science teachers and the easy sticking plaster is to say to the music teacher, 'Well you can teach music, but you're going to have to teach four periods a week in key stage three science, otherwise we can't offer music or we can't give you music as an area that we can deliver in the curriculum', and I think that schools are finding it easier to staff schools in that way, than trying to appoint a music teacher for 0.8 of a timetable and a 0.2 science teacher, because there's not enough science teachers that come around, or if they do come around, they're not necessarily any better than what the music teacher would be.*

S6 also identified tight school budgets, and noted that school leaders make judgements based on value for money considerations:

> *… a lot of school leaders think that the best place for a teacher is in front of their students and don't see the greater good of a day or two days out of the classroom can give much, much bigger impact in the longer term*.

The importance of school leaders and school constraints were most clearly recognised by interviewees whose organisations are involved in CPD delivery. Two organisations actively work with leaders in support of their initiatives, with one recognising their role as policy making.

As described above, subject-specific CPD was envisaged by many interviewees at workforce level. S3 saw CPD as having the dual purposes of: "*Creating a large enough workforce to be able to deliver … and then making sure that they stay and they're*

interested". Individual teachers' needs were not always described: system considerations were more emphasised. Interviewees expressed concerns about the limitations of the post graduate certificate in education (PGCE). The lack of subject focus was a common concern: the PGCE was seen as generic, and subject CPD was proposed as a means to compensate for this. S3 argued:

> *Ultimately, there are far more teachers with a biology degree with no physics and chemistry A level in the classroom than there are in other subjects. So how do you equip these people better? Teacher training can't do that. The PGCE year isn't long enough to do it.*

Wider workforce policy restructuring, such as the early career framework (ECF), was suggested as presenting opportunities for supporting qualified subject teacher development. The ECF was seen by most interviewees as an opportunity for CPD to build on initial teacher education, by incorporating subject-specific CPD. However, S3, S4 and S5 were disappointed at the lack of subject focus within the ECF, despite early indications that subject would be a component. S5 noted that if there is just one teacher of a particular subject in a school, as might be the case in physics, subject mentoring (as can be an element of the ECF framework) in the early career phase need to be secured from elsewhere.

S3, S4 and S5 expressed frustration that school census workforce data doesn't record teachers' expertise and doesn't reveal the expertise or gaps across the science teaching workforce. S3 was concerned that: "*The government doesn't know how many specialists it has*". Badging was proposed to address this, as it could formally measure and record expertise. It was also proposed as a way of evidencing teachers' competency that could contribute to specialist national professional qualifications, another workforce development that was suggested as an opportunity to strengthen science teaching.

4.6 How organisations judge their involvement in science CPD to be worthwhile

When asked how organisations would judge their involvement to be worthwhile, interviewees tended to comment on ways of judging the impact of CPD rather than success criteria for organisational involvement. S1 recognises there has to be some

level of accountability for publicly funded programmes. He recognises the difficulty in evaluation and argues that: "*You have to have faith that teachers know how to deliver a particular concept and to understand the complexities of it and whether and where students go wrong … sometimes it is the art of the intuitive*". S2's organisation is exploring a possible quality assurance system for CPD. In contrast, S3 explained that: "*… we're concerned with the goal not the journey"*, reflecting the ambition to accredit experience and professional development outcomes.

Interviewees from organisations involved in CPD delivery noted the tension between effecting long-term sustainable change and the need to measure shorter-term indicators for funded programmes. S6 regretted that government and policy makers didn't always recognise that gains such as building partnerships between schools and developing teachers' confidence are long-term. His organisation uses a toolkit to gather data about impact – which is valued by the DfE as it presents feedback from teachers. Also considered to be important along-side this are value-added grades in science and:

> *… hard evidence that enables us to say quite clearly to funders and policy makers that if schools engage with the offer that we have, then they're more likely to have successful outcomes in science, STEM, for their students.*

Separate funding streams or workstreams impact on opportunities for a more holistic CPD offer. S6 explained:

> *I think the government-based ones are probably more separate, I think we try and fuzzy the edges, because it makes sense. But it boils down from that perspective, actually to KPIs; KPIs are the barriers because what you're doing is funding a programme for specific outcomes and actually that almost separates everything that you do, rather than being a blended approach.*

4.7 Summary

Policy influencers agreed the value of science CPD. Their perspectives about the purpose and nature of CPD differed. Their organisations hold different position in the landscape and their reasons for involvement in science CPD vary. Workforce and entitlement rationales for CPD were rarely linked to models of professional learning or CPD approaches. Approaches to policy influence are pragmatic, with value-for-

money approaches seen as persuasive. The next chapter explores the basis for local providers' enactment of policy, including the basis for their involvement and their perspectives on science CPD.

Chapter 5 Local CPD providers' perspectives

This chapter presents my analysis of local science CPD providers' perspectives of the environment for secondary science teacher CPD in England including their role, how CPD is envisaged and wider contextual influences. As explained in Chapter 1, the government's vision for education in England is predicated on a school-led, self-improving system. This is reflected in the funded role of local hubs for CPD delivery as part of national science, mathematics and computing programmes.

5.1 Interviewees

Table 5.1: local provider identifiers and their backgrounds and organisations

Identifier	Role	Background	Organisation
P1	Director of teaching school alliance	PE trained. More than 30 years teaching and leadership experience, including senior leadership.	School is an SLP, computing hub and teaching school.
P2	Director for STEM partnerships	Molecular biologist. Taught chemistry and biology to A level. Recently accredited to teach computing. Specialist leader in education	Further education college provides a regional STEM offer for students and educators. It works through local hubs and is supported by industry partners. It is an SLP and a computing hub.

P3	Science learning partnership lead	Science teacher, including biology GCSE and A level.	School is an SLP, maths hub and teaching school

All the interviewees have teaching experience. P1 and P2 no longer teach – their full-time role is concerned with leadership and management of local initiatives for subject or school improvement. Having taught PE, P1 currently line manages the science department at his school. He sees his senior leadership and headship experience as key to his role as teaching school alliance director, particularly in relation to connecting with other school leaders and business planning: "*I can think from a school's perspective, a headteacher's perspective about what they're after … They're very busy people and you don't want to waste their time*". His role in leading science CPD provision is a strand of his wider teaching school alliance leadership role, which has recently extended to include leading a computing hub.

P2 describes her role as: "*Working with schools and companies and trying to bring those together as an entity, so that if there are national activities and schemes that schools can be working with, the messaging is channelled into the schools and the right places".* She has previously led a local science learning partnership, and continues to contribute to its programmes, as well as leading a computing hub. Her experience of attending a two-day residential course about enrichment and enhancement early in her teaching career influenced her career path: "*That's where I think I became enthused to think beyond just my normal teaching role".* She subsequently made a bid for project funding and ran activities that led to being given a post of responsibility, and says: "... *that was a real pivotal time in my career, and the ability to go away for a couple of days and just have a bit of time to myself and really fully immerse myself in what we were doing was really special".* She supports schools in her role as a specialist leader in education for science, working with middle and senior leaders by carrying out needs analyses and facilitating engagement with local and national CPD programmes.

P3 sees herself as: "… *a science teacher first and foremost"*. Having initially assisted her school's science faculty head in running the SLP she later took the SLP lead role in her own right. Her perspectives on CPD reflect her current experience of science teaching, which she undertakes for three days a week.

5.2 Local providers' roles

The local providers are funded to provide CPD for secondary science teachers as part of national, government-backed initiatives. The two schools lead SLPs and the college contributes to one. They each fulfil roles in other funded national programmes for STEM CPD delivery, for example as a maths or computing hubs, and deliver other science CPD programmes. Both schools also have formal roles within teaching school alliances that entail school-to-school support for improvement.

Interviewees explained that their institutions are well placed to bring national programmes together. P2 sees this as: "… *forging a STEM alliance that works out of there*", for example raising local awareness of National Centre for Computing Education, STEM Learning and Institute of Physics (IoP) programmes. P3 described a similar role – including links with the maths hub that her school leads. P1 was frustrated that geographical delivery areas for government-funded programmes differ, and sought greater coherence.

Provision of science CPD is a strand of the wider teaching school alliance work which P1's school leads. He sees the aim as: "*To provide high quality CPD for teachers and technicians".* Meeting schools' needs is important: "*We listen to what they want. I go to headteachers' groups or subject network groups and talk to them and try to find out what they want in terms of CPD".*

Needs analysis enables P1 to match courses with schools. He explained that:

> *There's a whole range of courses. So, if I go and talk to a school about what their needs are, I will go through that list with them and say are any of those courses hitting the mark with you?*

He also described how courses might be tailored:

> *A lot of the work we do is bespoke to what the schools want. I would get a facilitator who I know can deliver the course well … They have a conversation with the school beforehand … to make sure they're hitting exactly what the school wants. That's the way to get the best result.*

P2 and P3 also see meeting local needs as a key a key aim. P2 believes that school-led providers bring knowledge of the school landscape and school leaders. In some cases, this is proactive rather than responsive. P2 explained that:

> *We're trying to target particular areas, so hence setting up a (name of locality) hub, working with some of the larger multi-academy trusts, and implementing CPD in a particular area that has low social mobility particularly*.

The three interviewees believed that building relationships is important. P2 explained:

> *Once you've built those relationships, then everything else is then much easier. They trust us, which I think is important, and I found that with the science learning partnership, regardless if it was a school or a company it was really important to make time to meet people face to face as much as you could*.

The local providers saw that building capacity for science CPD was important. For example, by training CPD facilitators, or working through geographically distributed delivery hubs.

Rationale for involvement

Successful track records in science and their position in the education landscape are the basis for institutions' involvement in provision of science CPD. P1 and P3's schools were designated, and funded up to 2012, as specialist science colleges and in this capacity provided school to school support for science teaching and curriculum. Their schools continue to be high-performing, with strengths in science leadership and teaching, and strong uptake and attainment in sciences, including at A level, thus fulfilling criteria for the SLP role and building on the previous specialist designation.

Provision of science CPD contributes to schools 1 and 3 fulfilling their outward facing teaching school remit, which includes a requirement for professional leadership and development, and school-to-school support. P3 noted that: "*… being a teaching school we already had those contacts across the region"*. The school's status provides: "*… the overarching umbrella and then within that sits the maths hub and the science*

learning partnership". The headteacher's role as a national leader in education (NLE), and SLEs within the staff, enhance the teaching school role in provision of school-to-school support: "*If there is science support that's needed that comes in from our teaching school, then it would be passed onto us to deliver it".*

The drive and commitment of the headteacher and principal of P1 and P2's institutions were crucial to initial and ongoing involvement in science CPD delivery. The principal of P2's college:

> *… has a massive vision for improving the outcomes of our students in our region, so that they're engaged with science ... obviously from a more holistic point of view that they are aware of how science impacts them, in terms of making decisions, for everyday life but also to further the pipeline of potential people that'll want to go into careers somewhere within science and STEM. So, for him, it's about training teachers and having really good teaching to inspire their students to want to be able do that. Building an outward facing college workforce*.

In P1's case: *"The headteacher's passion for science education was a significant factor in early involvement".* Still teaching chemistry, the headteacher is supportive of and encourages the school's role in science and STEM CPD initiatives.

Fulfilling the CPD delivery role benefits institutions' recruitment and retention of science teachers. Teachers at P1's school are offered free places on science courses and opportunity to train as facilitators. He explains that:

> *When we're appointing science teachers to the school, we'll mention the science learning partnership and say, 'There's ways for you to get involved'. One of our science department works, one day a fortnight, in our feeder primary schools.*

P2 explained that:

> *We're seeing particular types of teachers that are now more interested in coming to work here ... to teach, but also because they know that the opportunities to do something different are also there, to work in partnership with more schools.*

5.3 How is CPD envisaged?

Purpose of CPD

Interviewees spoke about 'courses' and CPD interchangeably: with most courses one-off instances, varying from a lunchtime session to a one-day event. In commenting that: *"I am trying to sell something"*, P3 reflects the notion of CPD as a product. She is trying to sell courses. The influence of government policy and funding streams was clear. P1 explained that CPD has changed over time: "*It's linked to our key performance indicators. They change over time and that drives what our main focus is"*. Less frequently, interviewees described provision of other forms of CPD, including formal and informal advice and support to departments and subject leads; shadowing; and brokering links between science departments or science departments and other providers.

When asked what she saw as the purpose of CPD, P2 identified subject knowledge and pedagogy, with immediate classroom outcomes as important:

> *I think from a teacher point of view you do need to keep refreshed especially in a subject like science and STEM, there's the subject knowledge part of it, but then there's also pedagogy from research, things that change and I think that most people that go into teaching care that the methods they use are correct and make impact in the classroom , so you do want to keep that fresh and also different ways of, not necessarily particular pedagogy, but ideas for teaching. It's always nice to come away from a course and go, 'Oh I'm really excited, I really want to try that in the classroom, I wonder if that will work?'.*

Immediate classroom and working practice outcomes are also important to P3:

> *That teachers will feel that at the end of it, they have something that is going to help them in the classroom to actually make a difference to their students, but also to their own time, to save them time, in terms of their planning, if it's going to make teachers' life easier and at the same time impact on their students in terms of it could be, it doesn't necessarily have to be attainment even, it might just be engagement or the students' attitudes to science.*

Connecting teachers with other teachers is an important purpose for P2:

> *I feel it's to create that network within the teachers. You see that by the time they've left they don't feel that they're on their own, either because they're*

meeting us as individuals but actually the rest of the participants in the room, so I think that's one thing they gain out of coming to the CPD.

CPD was envisaged by all three interviewees as a means of addressing specific aspects of subject teaching practice – most usually linked to public examination content or assessment requirements. P1 explained that: "… *key things at the moment are Ofsted, GCSE and A level. And supporting non-specialists. Key stage 3 gets a big miss"*. P3 also identified examination-related courses, particularly required practicals, as popular. In most cases science CPD drew on a national 'menu' of courses available to SLPs.

P2 recognises that professional learning continues after teachers attend courses. She hopes that courses provide ideas for new practice that participants can then implement in the classroom, and share with colleagues:

It's important they go back and implement it fairly quickly, I think, and share it and cascade it back with the rest of their school as well. The school has invested in a teacher to go out for the day, I think it's important it's built into their professional plan to be able to go back and cascade it to the rest of the school, then it has much more impact, not just one class, but for the whole school.

P1 described a national science CPD initiative, Project Enthuse, which he felt was being promoted to SLPs. A long-term model for CPD is embedded:

So, the idea is that you have groups of six to eight schools that are part of the project, a two-year project, £20,000 goes towards it, and that provides a whole range of things including a development plan of the actions they want to achieve over the two years. They might focus in on something like boys' under-achievement or careers in STEM subjects, and the focus of their development plan will be on making that better than it is at the moment across the six or eight schools in the project. There's opportunities there for people to have experience in industry. That's funded. And opportunities for student engagement and activities as well, so part of the money goes towards that. Part of the money goes towards sending two teachers from the six schools to go to York to do the residential courses. Some of the money is used to pay for teachers' release time to attend CPD which we as a science learning partner will deliver.

CPD is envisaged in this project as long-term, focused, collaborative and responsive to schools' needs. The interplay of funding and CPD is evident.

The nature of CPD

When asked about the process for effective CPD, most responses were concerned with practical aspects of aspects of course provision, such as timing, rather than approaches that maximise professional learning. Effective CPD was often interpreted as CPD that recruits – reflecting the influence of performance targets for funded CPD programmes.

Providers take a pragmatic approach to maximise participation in CPD. P1 explained that he runs: "… *CPD that recruits, when it recruits*". Courses and bespoke support to schools are offered at times and in ways to maximise attendance. P3 offers after-school and lunchtime sessions to local schools, although she recognises a draw-back of lunchtime CPD: "… *it's impacting on their well-being as teachers*". An annual one-day conference is a cost-effective way for P1 to reach a large number of teachers. Value for money judgements often lead to cancellation of courses. P3 described examples of leadership courses which weren't viable, with only one or two people booked on, even though they had been identified as a local need. P1 is mindful of costs when planning CPD:

> *We provide our courses at minimal cost. We work very carefully with the cash that we've got to try and maximise support for schools. It's a real challenge. If the funding changed and there was more funding towards schools, then it would be more sustainable. That's one factor. The other factor is the sheer number of providers of CPD that are out there. Not everyone can survive. There are massive big players that do massive big conferences. They do charge a lot of money.*

P1 recognises that social aspects of professional learning as important. He provides: "*Huge opportunities for people to share and impart their knowledge of what works best for them*" and encourages network groups. P3 also encourages teachers to share within and between schools. She recognises that the collegiate culture of her science department is not always the case elsewhere:

> *… I think some teachers feel a little bit isolated within their department and some teachers feel a little bit precious about their resources and about what they do in the classroom. So I think maybe, it's just initiating that sort of environment and that 'we can do this together', I'm facilitating this, but*

actually this is something you could do in every department meeting, because you have the experts here within your department.

Social interactions and sharing practice were seen as important to long-term development. P2 links short after-school courses with follow-up network meetings, to provide opportunity for participants to share practice:

We've always tried to tie up all of our science courses with the network meetings, so that they're able to attend a course, but then follow those ideas up in their network meetings. We can see who's been on which courses and can ask them to run a little session within that as well if they're feeling confident or even just share what they've done. Hopefully, it's going to be a good model for ensuring there is that sustainability but also about engaging people to keep coming to those communities.

All the providers offer subject-specific CPD, in some cases associated with an immediate teaching requirement and not confined to teachers teaching outside their specialism.

P3 observed that subject focused courses: "*… have more of an impact and I feel the teachers go away a lot happier and satisfied".* She suggested that the impact is likely to be greater the more specific the focus. For example:

… a department we gave training on monoclonal antibodies, so very, very specific. And another … where our chemistry facilitator goes in and talks about mole calculations in chemistry. So, it's very specific, but they love it because it's something they have to teach. They don't know what the best way is to teach it and sometimes they don't have the subject knowledge to teach it, so they go away more confident and with some strategies of how to do it in the classroom.

Less formal than courses, and in some instances outside the remit of funded science CPD programmes, provision of advice and support to teachers was seen by interviewees as an effective means of supporting development – particularly for new department and subject leaders. P3 explained that:

… quite a lot of our teachers will just drop us an e-mail and say, 'Oh have you got any ideas how to do this or how to do that?' and that's why I think we're successful because they can see a value in what we're doing, because they're asking us for more help and more support. They don't see it as help, but they see it as some ideas to share. It's that conversation, it's not us going in and

saying we're the experts, we're brilliant at this, we know what we're doing, this is how you should do it, it is a conversation. It's relationships.

P3 envisages a CPD approach that is on-going and provided by a credible facilitator who establishes good relationships. It isn't, however, in line with KPIs:

… we build good relationships with our schools. I think the biggest impact you have, although it's not part of our KPIs, the biggest impact is when we go back and work with the same teacher over and over and over again. When we just do a one-off session, I think they're great, they're really good and those teachers will go away with something and they'll find it useful. But in terms of the best impact, so for we had a teacher to go over, and they did all the chemistry PAGs[1]*, so they went over in lunchtimes, it was every other fortnight. So they did five sessions and they covered all the PAGs, and that was brilliant because she was able to build up that relationship, that rapport with the department and they were absolutely positive about it and the technicians as well. To have that continuous, that regular contact, the relationship, although it's not our KPI, it does help with the teacher to have that regular support.*

The CPD providers provide support to other schools, with relationships an important basis for this. P3 explained that:

Practitioner-led CPD was seen as adding credibility and more likely to influence classroom practice. P3 saw it important that facilitators could say: *"I was teaching this last week. This is how I do it".*

As an SLE and current practitioner, P2 brings credibility to her role and is trusted by schools. She establishes long term relationships:

I'm still in contact with most the heads of department that I've worked with. They'll come to network meetings and can email and ask things. I'm not charging for that; it's about building relationships and friendships with people that you've worked with.

The three interviewees noted the value of the Project Enthuse and Triple Science support[2] initiatives. These funded long-term CPD programmes focus on science departments rather than individual teachers and match coaching, mentoring and courses to needs identified in departmental development plans. Schools are

1 Practical activity groups (PAGs) are groups of skills and techniques which A level science students must demonstrate to meet assessment criteria, having completed at least 12 practical activities.

2 CPD and resources to support schools to deliver triple science GCSEs.

incentivised to participate. The providers fulfil a broader improvement role than simply offering courses. P3 explained:

> *The Enthuse partnerships which are brilliant, and they're funded through industry. They're amazing. We've got a new one, a new Enthuse partnership that's literally just starting in (specific geographical area), and that is really interesting cross-phase. Their project is all about creating an all through science curriculum from EYFS up to year 11. An amazing project, I'm really excited about it. I think those projects are so good because it's all about collaboration between schools and CPD across those schools.*

Curriculum, teaching and learning links

The perceived impact of the national funded programme to encourage more students to pursue triple science courses at GCSE was notable. P1 explained:

> *Four years ago, DfE had identified a group of schools where not enough students in their eyes were doing triple science and there was funding attached to those schools to help develop their teachers and departments to enable them to feel confident and for more students doing triple science. Since then, we've had about 40 schools in the project getting about £1500 a year, some of them are two-year projects, for bespoke CPD in support of their triple science offer.*

The interviewees didn't otherwise perceive that national CPD programmes promote a particular view of the science curriculum. However, the link between CPD and public examinations, particularly as a basis for recruitment to CPD, was evident across the interviews. P1 described an example:

> *We set up required practials in physics, chemistry and biology manned by practitioners to field questions. Teachers and technicians wandered around and asked questions and that got them really engaged. That was what they were wanting to work on, required practicals, at that particular time and we put it on for them.*

He explained that the programme for an annual science conference responds to what school and subject leaders want:

> *For example, we've got three exam boards coming. They've got a slot every year now, which is very popular, and they can be held to account and questioned about the GCSE or A level exams by the delegates, which is good.*

P3 noted that CPD is concerned with wider aspects of curriculum than science:

> *It depends on what the CPD is that you're doing, but a lot if the time it is about actual learning. It's about making it relevant and contextualising it, obviously in that will come literacy and numeracy skills as well. All those things need to be addressed in terms of making students feel successful.*

When asked whether national science CPD programmes are underpinned by particular models of effective science teaching, interviewees didn't suggest this was the case. Rather, they drew on school practice, personal beliefs and their own or other CPD facilitators' experience. P1's school shares practice within subject groups within the teaching school alliance. P2 and P3 draw on their experience as science teachers, and their beliefs about effective science teaching when facilitating CPD themselves. P2 sees the experience of her team of facilitators as important: "*We try to base it on research and experience. We're all experienced practitioners in the classroom, so working through good science I believe".* She acknowledged that some CPD was based on research at national level, so that: *"… you're modelling good practice".*

Acknowledging the link between CPD and teaching practice, P3 recognises that teachers value *"take-aways"* that they can use in the classroom immediately after CPD.

What does success look like?

Course feedback is important to P1. He recognises that it is more difficult to track longer term impact of CPD, even after sustained involvement with a department, in some cases because of because staff changes. For P3, success in the short term is indicated when: "*Teachers go away a lot happier and satisfied*" and in the longer term: "*Schools come back to us*". She explained that: "*I think the biggest impact you have, although it's not part of our KPIs, the biggest impact is when we go back and work with the same teacher over and over and over again".* Describing relationships built up with schools, who approach her for advice about science teaching and curriculum, P3 explained that she regrets that "*… sometimes when I'm writing a review at the end of the year and it's all about what have they have done and the activities and what impact of that in terms of ticking off these boxes and putting in the numbers, but actually it's more than that".*

P2 also contrasts performance indicators with other aspects of successfully fulfilling the provider role:

> *I just recognise that the link is keeping that relationship sustained and not to be too bogged down with the KPIs, kind of things, we all have particular targets, for numbers for people that go on courses, and things like that, and that's important, because that's what brings the extra funding in so you can do your work and so forth, but I think it would be very sad if that's the only thing we looked at – you know, 'Thank you for coming on my course, and see you later', because that wasn't the point of why you wanted them to come on the course in the first place.*

P2 has a wider perspective on success:

> *Outcomes for students might improve in the area. The teachers would obviously be more confident and feel like they were supported and therefore teacher recruitment and retention would be better in the area, if they felt that there was somewhere, a place to go where they could get support.*

She also describes impact for her own institution in terms of staff recruitment:

> *… from the college point of view, we might be recruiting a higher calibre of teacher and lecturer because of who we are. I've found that in previous establishments, that because we were the science learning partnership for the region, that people naturally would then come in and investigate and through word of mouth know that each and every member of staff there is able to go on CPD and that it's invested on and therefore you're more likely to recruit good teachers.*

Recruitment of students was also an indicator of success:

> *If the teachers are well trained and inspiring then the children will have a better idea of what is involved in science and STEM, will enjoy the subject and at least be curious about taking it as a higher level. We would hope therefore that we would be filling all of our courses, whether it be A level, or BTec or higher through to degree level.*

5.4 The wider context

The school context

Interviewees described constraints to teachers' engagement with CPD, particularly schools' financial circumstances and the impact on science examination classes. They take account of financial considerations and understand that attendance at courses is vulnerable. P1 ensures the annual science conference is affordable, explaining that:

> *I would say it's difficult because of the schools' funding situation. Schools are really strapped for cash, some more than others, and when it's not managed well, they're having to cut their cloth accordingly. CPD is one of the areas that goes – they'd just do their own thing.*

Interviewees pointed out that examination class teachers are not likely to be released to attend courses. P3 noted: "*Most scientists teach exam classes".* P1 reiterated that one of the implications of the shortage of science teachers is that: *"Schools who are struggling with staffing top load their examination classes*". According to P2:

> *Teachers are not engaging with CPD, even if the CPD is free, because they're not able to get out because of cover. Even if cover is paid that still doesn't mean that they'll come out because of the time constraints in terms of teaching. If they're the only physicist for example, you can't cover it with the teaching that's needed.*

P3 reiterated the challenge:

> *… then to allow somebody to go out for a whole day CPD that's going to end up costing £400 - £500. And if they're missing exam classes as well, it might be even if they did see that they wanted to fund it if you're missing year 11 and year 13, then that's … you're sacrificing those classes. I know it might only feel like one lesson, but sometimes there's double lessons, so that's two lessons those year 11s are missing, so it's difficult.*

She is aware that teachers themselves might be reluctant to miss examination classes:

> *… so, most science teachers will be teaching exam classes so it's the fact that they're going to miss their exam classes, and the cost of supply and then knowing that, that lesson, because it's a supply teacher, will be a bit of a wasted lesson for the students.*

Difficulties in recruiting and retaining science teachers prevail in some schools. P1 explained that:

> *There's a whole range of issues out there for schools. Some of them, it's just about fine tuning and tweaking, because they've got a really stable department. They've got good teaching and it's about moving things on. Others, they are in chaos because the department keeps continuously changing, they've got non-specialist teaching and that becomes more problematic because it becomes more about survival and get through the day rather than a three- or five-year plan.*

Whole-school CPD is seen as cost-saving by P3, and she regrets that subject-focused time for departments often isn't built into it.

> *I personally believe that's the best CPD you can have, subject-specific CPD, but unless schools think it's essential ... it's easier for all us to sit in the hall on the INSET day and all have training on using an EpiPen. That's much easier than arranging for subject-specific CPD for each department.*

P1 agrees the value of school-based CPD, also noting that subject-specific CPD can be a casualty:

> *We have got a brilliant in-house CPD, but it's not subject-specific and that's what the teachers miss. Good pedagogy and good systems about how they want to deliver and engage students and get metacognition or growth mind sets or what – ever it is you're working on. But subject-specific CPD is the big thing that teachers miss when the funding is cut.*

School leaders were recognised as important in enabling participation in CPD. P3 described the stark choices they make, even within a science context. For example, choosing between a health and safety course, radiation training, which might be seen as essential, or more general science CPD which is less likely to be supported. P1 sees school governors as important, and briefs them about CPD: "*If the governors are talking to their headteachers and say, 'Oh tell me more about this science learning partnership, why aren't we involved in that, taking the opportunities'?"*.

The providers emphasised their knowledge of local schools' needs for science CPD, which P3 explained are:

> *… really specific parts of the curriculum in terms of subject knowledge and how to deliver. Fun ways of delivering, some of the more boring parts of curriculum. And required practicals …. not only how to actually do them but also how students can be successful in answering questions on required practicals, exam techniques. Around practical work and data.*

P1 and P2 reiterated schools' focus on aspects of examination syllabi. P1 is concerned that "*Key stage 3 misses out".* The scenario appears to be that examination class teachers are reluctant to miss classes and schools reluctant for them to do so, and because it is less likely to recruit, there is little CPD provision for key stage 3.

SLPs have income targets and charge for attendance at some courses. Even when CPD is free or subsidised, however, there are barriers to access. P3's approach is to:

> *… go in and do the course at school. But mostly it's departmental time. The trouble with departmental time is some schools don't have many departmental meetings. They might only have one a half term, and then to use that whole departmental time, that one time in the whole half term for CPD when there might be other issues they need to do. It's really limited …*

Workforce development

The interviewees work in institutions with strong science departments, which they believed to be strengthened by involvement in local provision of science CPD. They recognised features of the wider context for recruitment and retention of science teachers. P2 noted that: "*… the landscape of recruitment is uneven. Some schools are less likely to recruit good teachers*". She described a scenario where:

> *It's difficult to get science teachers. Good science teachers. You do find that there are certain schools that, you are always going to have someone in your department that needs a little bit more support, but there are certain schools where the entire department needs a higher level of support. They just seem to have amalgamated in one school and that's having a massive detrimental effect on the outcomes for those particular children. And then it's really difficult to … you get into a vicious cycle because they just can't recruit into those departments.*

She described the impact of non-specialists teaching science, particularly on key stage 3 students:

> *So key stage three might be a PE teacher who's doing four lessons a week in science, or a music teacher, or any-one who's light on their timetable. It means those students get a really poor – I'm not saying it's all poor, but not as good as they should get in terms of key stage 3, so by the time they get to key stage 4 they're behind because they've not been taught properly, and they're switched off, disengaged from science because they've not liked what's been happening compared to having qualified teachers in many of their other subjects.*

P1 noted the lack of subject focus in post graduate teacher education and would welcome greater involvement – suggesting that many of the courses that he offers would be useful to trainees. His SLP provides a programme for science NQTs. P2 and P3 provided examples of the challenges faced by inexperienced science department leaders, who they support through school-to-school approaches as leadership courses are not recruiting. P2 described an example of a new head of department who was promoted early in his career. *"I don't think it's that teacher's fault*

necessarily. They've been given a responsibility that they probably haven't realised what that fully entails, and haven't known where to look for it, basically".

The science CPD landscape

P1 described competition between CPD providers and argued that addressing current key concerns, which he saw as Ofsted, public examinations and subject teaching for non-specialists, is important to*: "… get ahead of the game".* He explained that:

> *It's a market. Teachers, headteachers get stuff across their desks every day about courses. They're swamped. What we have got to try and do is say 'We're DfE-funded this is slightly different; we're not a commercial player in this, we are supporting schools through STEM Learning which is funded through the DfE'. We've got the keep promoting that.*

P2 described the impact of the variety of providers on science teachers:

> *I think they're bombarded from all the different organisations that can help them in terms of CPD and out-reach and support, be it the IoP, the science learning partnership, or STEM Ambassador hub, they're getting bombarded with lots of e-mails from lots of different people and it's actually quite difficult to see the wood from the trees, so we're trying to collaborate more, so that if I go into a school I can give them the entire package …*

P3 welcomes the wealth of CPD but is also concerned that:

> *… some schools find it a little bit overwhelming, because they are, not bombarded, but all the examining boards send their flyers, and all their different offers and their e-mails. Then there's companies that run, different businesses, money-making businesses that offer things as well, then there's different bursaries that are offered. There's so much out there. And obviously all the on-line CPD that's available.*

P2 reported that teachers say:

> *I didn't even know that initiative is there, even though they've almost certainly been emailed with information it, but because of their busy time, they're just not reading it or it's not getting sent to the right person, there are a number of reasons why they're not engaging with the information that's coming through to them.*

She sees that an important aspect of her role is helping busy teachers easy to know what is available. Her approach is collaborative: "*Where we've had local providers of CPD within STEM we've always worked with them and joint badged things because, if you're competing, nobody's winning at all".* She suggests the benefit to schools of

bringing national initiatives together at points of local delivery, particularly when different initiatives are coordinated by the same organisation as is the case for the STEM Ambassadors programme, the National Centre for Computing Education and the national science learning network – all managed by STEM Learning. She understands the difficulty for teachers in making choices:

> *… there's a lot of really good quality CPD, which is brilliant, but I think that as individual teachers, and sometimes as heads of department, it's hard to choose and to know where to go for the best in terms of your own personal development, what would be best, most suitable for your school and for your department, and then obviously there's the budget.*

National CPD programmes were generally described in terms of products or outcomes, such as for more students to take triple science at GCSE, to train more physics or computing teachers, or for more teachers to attend courses. The IoP and RSC are held in high regards by interviewees and suggested as key organisations to work with.

Not all science CPD is through designated providers. School-to-school support for science, including instances where one school funds support for another within a multi academy trust, reflect the school-led landscape. P3 observed that: "*Teaching school alliances are doing a job locally, but less so nationally in a consistent way. It's how you quality control what goes out"*. P2 described the importance of a national centre and resource bank for science teachers. She recognises that course materials for national programmes are likely to be quality assured: *"They've been worked out and trialled and tested over time and are trusted and even if the presenter tweaks them and adds in little bit of local need".* She sees that SLPs have a major role to play, although: "*More schools need to know about what they do and what they can offer"*.

External funding for national CPD was seen as crucial to continued local provision of CPD by all three providers.

5.5 Summary

The local CPD providers explained that their institutions are well placed to fulfil local delivery and to bring coherence to national initiatives, with relationships and local

knowledge key. They described tensions between indicators of success such as building relationships and sustainable networks, that they consider to be important, and performance indicators for funded programmes, which often are concerned with course attendance levels. They are pragmatic in their approach to planning and scheduling their CPD programmes, particularly in response to schools' financial constraints. Some longer-term examples of CPD, made possible by external funding, were seen as worthwhile; however, much CPD provision is comprised of short, one-off courses, with links to public examinations proving popular.

Chapter 6 Teachers' perspectives

This chapter presents my analysis of data about: teachers' experiences of CPD; their perspectives on the environment for secondary school science teachers' CPD; the influence of their school settings; and their understanding of the wider science education context.

6.1 Interviewees

Table 6.1: teacher identifiers and backgrounds

Teacher 1	T1	T1 has taught for more than 25 years, at two schools, and now is head of science in a London girls' comprehensive school. Not ambitious to progress into school leadership, T1 has enjoyed participating in long-term research projects for a local higher education institution, which she experienced as powerful professional development. She identifies a dichotomy between 'ethereal' research projects and classroom-focused CPD.
Teacher 2	T2	T2 has taught for six years at the same girls' comprehensive school in an urban setting close to London. He now is head of chemistry. An RSC scholar during his post-graduate training, T2 values opportunities to share practice with other chemistry teachers, and hasn't participated in much formal science CPD.
Teacher 3	T3	T3 has taught for seven years in the same girls' comprehensive school in the fringe of London. She has taught chemistry and biology to A level, and now is head of key stage 3 science. She previously taught in a further education setting. Her doctorate is in biochemistry. Her role as an A level senior examiner provides professional learning that influences her classroom practice.

Teacher 4	T4	T4 has taught for 7 years at the same school. With a degree in sports science, he has taught chemistry and physics to GSCE level and biology to A level and now is second in science department at his school. Two years after starting to teach, he acted as head of science for a year, which he described as 'insanely hard work'. He appreciated opportunities to learn about how other heads of department were tackling key challenges, such as choosing GCSE syllabuses.
Teacher 5	T5	T5 has taught for more than 20 years, at four schools, and now is her fifth year as head of chemistry as a mixed comprehensive school. She considers her subject knowledge to be good, but still is keen to try new approaches out and share ideas with teachers. Credibility of CPD facilitators is important to her, particularly as she often has more teaching experience than them.
Teacher 6	T6	T6 is in her second year of teaching at a rural mixed comprehensive school. She teaches across key stages 3 – 5. Her doctorate is in neuroscience. She enjoyed the research element of her post-graduate certificate in education and has already started pursuing a research-based master's degree.
Teacher 7	T7	T7 was a trainee and subsequently has taught for eight years at the same school as T6. She works part-time as head of biology. She came into teaching because 'I loved my subject and I love being able to help others with my subject. I didn't come into teaching because I loved teaching.' She values CPD that leaves her thinking afterwards.

Interviews were conducted remotely. Teachers were home-based, and the challenges of their new working situations were reflected in interruptions to interviews such as dogs needing to go outside, a smoke detector set off as pancakes

were being prepared near-by, and a child stung by a bee and needing attention. The teachers, though, were generous of time and appeared to be focused on the interview questions. Most indicated that they were pleased to have taken part, in some cases linked to the prevailing situation. For example: "*It was nice to chat actually; it's amazing how I miss conversations …"* (T5).

6.2 How is CPD envisaged and experienced?

When asked to describe examples of CPD, teachers referred interchangeably to training, support, CPD, INSET and professional development. A variety of development activities were described, including: formal courses – both science specific and general, which could be in-school (usually referred to as INSET days) or external; informal and formal practice sharing within departments and schools, and between schools; observation; examination board meetings; research projects and degrees; facilitating CPD themselves; and supporting other teachers.

Courses external to school were the most usual examples of CPD. Most of these were examination syllabus related, often concerned with assessment of practical work at GSCE and A level, although courses associated with teaching particular areas of content and raising attainment for specific groups of students were also described. External subject specialism courses, for teachers teaching outside their specialist subject were also described.

Some CPD was concerned with teachers gathering information that would influence departmental practice. T4 saw research about syllabuses, including attending examination board meetings, as important professional learning for his subject leadership role: "*With the curriculum, it's really important for me to understand what's happening above myself. Why changes have been made by the government? What's likely to happen it in future?"*.

Presenting at the annual Association for Science Education and at a research conference, about work undertaken as part of a project with a higher education institution, was seen as powerful professional learning for T1. She described:

> *A conundrum for science teachers, because we're so driven by the syllabus and that's always the balance that science teachers have had, where, CPD enlivens you and makes you think about all the wealth of things that you could be getting students to engage in and then interpreting that, and coming down to a syllabus to get through an exam, and I think that's still a massive conundrum for all teachers*.

T6 also believes that research is an important strand of professional development: "*Having practitioners who are researching is important".* T7 agreed the value of research, but wanted CPD leaders to synthesise and summarise key messages.

Teachers' understanding of CPD also included sharing practice with other science teachers, and school-based CPD: both are considered later in this chapter. Observing other teachers was another CPD activity: T7 observed history teachers to help her to teach ethical aspects of biology curriculum such as vaccinations, STEM cells and cancer treatment. Observing teachers in another school was useful to T1. Shadowing another head of department as part of his middle leadership training was valuable to T2, who reflected: *"I don't think there's much that is more valuable than seeing someone else do something and seeing how differently you could have done it".* Mentoring trainee teachers contributes to T7's professional development – introducing her to new terminology, concepts and models of teaching.

Changes in teachers' practice were not all associated with specific CPD activities. Teachers described gains in confidence and knowledge during their early career phase, and after 15 years teaching all three sciences to GCSE, T1 experienced starting to teach A level as powerful professional learning. T3's role as an A level examiner influences her teaching practice, with assessment a key focus. Training to lead CPD, and subsequently doing so, influenced T3's practice, including through interactions with other teachers.

Social aspects of CPD

Sharing practice with colleagues, either within school or with teachers in other schools, was the most frequently described influence on practice and was valued by all the teachers. T2 explained: "*I've not done much specific science training, but to be honest, I've always found the most useful thing to do is to chat to colleagues or people*

in other schools in similar positions". T4 believes that: "*The biggest thing in any training … is the sharing of knowledge on that course*" and prefers informal sharing to a facilitated process: "*Just the informal chatting and saying, this is what we do".*

Finding out how other schools do things was useful to many of the teachers – particularly practice related to public examinations, such as predicting grades or assessing practical skills. T2 explained:

> *… it's now been two years through but the GSCE changes and the A level changes, especially with the core practical competency work that you do at A level now instead of the assessed practicals, just having that time to discuss with people about what they do and what we do. What works? What doesn't work? That sort of thing has been super, super useful.*

It appeared that teachers were more relaxed about key stage 3 than key stage 4, hence the interest in other schools' approaches to GCSE and A level teaching. According to T2:

> *Your hands are tied at key stage 4. There's more flexibility as an academy, at key stage 3. Because we've got it working for us and because we've got a bit more flexibility, we can be a bit more creative. It's where your hands are slightly more tied, where you feel you want to gather more ideas of how other people do it, and you can't necessarily run with what you want to do, you have to do certain aspects. So yes, that is more a of a focus because you are hamstrung a bit more.*

T3 is confident in her subject knowledge but appreciates the opportunity to share approaches to practical work with colleagues from other schools: "*… it was nice, again, to have the opportunity to meet different teachers from different schools that you don't normally meet … and talk to them about what they're up to".* T5 is also a confident subject teacher who values opportunity to meet others, for example at teacher-led meetings:

> *I'm looking for how to deliver my lessons the best, because I think my science and chemistry knowledge is fine, so I'm looking at new and imaginative ways of delivering it or if there has been a change in policy … when you go to these places, you meet another chemistry teacher and say, How are you managing with the practicals, what are you doing? And sharing practice that way.*

Sharing leadership practice is also valued. T4 was rapidly promoted to act as interim head of department and explained: *"It was good to see other heads of science to see*

how they approach things and see what they do". T2 shares practice with heads of chemistry within a consortium of schools. T1 misses local authority meetings for heads of science. Examination board meetings now provide a useful forum:

> *Just talking again to other teachers about how they're implementing things. And everybody does it differently … you see how other people do it, and think well actually I could change that, or it's almost the same but just done slightly differently.*

T1 values networking between schools and with universities. She finds local CPD useful because it offers the possibility of building relationships with other schools.

Some teachers had participated in on-line CPD. This offered the chance for social interaction, and flexibility, as valued by T6:

> *You could progress through at your own speed. I actually joined the course two weeks late and was able to go through and still add to bits of discussions and see what other people had done. That timing issue was actually really good, because teachers are busy and being able to do things at your own pace is really useful.*

T4 also saw the positive aspects of on-line CPD as interacting with subject experts, learning what other teachers do, progressing at your own pace. T7 was enjoying an on-line course that she wouldn't have been able to attend if face to face, due to timing clashes. She also increasingly shares ideas with other teachers via a Twitter account for biology teachers.

The CPD facilitator

Characteristics of course leaders (who were generally described as trainers) are important to teachers. Current or recent classroom experience is important to credibility and trust, as is expertise in subject. An overriding theme was the importance of understanding the everyday pressures that teachers' experience. T1 explained:

> *You get that sense of trusting them because they're still in the classroom. There's always that sense, when you're being talked to by a consultant who hasn't been in a classroom, there's always that cynicism, 'It's all very well you saying that, but you're not in there doing lessons every day'.*

T2 echoed this perspective. His reaction, when facilitators don't understand the everyday pressures of teaching, even if in other respects they are good, is:

> *Well, that's fine. And you obviously know a lot about what you do and you're good a running a training session, but you're not actually in the classroom, so while I can accept 50% of what you say, the cynical side of me is always going to say, your job now is a trainer and not a teacher'. Rightly or wrongly, personally I struggle to accept what they have to say a lot of the time because I think it's much better coming from someone who teaches 20 lessons a week and has to deal with all this other stuff.*

T4 was inspired by a physics course leader who was a teacher:

> *The fact that it's coming from someone who genuinely understood why they're running it and they're not doing it to, sort of, tick a box, but someone who's passionate about their subject. The physics days that I did, the chap who did it was incredible. He just had an absolute thirst for knowledge and he just wanted to do everything, he took up every question, he unpicked every misconception.*

His experience of course leaders' practice on a biotechnology programme influences his own practice:

> *They want us to do the best we can. They know what they're talking about, and they know what issues you're going to have, they take it seriously. They take your concerns seriously and they take feedback. Anything I've said, 'Oh can we do this?' they've taken it seriously. It makes me feel I've learnt something. As a student I can see how that really boosts you, because I go through so many observations of teachers, and I think, 'What have the kids learnt in that lesson?'.*

Before selecting courses, T5 researches the trainer:

> *One of my big criticisms was a few years ago I looked at how to deal with difficult boys and I looked at the résumé of the person that was actually delivering it and she worked in a girls' school, so I feel like the person who's delivering the CPD, to me, has to be current. I like the idea of teacher practitioners … I think then they understand what you're doing instead of remembering what it was like five years ago trying to fit 10 million things into your schedule.*

Subject specialism CPD

All the teachers teach across the science curriculum at key stage 3 (in most schools, years 7 and 8) and their specialist subject at key stage 4. None said that they were

reluctant to teach outside their specialist subject, and some enjoyed doing so. Where this led to professional development needs, teachers valued support and advice within their departments – particularly in the early years of teaching. Some had attended external courses.

T4 has valued intensive physics-focused CPD, which helped him to identify areas that students struggle with and ways of making content more accessible. T6 also values subject specialism CPD that addresses content, pedagogy and misconceptions. A biologist, she taught chemistry and physics in her first year of teaching and relied on "*helpful colleagues*", explaining:

> *It's just so difficult if you're not a specialist, because you just don't have the depth of understanding that you have in your specialism, and finding the questions and links that help students to progress is so much harder.*

She linked this to her own science background:

> *… part of it is the content knowledge. I don't know a lot about energy, or transfers or energy stores. I didn't know a lot about that. And certainly, physics was not my strong suit when I was at school. I didn't study it at key stage 5 and I was very under confident at maths, so it was not my thing at all, so content knowledge, I would find that useful. I think, yes, pedagogical content knowledge which then is different, is also super useful because I think that helps you to know more about misconceptions that students might have and how you would best address those and I think that is really important.*

The need for subject-focused CPD wasn't only linked with teaching outside specialist subject areas. T7 suggested that even recently qualified teachers can need CPD in their own subject: *"Everyone just assumes that just because you've got a degree, you'll be fine using certain techniques in the classroom"*. She also pointed out that CPD needs can arise from subject developments within teachers' specialist subjects. A biologist, her ideas were refreshed through CPD about ways to make practical work more interesting and engaging. She would like to see CPD on approaches to teaching ethical discussions on developments such as vaccinations, STEM cells, cancer treatments. She has recently participated in an on-line course on plant biology, reporting:

> *I am interested in all the pedagogy and things, but I think I've always just loved it when a student suddenly turns round and goes, 'Ah, plants aren't that bad'. I just want to get that enthusiasm in there.*

Useful and effective CPD

Relevance to science classroom practice, including ideas and approaches that could be immediately used were described by all the teachers as characterising useful CPD. As T1 explained: "*It's more powerful when you take something away from it that you feel is going to help your practice".* T3 wants: *"… concrete examples that people have used to show things work*". T7 explained that: "*Your time is so limited as a teacher … to take something away with you and actually use it in a classroom*" is important. Whilst valuing 'ready-made' classroom approaches, teachers were happy to try them out and modify them – as summarised by T3: "*I want to know what works and I would be happy to try things out".*

T1 still uses materials and pedagogical approaches from the key stage 3 science strategy, which she described as some of the best CPD she has experienced, in part because: "*They were produced by people who had research behind them, evidence-based activities*". She provided insight to the notion of relevance:

> *They were relevant to what we were teaching. They were making us think about pedagogy. Because they were based on pedagogy. They were based on how students learn. OK, some slightly better than others, and you always had that pick and choose thing, but there was plenty there and if you took the time to read the stuff it was very clear about how it could be used practically.*

Early in her interview, T1 described how excited she was by involvement in long-term, HEI-led education research projects. For her, interacting with researchers, other teachers, and research literature, as well as opportunities to present at conferences, was energising. Later in the interview, she described a very different kind of CPD. Her school has signed up for a national, whole-school CPD initiative. As part of this, she attends regular conferences, at which she values the chance to meet heads of science from other schools, as well as the 'take-aways', such as three types of PowerPoints:

> *The grasp-its are for getting the basics. The know-its are the recall and the think-its are the extension and they do them for GCSE and for A level. They're*

really good for revision tools, to give the kids a different PowerPoint to the ones that you've used in lessons. They've got everything there, and questions.

She recognises the contrast between the two CPD approaches that she described:

And this is, for me, is the dichotomy with CPD because, I loved the challenge of the research and the stuff that's ethereal. I've loved that, when I've done it, but then actually, most teachers just want 'Well what's going to work in the classroom?' And PiXL[3] *does that.*

Some teachers described longer term outcomes that characterised effective, rather than immediately useful, CPD. For example, T7 explained that:

One of the things that shows me that that things have been effective is when I carry on thinking about it and I carry on wanting to know about more about it. The thing I find difficult is trying to back it up with reading, so I know that in a perfect world I should be going to the world of academia and reading more about these concepts, like the dialogic teaching approach or whatever.

Like T1, T7 recognises the importance of research literature but wants the facilitator to synthesise it. She is pragmatic in her views:

I think effective CPD for me is something that is not only interesting and keeps me thinking … but presents it in such a way that it doesn't matter if you don't know the lingo. You can fall into it, understand it, and tweak what you're doing, and try it out, and see whether it works.

And I don't want to have to back it up with reading six books and prove it works … you know, as a teacher, you can see in your students their engagement and I think it's their engagement that matters more to me than everything else.

She sums up the dilemma for many of the teachers: "*When on your job list for that night, well you could read about this teaching approach or you could mark your year 13 mocks …".*

T1 suggested that schools are reluctant to support teachers' participation in courses when there isn't clear impact:

There's very little going out on courses anymore. I think half of that is because things don't get implemented anyway. But it's not just about the implementation, is it? It's about, as I said, the chance for you to use your brain

[3] https://www.pixl.org.uk/ A partnership of more than 2,500 schools that 'share best practice to raise standards'.

in a different way, and that's one of the things that I've found that I've enjoyed most about CPD.

Teachers' CPD suggestions

When asked what CPD provision they would suggest, teachers' answers were most usually concerned with social interaction, subject and examination specific foci. T2 and T3 suggested more CPD with technicians. T4 would value CPD with primary teachers. T2 would welcome more opportunities for informal observation of teachers within his own and other schools. T7 identified the need for CPD focused on new subject developments, such as microbiology, that are included in examination syllabuses. T5 suggested the need for CPD focused on A level teaching, which she considers are not well addressed in initial teacher education.

CPD linked to individual needs and professional development was less frequently suggested than CPD linked to external changes or requirements, although T4 and T5 perceived weaknesses in teaching low ability groups and would welcome CPD that addressed this.

6.3 The context for CPD

The education landscape

T1 regrets the loss of local authority CPD and support for subjects, such as subject leader meetings and key stage 3 science strategy CPD. T4 regrets local authority curriculum leadership role. T1's experience is that her school, an academy, is: "… *an isolated island*". Other teachers described formal and informal connections with staff in other schools through teaching school alliances and school networks. T2, for example, connects with other heads of chemistry in a local consortium that his school belongs to and values: "… *the knowledge that you can approach anybody. It's not necessarily a group that meets on a regular basis … but people know you can*".

Links with other schools also provide opportunities for T3: "*Because we're a consortium school, we meet regularly, well, once every half term, and talk about how the A level teaching is done, because we share A level students*".

The school context – external CPD

Some schools are experienced as by teachers as supportive of external science CPD. T4 explained that: "*Choices for my CPD have not been limited by my school. They've supported everything I've tried to do".* More often, CPD needed to reflect school or science department priorities. T2 thought that she would be most likely to be supported to attend CPD on engaging with student premium students, a key school focus for the year. All the teachers described constraints to participation in CPD – with financial ones prevailing across all the schools. In most cases these were increasing. T1 remembers when:

> *We were encouraged to look for courses and a day out would be easily accommodated and we're not encouraged any more to do that, and I think most of it is budget, because if you're out for a day you've got supply cover for the day, plus the cost of everything else.*

She notes that:

> *… even getting on exam board CPD these days is difficult, whereas traditionally it was always expected that you went to the exam feedback CPD that they gave. That doesn't happen any-more.*

T2 summarises the constraints as being: "*a mix of time and money*", and illustrates the dilemma for departments:

> *My inbox gets full of invites to various things, this, that and the other, and then you look at the price and it's £300 for a day and that's more than 10% of our budget. And although that would be useful, I also need some chemicals to do some practicals with. So, it isn't a toss-up. It's not that we chose to ignore it, but time and money wise, the course is one price, but cover cost is another, when it costs about £200 a day to get someone in, it then doubles the actual cost of the training and if it's not as bespoke as you might want it, you question whether or not it's worth it.*

Not all constraints are financial. T2 observes that as a successful school and department: *"… there's no particular onus for CPD".* At T4's school: "*CPD fell off the radar…*" after an Ofsted inspection. Teaching examination classes is a constraint for some teachers, who recognise the impact of missing lessons, and wider school commitments were described. For example, T5 described instances where she had

applied to attend CPD and been told: "*Sorry, no, on that date too many people are already out from the staff, you can't go".*

Two teachers explained that their schools have bought into national CPD schemes, which were presented as providing better value for money compared with individual teachers attending external CPD. T1's school encourages and supports staff to attend PIXL courses. Other schools were perceived to have implemented whole-school CPD as a response to financial constraints. T5 explained:

> *The head felt it wasn't good use of money because as budgets became tight and it costs to go up to London and CPD was about £200 a person, it would be better to bring somebody in and give it to the whole staff, so the opportunity to actually pick and choose and go on any CPD that you like was reduced.*

Financial constraints also impact at department level. T3 explained that some of the most effective CPD for her faulty was focused on saving money:

> *Science technicians have gone on courses to give them ideas of how to do practical cheaply and not having to buy in expensive equipment and what you can use, and they have been very, very good at feeding that down to us, and that probably as a faculty has been the most effective CPD I've seen*.

Schools are creative in their approach to managing funding associated with trainee and early career teachers. T2 explained: "*The school gets paid for the trainees, we use that money for the trainees, instead of paying the staff we use that for CPD"*. He described another example, about a teacher in her second year of teaching who wanted to pursue a master's degree: "*We came to a little agreement where all of her NQT training money, the money that's in that pot, we put all of that into funding some of her master's, so you work around it".*

T6's school has a rich internal CPD programme, and a research focus. Yet her experience of pursuing a master's degree illustrates contradictions:

> *They gave me reduced timetable, so I'm on a 90% timetable this year, I asked for and they gave me, but equally I was presented with the other side of the argument which is, 'This means that this means you won't progress so quickly in terms of management because you're doing the master's'. They were giving the impression that I would miss a year of professional development in terms of furthering my career, which I don't think is true, that's why I'm doing the*

> *master's, and I wonder if schools do see the value in terms of doing those kinds of master's or further courses.*

T3's school supports her role as an external examiner – however, it has detracted from her opportunity to participate in other, formal CPD, and the school considers it to be part of her CPD time allocation.

The school context – whole-school CPD

Teachers held different views on the value of whole-school CPD when they described examples focusing on behaviour management, metacognition, interleaving, behaviour management and literacy. All interviewees valued subject focused CPD more highly than whole-school, and described frustration at the lack of time to follow up whole-school CPD in departments and to conceptualise the generic focus within subject teaching. T4 explained that whole-school CPD is: "*Not really improvement. It's just change*". T1 regrets that: "*With CPD within school, very rarely do we get subject specific CPD, it's all very general now*". Her experience is that:

> *Education has gone to, what's the pedagogical buzz learning activity of the year? Because rather than buzz word. At the moment it's retrieval … and all the CPD, it could be AfL, it could be questioning, it could be literacy, numeracy, whatever it is, for a year or two … the whole-school CPD is on that. You get people coming in who may or may not be science specialists. Generally, they're not.*

T6 judges that at her school:

> *In-school professional development, the school itself is very good, I think, at providing quite a lot of CPD which is well thought through and very relevant to teaching. So our focus this year has been on metacognition and thinking about ways that we can introduce metacognitive practices into classrooms. That's not science specific, but it actually impacts quite a lot on your practice.*

She believes that teaching science is: "*… a very different pedagogical approach than a lot of other subjects*" and regrets lack of opportunities to discuss things more in depth, in departments, rather than school-wide groups. T7 pointed out that "*Whole-school CPD makes you do things you wouldn't otherwise do"*. She described examples of introducing new pedagogic approaches such as modelling and flipped learning as a result of engaging with teachers of other subjects and observing their practice.

The science department

Teachers described ways in which science departments provide an important environment for sharing practice and CPD experiences including through department meetings and informal observation of each other's practice. Departmental culture is important and varies between schools. There are five chemistry teachers in T5's department who, she explains, are: *"… always saying, 'What do you think about this, what do you think about that? How have you done this? What have you got on that?'"*, also noting that: "*We are in and out of each other's labs*". T2 sees the departmental culture as key to its success:

> *… we do constantly help each other out and talk about stuff. Every department meeting starts with something that someone's done that was either terrible and so no-one does it, or was really good, so we try and embed it across.*

Support can be for teaching outside subject specialism. For example, T4 explained why on-line chemistry courses weren't as helpful as colleagues:

> *When I don't understand something, I need someone to talk me through it and work me through the examples. I don't understand moles in chemistry and I just can't teach it. I can balance equations, I can tell you everything about it, but tell me that there's four moles of this and four of that and I don't understand it. My chemistry colleague at school talks me through examples, and I can teach it.*

T6 is: "*… surrounded by good colleagues so think about my professional development a lot"*. A biologist, she also valued assistance of physics and chemistry colleagues in her first year of teaching. None the less, there isn't time within her department to explore GCSE practical work, so she is looking for CPD to enable her to: "… *think a little bit more about how I could explore my practice to make sure students are getting the best out of practical work*". Other teachers described lack of formal departmental time – in some cases just one meeting per half term.

The science CPD landscape

When asked about the national landscape for science CPD, T6's response was typical: "*I know things are out there but not what …*". Despite receiving lots of information,

T1 explained: "*I don't have time to go through courses".* Like other interviewees, T4 was: "*Not sure what CPD there is*".

Teachers described the vast amount of science CPD marketing material they receive, and identified time as a constraint to finding out CPD opportunities. Their knowledge of the science CPD landscape was sketchy. None of the teachers referred to the national infrastructure for science CPD or other national CPD programmes. T5 valued CPD that she had attended at a local school – although she didn't refer to it as an SLP. When asked directly, T1 wasn't aware that there is an SLP local to her school. With the exception of examination boards, teachers in many cases were not confident about who the provider was for CPD they had attended.

Relatively few provider organisations were specifically mentioned during interviews. The Institute of Physics (IoP) and the Royal Society of Chemistry (RSC) were well known and well regarded, irrespective of interviewees' subject specialisms. Teachers described how IoP and RSC resources and websites were useful, particularly when training or at early career stage. T6, a biologist, commented:

> *IoP: they have a great platform … about teaching physics and how best to approach teaching those big ideas, and it's just super useful as an early careers teacher, just to have something there that is concrete and I know it's important to debate those things and talk about those things, and find out what the best thing is, but as an early carers teacher you just got to know that stuff … because you're going to teach a class in an hour and need to know what you're doing.*

When training, as an RSC scholar, T2 valued RSC support for his development, particularly face to face networking, and resources that presented: "… *options of what to do in the classroom*". T5, an experienced teacher, was enthusiastic about the RSC website, free resources and CPD.

The Wellcome Genome Campus, the Science and Plants for Schools initiative, University of Hertfordshire and the Association for Science Education (ASE) were also mentioned. Four teachers described attendance at the ASE annual science education conference as valuable in their training or first year of teaching. T6 explained:

> *It would be great to go to the ASE conference that's on in January every year, but I asked the school and they can't afford for me to go, which is a shame. I did go to an Association of Science Education conference at the end of my PGCE year, once I'd finished training and that was really good. I thought it was great, actually. I can definitely see how it would be useful CPD, especially to a young career teacher.*

T1 sees the benefit of the ASE conference as having a wealth of choices. T2 during his NQT year attended ASE conference for a day:

> *That is super useful … I went to a couple of sessions that were just for me and a couple of sessions that were for the department. We feed-back and then now every year we try and do that, to send people and say 'Look as a department we'd like you to go to this thing, but the rest of the day is yours, go and see what you want'.*

T6 and T7 identify the lack of biology CPD compared to chemistry and physics, which T6 finds dispiriting not least because: "*A lot of biology could be better taught*". She observes:

> *… more of a discussion going on around physics education. I actually think there's a huge disparity between the amount of physics CPD there is and the amount of biology specific CPD there is. I find that quite dispiriting, actually, because it's taking it for granted that physics isn't particularly well taught in schools, but actually I think a lot of biology could be taught a lot better in schools as well. As a biology teacher, predominantly, I find that quite irritating in some respects, that there's a lot of focus on physics and actually, we could be talking about biology as well at the same time. They're very different, I think, so it would be nice to see more biology.*

6.4 Science teachers and curriculum

Subject identity

Insight to teachers' subject identity emerged during interviews, as teachers described their CPD experiences and ways that CPD linked to their practice. Identity wasn't simply linked to subject background. T1 explained that she taught across the science curriculum and didn't teach A level for the first 15 years of her career: *"… and so I've always seen myself as a science teacher*" rather than a biology teacher. T3 teaches across key stage 3 and chemistry and biology at key stage 4 but has found that she tends to: "… *get pigeonholed into the biology*". The teachers seemed to be

comfortable teaching outside their subject specialism, and some enjoyed doing so at key stage 4. T7, a biologist, explained that: "*I think I'm probably a slightly better teacher in chemistry because you have to follow the rules about more in chemistry. In biology I just get carried away*". While teachers at T2's school teach across subjects at key stage 3, and usually their specialist subjects at key stage 4, the school is supportive if they wish to teach another subject. On this basis, T2 recently taught physics at GSCE. T5 pointed out that departmental culture can influence expectations and response to teaching across science subjects. In her previous school this had been the norm, whilst at her current school staff are reluctant to do so – the culture is to teach within specialism.

Teaching outside their own subject was most challenging in early stages of teaching, when support from colleagues was particularly valuable. T6 suggested that this is because:

> *It can just feel very shaky. Kind of, 'Oh I've got to do this, and I don't know' and maybe just to have somewhere that is, for early career teachers to be able to share ideas or to talk about different approaches and stuff like that*.

Science teaching

Interviews provided insight to teachers' professional development at different stages in their teaching careers. T4 reflected on his professional growth:

> *My first year of teaching was a blur and I wasn't very good at it. My second year I found what I liked to do and I was actually pretty good, and then everything changed. My head of department left and the school said, 'Can you do it?'. It was a huge responsibility, I had a big crisis of confidence and then I thought I'm just going to do what I'm doing correctly and then to hear from other people who also said, 'I don't know what I'm doing'. They found confidence in it as well. If made me a lot more stable in my thoughts.*

T6, in her second year of teaching when interviewed, also provided insight to what it feels like to be an early career teacher:

> *It's just super useful as an early career teacher, just to have something there that is concrete and I know it's important to debate those things and talk about those things, and find out what the best thing is, but as an early carers teacher you just got to know that stuff … because you're going to teach a class in an hour and need to know what you're doing*.

Experienced heads of subject observed that initial teacher education varies between different providers, and that this influences newly qualified teachers' preparedness for subject teaching. T4 was concerned that two local initial teacher education (ITE) providers: *"… both give utterly different experiences to trainees".* T6 explained that she valued the opportunity during her initial teacher education to teach outside her subject. However, interviewees' accounts suggested that this isn't always part of the ITE experience. The importance of subject support during the newly qualified and early career phase was agreed, yet schools' support programmes were perceived and experienced as generic rather than subject focused. T2's NQT year was: "… *a bespoke programme from the school on just general NQT stuff like dealing with parents*". The programme at T5's school focuses on behaviour management.

T4 sees himself as: "*Having taught for so long …*" after seven years in the profession - perhaps an indication of the current retention situation, as was his promotion to act as head of science after 3 years' teaching. T1 and T5 are the longest serving of those interviewed and still relish learning opportunities. T5 describes herself as having good subject knowledge and: "*… still learning, trying things out and trying to improve teaching*".

Teachers described how different motivations and ambition influence their CPD interests and values. Participation in CPD is important to T1:

> *I didn't have this drive to become a senior leader, but I did have a drive to want to keep learning about education and science. Being part of research projects within science has enabled me to do that.*

T6 is interested in becoming an educational researcher. T7 sought the role of head of biology, which she now holds. She attends CPD about her subject, believing that students are easier to teach if they are interested in biology:

> *I care an awful lot more about the kids and what happens in the classroom. I came into being a teacher because I love my subject and I love being able to help some others with my subject. I didn't come into teaching because I love teaching. I think you get the two sorts of teacher. I love my subject and I love enthusing others and by tweaking a few things I can gain that … and that's what I care more about*

Some teachers linked their preferred way of learning to their background as scientists. T1 commented: "*We are scientists. We are curious about the world*". She reasons that she enjoys research – based development projects because she is a scientist. T3 facilitated a course for science teachers: "*It was kinaesthetic, if you're going to have CPD for science teachers you have to get them to do stuff* …". T6 linked her background as a research scientist with her interest in educational research and her belief in research-based teaching practice.

Interviews provided glimpses of teachers' beliefs – particularly about practical work and the nature of science. For T7: "*Engagement matters more to me than anything else";* T6 believes that school science should reflect the nature of science, including practical, questioning skills; T1 wants to: "… *give students of all abilities appreciation that science is relevant to their lives*". There were some examples of practice changing through experience and CPD, but no indication of changing beliefs. Notwithstanding the significant impact of public examination requirements, particularly in relation to assessment of practical work, teachers' practice seemed to develop mainly through refining tried and tested approaches or using new resources.

The science curriculum

When asked about the possibility of links between CPD and curriculum change, two teachers suggested that IoP and RSC CPD has curriculum implications through the resources and conceptual frameworks provided. Otherwise, teachers described examples of curriculum change driven by external and school factors rather than CPD. T1 reflected:

> *I was trying to work out the other day, and I still didn't get there, how many different GCSE syllabuses I have taught in the time I've been teaching … I think I got to about 12 … OK the science is the science is the science, but the emphasis changes each time.*

The curriculum influence of examination syllabi and associated methods of assessment, particularly of practical work, were described. T6 is concerned that this leads to too much emphasis on content and the impact on practical work was agreed by all. T1 identifies the benefit of required practials in setting a minimum requirement

for practical work. T7 regrets that GCSE doesn't address understanding scientific skills well and that the biology curriculum is compartmentalised, rather than enabling students to see the big picture.

Some curriculum change arises from within schools. T4 regretted that at his school:

> *We've changed our key stage 3 curriculum six times in seven years … there's no evidence or proof that what we've done is correct. We've picked up the slack at certain points, and everyone's done different training courses, and we've all done different things. We've shared that knowledge and picked the best points out of all of it.*

T4 describes his department as the most stable in the school, yet: "… *changes in departmental leadership, whole-school foci, such as literacy, and changes in national curriculum and examination syllabuses*" have led to the continuous change.

As with other interviewees, T4 didn't perceive that CPD was promoting a particular science curriculum or way of teaching science. He would welcome external curriculum leadership:

> *There's so many different leaders in science, the local authority, headteachers, science specialisms, subject specialists, training courses in different parts of the country and it's great because we get to go on loads, but there's not that tree, that authority at the top that says, 'This is what we need to do and this is how we need to train teachers, and this is where we should be leading teachers on the teach' or whatever. There's no one at the top, I guess.*

6.5 Summary

Teachers' accounts suggested that their practice develops through: gradual gains in experience and confidence in their early years of teaching; exchange with other practitioners; trying out and modifying approaches that were commended to them; and responses to external curriculum changes – particularly public examination syllabuses. They described different experiences of CPD and different needs – although teaching outside specialist subjects in the early career stage, and assessment of practical work for public examinations were most often mentioned. Immediate relevance to classroom practice, credible CPD facilitators (usually current science teachers) and sharing practice were valued. School constraints to

participating in CPD were in some cases linked to local workforce issues, such as cover for examination classes.

Teachers didn't convey knowledge of national science CPD programmes or infrastructures for their delivery. Interviews provided insight into teachers' identities, ambitions and professional growth. There wasn't any indication that teachers perceived that science CPD was promoting particular policies for science teaching, learning or curriculum. The early career phase was consistently suggested as key to successful science teaching. Some teachers' accounts appeared contradictory as they described how CPD addressed their different needs and interests. For example, one teacher enjoyed the long-term challenge of undertaking research, and also welcomed PowerPoint 'take-aways' from courses.

Policy influencers', local CPD providers' and teachers' perspectives, which are presented separately in Chapters 4, 5, and 6, are the basis for interpreting my findings in the next chapter, to bring together my answers to my research questions.

Chapter 7 Data interpretation

At its simplest, CPD for secondary science teachers is concerned with improving the quality of science teaching. My research questions focus on policy for CPD and ways that policy is enacted and experienced. A simple representation of the environment for secondary science teacher CPD in England might be a linear sequence in which policy for science teacher CPD is formulated, then enacted, leading to subsequent, desired changes in teachers' practice. Within this, the three groups of interviewees might be considered as occupying different niches in the sequence: with policy position holders influencing CPD policy, local providers enacting policy and teachers experiencing CPD. Research findings, however, suggest that the environment for science teacher CPD is complex, with varied ambitions, drivers and constraints shaping policy development and implementation, and teachers' participation. Distinguishing between policy position holders, local providers and teachers is a helpful means of organising data; however, the three niches are neither distinct nor uniform, nor do they represent the breadth of influencing niches and factors within the landscape. Bowe, Ball and Gold (1992) identified, in a cross-sectional study, the contexts of influence, policy text production and practice. Referring to these three contexts, Ball (1993, p.16) explained that: "Each arena involves struggle, compromise and 'ad hocery'. They are loosely coupled and there is not a simple flow of information between them". This kind of complexity, within and between tiers of the environment for secondary science CPD is reflected in my study.

I started my research with the assumption that national policy or policies for science teacher CPD were more tangible than I found to be the case as research proceeded. During field work and data analysis phases of my research, which were interwoven rather than distinct, it became clear that national policy for science teacher CPD was an elusive concept and that complex policy interactions and interpretations intertwined at different niches in the environment for science teacher CPD.

In this chapter, my research findings are interpreted by drawing on literature perspectives on teacher change and CPD, science education and education policy more generally: areas which are usually considered separately in the literature and which, of the breadth of literature initially reviewed, were most useful and are drawn on in more detail than when introduced in Chapter 2. My findings suggest that these are interwoven dimensions of the environment for secondary science teachers' CPD. Each research question is considered in a separate section.

7.1 What is the basis for current policy for continuing professional development of secondary science teachers in England?

The policy landscape

My research set out to explore ways in which national policy for science CPD is developed, interpreted and experienced. I began by interviewing people in positions of potential influence on government policy from organisations with a track record of engaging with science education, including CPD. As research proceeded and national policy became increasingly elusive, it was tempting at times to search further for it by carrying out more interviews.

To reflect emerging findings more realistically about the role of individuals and stakeholder organisations, I changed terminology from policy makers, the term I originally used in my research proposal and invitations to take part in research, to policy influencers. All interviewees believed that CPD is a good thing. Some of their organisations have stated policies for science teacher CPD, others do not. Their rationales for advocating science CPD included the needs of future citizens, promoting public health, science teacher recruitment and retention and the pipeline of scientists and engineers. Behind the consensus about the value of science teacher by policy influencer interviewees and organisations, I found that policy for science CPD is not a single entity and came to recognise the complex social, political, cultural and historical processes and influences (Adams, 2014) on policy for science CPD.

Government allocates significant funding for CPD for science teachers on the basis that this will contribute to increased economic growth and competitiveness. Its role

is a commissioning and monitoring one, historically reflecting decreasing central influence and increasing privatisation and commercialisation (Ball, 2007). This leaves open the possibility of public, private and philanthropic influence and involvement in policy discourse and enactment across the environment (Lingard and Sellar, 2013), as was indeed evident in the nature and role of stakeholder organisations in my research.

The policy landscape is messy. Fractured internal communication and lack of internal coherence within stakeholder organisations and government appeared to contribute to this. For example, when different teams within an organisation work on CPD and curriculum. As someone working in the field, I was surprised that policy influencers' commitment to CPD wasn't always associated with beliefs about effective teaching and learning in science or teacher change: it wasn't clear what CPD was aiming for, or how. Rather, in many cases, it was simply seen as 'a good thing'.

Some stakeholders, perhaps as a means of influencing government, argued the case for subject CPD on the basis of market forces and cost-benefit analysis (Apple, 2005): the cost related to initial teacher education, and the benefit was through the impact on CPD on teacher retention. While some interviewees, particularly those with teaching backgrounds, held views about the nature of CPD, the science curriculum and teacher professionalism, these were not always reflected in organisational policy rationales for CPD as described by interviewees or in organisations' stated policies.

My experience and research suggest that there is a small close-knit group of influential STEM stakeholder organisations, although they don't always convey a sense of core or shared values. Falk et al. (2015) describe the UK science education community as highly connected and collaborative, though schools and, to a lesser degree, higher education institutions are seen as outliers. Commercial dimensions of the landscape and accountabilities were not considered by Falk et al. yet these are significant, and the school-led nature of the education context has further developed since their study was undertaken. My research findings, taking a different perspective, suggest the centrality of schools' influence on the landscape for science

education as providers, gatekeepers and contexts for teacher change and raises questions about policy influencers' relative positions.

The policy cycle

The policy cycle (Ball, 1993; Bowe et al., 2017)) is a useful framework for interpreting my findings about the policy environment for CPD for science teachers. It proposes a model for considering the way that different players in the environment, in this case in this case policy influencers, local providers and teachers, interact with each other and policy as it is translated into practice. Bowe et al. (2017) describe a cycle of policy influence, text, practice, outcomes and political activity, each a context characterised by discourse that shapes policy in relation to the overall environment being considered – in this case, the environment for science CPD.

In the context of influence, key policy concepts are established through discussion between different interest groups. In my study, an over-riding policy concept agreed by the policy-influencing stakeholders and supported through government investment is that CPD for science teachers is valuable. Some policy influencers strongly asserted the importance of CPD to science teacher recruitment and retention. Another prominent policy concept was CPD for subject teaching. Policy concepts linked to young people's experiences of school science were less often associated with CPD, although their entitlement to a well-qualified subject teacher emerged as a policy theme linked to teacher recruitment and retention.

The policy discourse between stakeholders and with government does not appear to be concerned with characteristics of effective science teaching nor with the nature of students' experiences. Rather, neoliberal aligned discourse (Bottery and Wright, 2006; Whitty, 2008) is embedded in policies and reflected in policy-influencing approaches.

Interviewees described pragmatic approaches to influencing government. Pragmatic, in the everyday sense of the term, in that their approach is common-sensical, rather than theorised, based on what has proved to work previously in particular circumstances, for example to take account of changes in the civil servants or through

shared vocabulary. Economic arguments prevail in policy influence: value for money, efficiency and cost-benefit arguments are both a pragmatic basis for influencing government (seen as the policy makers) and a rationale for provision of CPD. In this interpretation, CPD is a commodity: an investment or policy solution with measurable economic outcomes (Watson and Michael, 2016; Apple, 2018; McGregor, 2018). Linked to this, influencing approaches included: the use of economic comparisons; large data sets; workforce data as drivers and measures of success; and student data such as more students taught by qualified teachers and more students studying triple science. Broader student outcomes were less frequently described as influential in CPD policy development – although some stakeholder organisations were concerned with citizenship outcomes and employment opportunities.

In the context of policy text production (Ball, 1993; Bowe et al.,2017), formal policies and organisations' stated commitments and commentaries represent policy. In the case of CPD for science teachers, for example, government policies, invitations to tender for delivery of CPD programmes and stakeholder organisations' websites convey policy about science teacher CPD. Many are concerned with CPD as solutions to problems, for example to train more chemistry or physics teachers to solve the problem of lack of suitably qualified teachers, rather than the nature of CPD.

Ball (1993) envisages the context of practice as where policy is enacted and interpreted. There are different contexts of practice in the environment for science CPD. Some policy influencers are funded by government to deliver national programmes for science CPD. This might be through their own infrastructures; or through sub-contracting arrangements with schools to deliver local programmes of CPD. This reflects another government policy, for school-led improvement (Whitty, 2008; Ball, 2015; McGregor, 2018). In both scenarios, policy enactment is based on contractual arrangements in which CPD is marketized, featuring as a commodity within policy discourse that is concerned with performativity and managerial accountability.

As is explained in more detail later in this chapter (Section 7.3), teachers' practices and their opportunities for and participation in CPD are influenced by a variety of

policy texts. For example, government policy texts for teachers' standards (DfE, 2011) and the generic DfE standard for professional development (DfE, 2016) are relevant, as are the policy texts of examination boards.

In the context of policy outcomes (Ball, 1993) for science teacher CPD, measurable outcomes for the state, for example more specialist teachers, are more frequently described than outcomes for individuals, such as improved individual science teaching practice. This reflects both the managerial context as well as the lack of detail in policy texts about the nature of science teaching or about the nature of effective CPD.

The pathway from policy to intended outcomes in not straightforward. The triple science support programme offers schools CPD (courses, networks, consultancy and support) and resources in support of government policy to increase the number of young people studying triple science at GCSE. This incentivised policy linking curriculum and CPD was introduced in 2008 when access to triple science became an entitlement for high attaining students. Since then, the target cohort has broadened. Archer et al. (2016) describe unintended consequences from this policy which was introduced in an attempt to solve economic problem of too few scientists and engineers. It appears that inequalities in provision between schools and access by students, and perceptions by some students that science is a route for 'clever' students and not for them, mitigates against increase in the supply of scientists and exacerbates inequality.

Ball (1993) describes the context of political strategy as the place where activities are identified which might tackle problems or inequalities. Inequalities in access by young people to qualified physics teachers and uneven access to CPD by science teachers were described during field work. The former is addressed through policy for CPD to train non-specialists to teach physics. The latter represents the dilemma encompassed in a national policy position which is concerned with the provision of science CPD but not teachers' participation.

The policy cycle provides a useful framework to conceptualise my research findings from a policy analysis perspective. The literature, however, suggests other ways that the basis for policy for CPD for science teachers might be considered. I was curious, for example, to understand how models of teacher change and effective CPD prevail.

Teacher change and CPD

Clarke and Hollingsworth (2002) identify different perspectives on teacher change which are a useful basis for interpreting my findings about the basis for policy on science teacher CPD. Their perspectives, of change – done to teachers, adaptation, personal development, local reform, systematic restructuring and growth or learning – might be seen as a connection between CPD and resultant teacher change. Some policy is based on CPD seen as training done to teachers, whose practice changes as a result, for example, CPD that involves training biologists to teach physics. CPD in support of the policy that more students should study triple science at GCSE is an example of teacher change as systematic restructuring, the basis being that teachers enact the change policies in the system. In these examples teacher change is concerned with the wider workforce rather than with individual outcomes. CPD for science teachers' individual growth and development, not specifically associated with a particular policy problem and in some cases proposed as an entitlement, was the basis for policy positions in which professional activity and participation in communities of practice are seen as valuable in their own right.

Policy-influencing organisations were supportive of subject CPD, in some cases seeing it as more effective than other CPD (cf. Cordingley et al., 2018). As is the case in the literature, there were different perspectives on what is meant by 'subject-specific'. Its purpose was clearest when concerned with subject knowledge and pedagogy for teachers outside their subject area – thus, workforce-focused (Connell et al., 2009).

Science learning and teaching

Perspectives on science learning, teaching and curriculum provide another lens to explore the basis for CPD for science teachers. I was interested to explore the possibility that science CPD might be linked to particular approaches as, for example,

was seen to be the case with the national science strategy, which between 2003 and 2011 provided local programmes of training for science teachers around frameworks for science teaching, learning and assessment.

I was surprised that, in most cases, policy-influencing organisations' perspectives on CPD weren't linked to perspectives on learning, teaching or the science curriculum, even though individuals themselves, particularly those who had previously been teachers, did convey a sense of belief about teaching and learning. It isn't the case, however, that organisations don't hold policy positions on these aspects of science education; many do, and some invest resource in researching and promoting them through different teams or projects.

Summary

Policy influencers see CPD for science teachers as worthwhile, although they hold different perspectives on its priorities, purpose and process. Much of the policy discourse is around managerial aspects of CPD provision and delivery and there is lack of clarity about the nature of CPD, how science teachers develop, or what effective science teaching looks like in terms of subject pedagogy. Physics most often features in policy discourse, and biology was not suggested as doing so.

7.2 How is policy for continuing professional development for science teachers enacted?

Context

Local science CPD providers operate in a complex landscape. They enact policy, making decisions about local science CPD provision (Ball, 2011). Their agency and autonomy are conditional – tempered by managerial accountabilities and targets. Their decisions are informed by professional experience and knowledge of the local subject and education landscape, resources and relationships.

The local providers exemplify the government policy ambition for school leadership within a self-improving system (Hargreaves, 2010, 2012). They are part of a national structural framework for CPD delivery intended to facilitate sharing of ideas between

schools and local solutions. The two provider schools in my study had previously been designated as specialist science colleges, and the third local provider was a college that collaborated closely with a specialist science college, also now an SLP. They illustrate the enduring legacy of the specialist school movement. The schools' history, values and material dimensions contributed to the system leadership role (Ball et al., 2011) and there was integrity and coherence about the niche they fulfilled in the landscape. The providers hold knowledge of local needs and relationships with school leaders and teachers – seen as important aspects of system leadership.

School leadership is key in the literature about system leadership and a self-improving system (Eardley, 2017; Woods et al., 2020). This was the case in my study: leaders' vision was identified as important in relation to the institutions' roles in science CPD delivery. Each institution fulfils other roles in STEM (for example, as maths or computing hubs) and more generally, for example as a teaching school or regional STEM centre. Institutional leaders were seen as supportive but were not actively engaged. The science CPD leads are less senior in institutional hierarchies, perhaps reflecting separation between the operation of science CPD delivery and wider school activity. In effect, science CPD is provided through separate business units – albeit with aims that supported wider school ambition as system leaders as the enactment of CPD policy intersects with enactment of other national and school policies. This scenario is one that I recognise: the Centre for STEM Education operates as a business unit within the School of Education at the University of Hertfordshire. As with the local providers, mutually beneficial ambition and activity are tempered by commercial imperatives.

At the tier of CPD delivery, where policy for CPD is enacted in a domain of practice (Ball, 1993), operational marketisation of CPD was most evident (Connell et al., 2009; Watson and Michael, 2015). Local providers referred to courses and CPD interchangeably. Managerial performance indicators (number of courses provided, number of teachers that participate, number of schools reached, amount of income generated) are important drivers. Local provision changes in response to policy and contractual changes, with value for money considerations influential (Apple, 2018).

For example, while courses linked to public examinations were likely to recruit and consistently featured in CPD schedules, other courses less likely to recruit, for example concerned with science leadership or key stage 3, were not provided, even if identified as much needed. Managerial influences could also be beneficial, however. In striving to attain targets for reach to schools and individual teachers, local providers are entrepreneurial, implementing creative ways of engaging more science teachers in CPD.

Local providers are pragmatic in enacting policy. CPD provision is shaped to meet success criteria and based on what was known to recruit. The timing, cost and focus of CPD are adjusted to maximise participation within budgetary constraints. In one example, it was difficult not to envisage a 'pile them high and sell them cheap' approach to meeting CPD targets. That's not to say that the providers don't operate with integrity: they know local schools and want to meet their needs. When speaking as educators rather than market providers or project managers, they conveyed a sense of compassion, understanding and wanting to make a difference. Lead teachers navigated different roles within the environment – teacher, entrepreneur and in some cases more. For example, the role of teaching school senior leader involves additional responsibilities and different accountabilities. Their science teacher professional compass (Brooks, 2016) steers the entrepreneur role for those with science teaching backgrounds – it is informed by beliefs about science teaching.

Local CPD provision operates in a marketplace in which the schools compete with other providers (Morgan and Kirby, 2016). DfE funding for their provision was seen by local providers to add credibility, as were links with key stakeholders such as the Royal Society of Chemistry and the Institute of Physics: both organisations were well regarded by teachers. The local providers facilitate connectivity between initiatives and with other local providers. In doing so they assist science teachers to navigate the plethora of STEM initiatives on offer.

Local providers understood the wider opportunities of the environment for science teacher CPD as well as local barriers to teacher engagement including: financial constraints, loyalty of examination teachers to their classes; limited departmental

time; and the impact of uneven recruitment and retention. They recognised the needs of early career teachers and inexperienced department leaders.

Teacher change and CPD

Local providers' perspectives on teacher change, based on Clarke and Hollingsworth's (2002) framework, include: training done to teachers, for example, subject specialism courses; change as adaptation, when teachers adapt their practice in response to changed conditions such as new examination syllabuses; change as systematic reform – such as the triple science support programme; and change as growth or learning through local networks and communities of practice. The range is broader than the more restricted examples of CPD described by policy influencers.

The providers recognised the importance to teachers' development of CPD focusing on specific aspects of subject knowledge and pedagogy (Schulman, 1987) and the provision of opportunities for teachers to sharing practice and ideas. Kennedy et al. (2016) argue the importance of clarifying the problems of practice that CPD aims to inform and the pedagogy (of professional change) used to facilitate enactment of new practice introduced through CPD. Perhaps unsurprisingly, local CPD programmes addressed problems of subject practice as distinct from student behaviour, participation or students' thinking and learning – the other areas suggested by Kennedy (ibid) that CPD might address. Public examinations rather than particular curriculum models or teaching and learning approaches influenced the content of CPD.

Subject-focused courses were envisaged as supporting teachers in teaching their specialist subject at GCSE and A level, as well as teaching outside their subject specialism, again a broader perspective than held by some policy influencers. The pedagogy of much CPD (Kennedy et al., 2016) was prescription of classroom approaches, particularly when CPD sessions were short twilight, lunchtime or conference workshops that provide take-aways for immediate classroom implementation or exam or Ofsted tips. Longer CPD sessions and on-going programmes were more likely to be characterised by goals that teachers should aim

for and rationales for possible approaches to do so. Some approaches, such as coaching, were seen by local providers as valuable but outside the remit of funded programmes.

The DfE standard for teachers' professional development (DfE, 2016) and meta-analysis of the literature on effective CPD (Cordingley et al., 2018) identify characteristics key to effective CPD. As with policy influencers, the standard was not evident in local providers' accounts – perhaps either not considered or over-ridden by pragmatic considerations. In line with the standard, credible facilitators were seen as key to the effectiveness of CPD: their CPD facilitation skills evidenced by a quality mark and expertise, and recent or current classroom experience. (Cordingley et al., 2015).

The government-funded triple science support and government- and industry-supported Enthuse programmes were more obviously in line with the CPD standard (DfE, 2016) and seen as more likely to lead to long-term impact and sustained teacher change. CPD in these projects is on-going over time, requires school leadership support for participation and builds in time for collaboration. It is worth noting that these projects, in which providers fulfil a much broader role than simple provision of courses, are focused on departments rather than individuals. Some address wider aspects of curriculum and student experience, such as science in industry, STEM careers and student engagement rather than one-off instances of subject CPD.

The local providers value different indicators of science CPD success to contractual ones, including relationships with and between science teachers, motivated science teachers, schools approaching them for advice, and repeat participation in courses. Some of these, such as long-term relationships, are in line with system leadership ambition but not reflected in CPD contractual performance indicators and in some cases are at odds with them. The local providers find tracking long-term teacher change through CPD challenging, even after sustained involvement, despite using varied approaches to do so, including gathering feedback on a range of aspects of individual and department practice, based on the evaluation framework proposed by Guskey (2000). Lack of evidence about impact of CPD makes it difficult for providers

to refine their offer to improve effectiveness; rather, in some cases, changes respond to performance indicators such as the number of teachers participating.

Summary

Local providers in my study occupy the 'context of practice' niche (Ball, 2002). Their decisions about CPD provision are influenced by managerial accountabilities and informed by professional experience and knowledge of subject and education landscapes. The local approaches to CPD provision are pragmatic and support enactment of other national policies, such as operating as a teaching school. The local providers believed that external funding is key to on-going science CPD provision.

It was difficult, on hearing the local providers' accounts, not to envisage them at the heart of the environment for science CPD and to be convinced about the centrality of their role in enacting national policy, far removed the outlier position described by Falk et al. (2015). Local prominence might well be the case when the CPD providers have established relationships with local schools and teachers, yet interviewee teachers' accounts of their experiences and understanding of the environment for CPD didn't suggest that this is always the case.

7.3 How do secondary science teachers experience the environment for continuing professional development?

Science teachers and science teaching

Teachers with between eighteen months and twenty-five years' experience, with different subject backgrounds and roles, variously described themselves as science teachers, biologists, chemists and members of a particular school staff: their identity was context-specific, socially constructed and multifaceted (Avraamidou, 2014). Subject identity influenced their choice of CPD which most often was concerned with teaching a particular subject to public examination level more effectively or enjoying a particular science subject. Teachers didn't suggest that they were reluctant to teach outside their specialisms. Rather, they accepted the need to do so and, in contrast to policy influencers, gave no sense that teaching outside subject specialisms was

detrimental to students even though they recognised the need to enhance their subject knowledge through CPD or peers.

Professionalism

The teachers said they were willing, not reluctant, to deal with change and didn't convey any particular sense of being weighed down by national policy for science education, with the exception of assessment requirements for external examinations. They came across as creative, able to navigate a complex landscape with managerial dimensions, ambitious for students and keen to participate in professional communities – demonstrating characteristics of democratic professionalism (Whitty, 2008). It wasn't evident that teachers felt empowered or de-professionalised through participation in CPD, or that they discerned that CPD was conveying particular teaching, learning or curriculum policy messages.

The literature about neoliberalism, managerial accountability and education policy during the early twenty-first century identifies limits to teacher autonomy and consequent detrimental impact on teachers' professionalism and the emergence of an acquiescent professional culture with teachers' work increasingly regulated (Bottery and Wright, 2000; Apple, 2005, 2018; Connell, 2009; Brooks, 2016). These observations apply workforce-wide. Individual teachers in this study didn't appear to be demoralised, although some expressed concerns about with the wider picture (cf. Bottery and Wright, 2000) as a result of national policies. However, notwithstanding the contested and theoretical basis of teacher professionalism (Whitty, 2008) the insights gained into their professional lives during this study didn't suggest that as individuals they felt de-professionalised or without agency. Teachers described examples of being responsive and pragmatic as well as principled and with agency, taking different individual positions within the structural and accountability dimensions of the environment and thus demonstrating features of hybridised professionalism (Noordegraaf, 2007, 2016).

Teachers' accounts suggested that they drew on different aspects of their professional identity in fulfilling different roles. Their relationships with schools and

their policies were more prominent in their accounts than relationships with the state and its polices, which features in the literature about professionalism. Concerns about the number of changes to their schools' key stage 3 curriculum, for example, or frustration that there was insufficient time to implement school agendas were illustrations of the importance of school-centred impacts on their professional activity and growth. There was little evidence of teachers' relationship with the teaching or science teaching profession as a whole, raising questions about the strength of their professional compasses (Brooks, 2016) and the implication for wider responses to the on-going changes in science education described in Chapter 1. Their accounts were 'point in time' and provide insight to what it meant to them to be a science teacher in 2020, with institutional influences rather than a collective science teacher identity conveyed. Indeed, some regretted the lack of external influence and national steer on science teaching, including local authorities and national strategies.

Teacher change

Teachers described ways in which their practice developed, including but not exclusively through CPD. Bell and Gilbert (1994, 2004) and Clarke and Hollingsworth (2002) conceptualise models that are useful to interpret teachers' perspectives.

As discussed in Chapter 2, Bell and Gilbert (1994, 2004) suggest three intertwined strands of teacher professional development: personal, social and professional, which prevail in different phases of teacher experience as they enter into initial teacher education, begin work as science teachers and subsequently gain experience. Whilst not distinct they are recognisable in teachers' accounts and relevant to their experience of CPD, as were ways in which social, personal and professional development were facilitated by school and external CPD.

Bell and Gilbert's (1994) model identifies initial teacher education as the first phase of teacher development with important personal, social and professional dimensions related to subject teaching, identity and growth. In the light of policy influencers', local providers' and teachers' concerns about the extent of subject focus and provision in initial teacher education, it is interesting to ponder whether some of the

growth Bell and Gilbert describe is displaced into the early years of teaching, with implications for CPD that might helpfully support this phase. Challenging aspects of early years of teaching, as well as general aspects of confidence, were described as teaching A level and teaching outside their subject specialism. In this phase, teachers were open to trying out new ideas and drew on science teacher colleagues constructively: social development within schools was seen as important in the development of teaching practice. As teachers gained experience, and moved into the next phase of development, external CPD provided ideas for classroom practice as well as further supporting social development.

Some teachers had taken on particular professional development challenges – for example, research projects, collaborative work with colleagues from other schools or a master's degree, illustrating Bell and Gilbert's third phase by seeking new challenges, addressing personal concerns and interests. Teachers suggested, however, that school priorities and constraints, as well as personal ones such as time limitations, mitigated against this type of professional development.

Bell and Gilbert's (1994) model describes individual dimensions of teacher development, albeit with social dimensions. Clarke and Hollingsworth's (2002) perspectives, as described in Section 7.2 link different types of teacher change to CPD. Practice change as adaptation was an overriding purpose for teachers' participation in CPD, for example, CPD that led to changes in practice in response to new syllabus requirements. Some teachers described how they learnt, or their practice changed, through professional activity, particularly membership of a professional community. External CPD, for example, provides access to other teachers which is much valued by teachers, even though change in practice is situated in the school context.

Some teachers' practice changed through personal development, for example, by gaining additional skills to teach an area new to them, as described by T4, who valued CPD on biotechnology, which he draws on when teaching A level biology. There were fewer examples of change as local reform, when teachers made choices for personal growth, such as by pursuing master's degrees. This conception is congruent with Bell

and Gilbert's (1994) third phase of professional growth and, as described above, resource constraints had impact. None of the teachers described examples of changes in practice associated with systematic restructuring – the perspective strongly held by policy influencers in relation to CPD to improve subject teaching.

Social interaction was a reason for teachers' participation in science CPD as well an influence on their practice. They valued sharing interests, information and practice with other teachers, although their interactions tended to be more transient than described by Wenger (1998) as characterising communities of practice. Even when short-term, though, teachers described the gains in support and agency through social interactions within communities, possibly reinforcing their subject identity (Brooks, 2016). School-based communities of practice, for example a science department or the school staff in relation to a shared CPD focus, were described as more sustained learning communities – yet school CPD was rarely valued as much as subject CPD.

Gilbert (2010) suggests the importance of science teachers understanding their own progression and areas for development. The reality described by teachers in this study is more pragmatic and influenced by responses to opportunities and constraints, rather than teachers pursuing planned, personalised pathways. Teacher development and growth was non-linear, and dependent on individual and institutional influences, with the early career phase particularly significant.

CPD

Teachers' engagement in CPD is ad hoc. They described experiences of a broad variety of CPD activities, most of which were one-off instances of external CPD, that didn't reflect the DfE standard for teacher professional development (DfE, 2016). Their CPD experience was characterised by lack of coherence and was messier than in many of the empirical studies from which characteristics of effective CPD are identified.

Immediate relevance to classroom practice, credible course leaders and sharing subject knowledge and pedagogy are important. Teachers look out for courses

related to GCSE and A level examination syllabuses and assessment. As well as finding these helpful in support of their ambition for students, this type of CPD is more likely to be supported by school leaders – a pragmatic consideration. Local providers, recognising that these courses are likely to recruit well, run more of them, illustrating a cycle of reinforcement that narrows the CPD offer and aligns it with managerial dimensions of science education accountability and restricted professionalism (Hoyle, 1974).

Teachers most often referred to CPD in term of students' success in examinations. Students' enjoyment of subjects is key to teachers, but not often linked to CPD in their accounts, illustrating a mismatch between the managerial indicators of CPD success and teachers' ambition for more young people to enjoy and achieve in science subjects. Teachers didn't refer to CPD in terms of personal career ambition. They described ways in which formal, planned CPD (Fraser, 2007) was valuable, often because of the information provided, as well as access to other science teachers or role occupants such as the head of science. As explained in Section 6.3 informal and incidental CPD (Fraser, 2007) was powerful in teachers' accounts and key to development and growth in role, and this was particularly in the early years of teaching. Subject specialism training – for teachers to teach outside their specialist subject – was much less prominent in teachers' accounts than policy influencers'.

Teachers receive vast amounts of literature and emails marketing CPD, evidence of the marketplace described in the literature (Morgan and Kirby, 2016) and by local providers. I was interested that teachers were unaware of who science providers are and I reflected on the time spent in my own organisation considering the implications of competition or collaboration with other providers – the attention paid to branding, marketing, badging and organisation or programme logos, including those that are government-funded. It appeared that these are backstage considerations rather than front of house. One teacher had attended a flagship CPD programme run by the UH Centre for STEM Education, yet was hazy about who provided it. Vague references to STEM, STEMNET, STEM Learning, York (the location of the national STEM centre) and York University reflected a general lack of clear understanding of the infrastructure

for science CPD provision. Only one teacher mentioned a local CPD provider – although she didn't suggest that it was part of a wider network. Kennedy (2016) describes the need for professional development that prompts real learning to avoid the possibility that CPD adds to the noise in the environment for teachers. Teachers and local providers described the considerable noise in the marketplace for science CPD, with a resulting lack of clarity about the infrastructure or opportunities it presents.

The teachers conveyed a sense of commitment to students that transcends institutional and external influences. Yet their core beliefs and ways that CPD influenced these weren't always evident. T1 through research projects and T6 through a master's degree had pursued CPD which offered reflective opportunities and research engagement. However, few other opportunities were described for teachers to reflect through school or external CPD on their values or beliefs – both seen in literature as key to agency and shaping their professional life.

Context

Schools are the immediate change environment for teachers (Clarke and Hollingsworth, 2002) and are central to teachers' experiences of the environment for science CPD. Their influence is both practical, for example on access to CPD, and cultural, for example through the situated characteristics in which teacher growth occurs (Clarke and Hollingsworth, 2002; Bell and Gilbert, 2004; Hewson, 2013).

Clarke and Hollingsworth (2002) envisage that teachers' practice changes through mediating processes of enactment and reflection in personal, practice, consequence and external domains, with the school as the change environment for this (Figure 7.1).

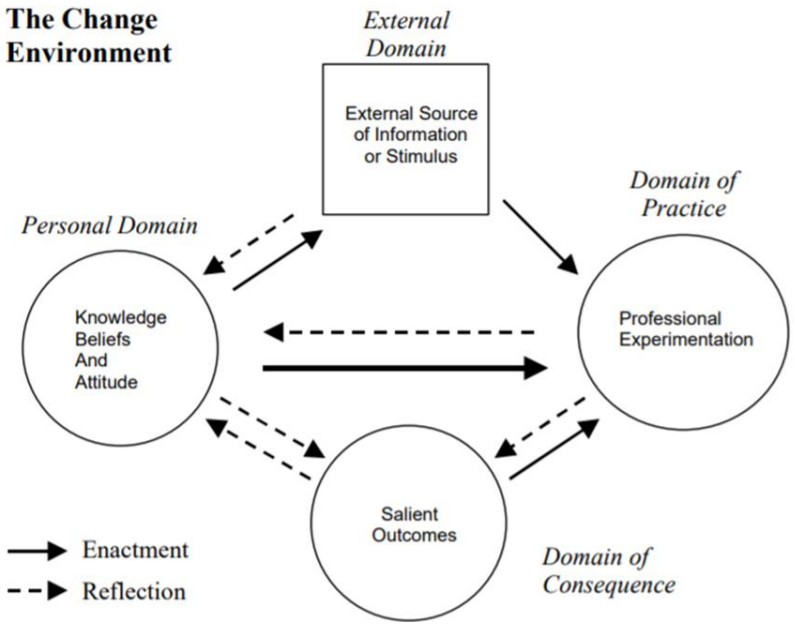

Figure 7.1. The interconnected model for teacher development (Clarke and Hollingsworth, 2002)

The impact of schools as change environments was most often constraining. Resource constraints meant that access to external stimuli, such as science CPD, was restricted. It varied between schools, although some barriers were common. Teachers didn't suggest that science CPD is favoured by their schools more or less than other subjects, even though government prioritises science CPD above many other subjects, illustrating a possible mismatch between national and school policies. Workforce issues impacted on individual opportunities. In some cases, science teachers suggested that teaching examination classes is a constraint to participation in external CPD. In others, the lack of colleagues who were specialist subject teachers impacted on dialogue and informal learning.

Some aspects of the external environment were described as particularly influential, for example, those associated with accountability. CPD linked to examination requirements, in the external domain, permeated the boundary between school and external environment: external sources of information were much sought. Others, for example relating to key stage 3 teaching, were much likely to do so. External science CPD provides information or stimulus. According to Clarke and Hollingsworth's model, teacher change is dependent on conditions within schools to enact and experiment in the classroom and to reflect on consequent changes. In

many cases, teachers described one-off CPD events and valued top tips that they could implement immediately. The absence of on-going experimentation and reflection on practice and consequent changes in student outcomes suggests that the long-term impact of this CPD could well be limited. In the same way, schools' own generic CPD didn't maximise impact on changes in subject practice: teachers regretted the lack of time to enact and reflect with colleagues on the CPD theme or to experiment. When they did so, they described changes in practice. For example, T6 observed history teachers, tried out and subsequently implemented some of their approaches.

Linking the model with science teachers' knowledge base (Section 2.1), external sources of knowledge sought and gained through science CPD were most usually subject knowledge or pedagogical content knowledge (Schulman, 1987) related to external examination syllabuses. The changing nature of science and scientific developments are often argued by policy influencers as a rationale for policy for science CPD, yet fewer examples of such CPD were described by teachers. With regards to subject pedagogy, it appeared that ready-formed classroom approaches that teachers valued from CPD were implemented without professional experimentation or reflection, stages in the interconnected model that were either bypassed or not part of a CPD process, perhaps explaining why it was difficult to uncover examples of changes in teachers' beliefs through CPD. There is consensus in literature about limitations to the impact of CPD which is one-off (El Deghaidy et al., 2013; Cordingley et al., 2015). The reality for science teachers is that this kind of CPD is most available to them and is valued. Not all were interested or able to pursue longer-term programmes, which the literature suggests would be more likely to lead to changes in beliefs and sustained change.

Teachers' accounts gave insight to the 'real-time' nature of school environments and the fragility of the relationship between policy intention and enactment (Maguire et al. 2015). Teachers described ways in which the influence of changing day to day situations, unpredictable circumstances and uniquely personal factors influenced their experiences of CPD.

Summary

Science teachers' experience of CPD varies. They have different experiences and needs. Sharing practice with others, immediate classroom takeaways and direct relevant to public examinations are much valued. The school context is key to teachers' access and experience of CPD, and its impact. Informal support from within departments is particularly important in the early years of teaching. Time and, in some cases, staffing were a constraint on reflection and experimentation. Individual teachers recognise and navigate the constraints of school life and acknowledge the need to respond to change. External policy for science education and science CPD was not foregrounded in teachers' accounts.

7.4 Overview of the environment for secondary science teachers' CPD

Based on policy influencers', CPD providers' and practitioners' perspectives, my research findings suggest a landscape in which the basis for policy for science CPD is opaque and fragmented, with national policy much influenced by economic imperatives and solving problems related to national performance, such as increasing the number of physics teachers. Local CPD providers are subject to opportunities that arise from the school-led landscape and to constraints that are in part a consequence of the marketisation of CPD.

The environment is rich with CPD opportunities for science teachers, reflecting policy that supports such provision. The basis for this is influenced by pragmatic approaches by policy influencers and local providers, workforce characteristics, particularly the recruitment and retention of science teachers, and school accountabilities.

Within the complex education landscape, different policies intermesh around schools. Neoliberal policies position schools within a marketplace, with science CPD one of the commodities. Some schools, as local providers, enact contested interpretations of what CPD for secondary science teachers should comprise. All schools are central to science teachers' experience of and development through CPD.

In the next and final chapter, I consider the implications of my research for practice, reflect on limitations, improvements and possible next steps, and consider the implications of ways in which the environment CPD for science teachers is changing since my field work was undertaken.

Chapter 8 Conclusions and reflections

8.1 Conclusions

My research explores the environment for secondary science teacher CPD in England from different perspectives and provides insights into the relationships between policy, provision and participation.

My first research question asked about the basis for policy for CPD for science teachers. I found that national policy is opaque and fragmented. At its basis is a consistent policy concept that CPD for science teachers is valuable. Perspectives differ beyond this – for example, about the purpose of CPD. Some policy influencers take a workforce perspective on science teacher CPD, associated with national economic ambition and solving problems related to national performance. This presents a clear rationale to policy makers, with measurable impact. It leads to national focus on particular subjects, groups of teachers and key stages, for example, to increase the number of teachers who can teach physics. Other policy influencers take an individual teacher perspective, seeing the rationale for CPD as one of professional entitlement. The basis for policy influence is less tangible when this is the case. Some stakeholders see both as important rationales for CPD. Stakeholder commitment to CPD is not underpinned by effective approaches for teacher development nor set in a national policy framework for CPD entitlement. CPD is marketised within the policy for school-led, local delivery within national programmes, with implications for provision and participation.

My second research question was concerned with policy enactment by local CPD providers within national programmes. I found that teachers leading local science CPD respond to opportunities that arise from the school-led landscape and funded national CPD programmes, and navigate constraints that are a consequence of the marketisation of CPD. They are pragmatic and entrepreneurial in their approach to enacting policy and bring individual beliefs and experiences about teaching and learning to bear on their decisions about local provision.

My third research question asked about science teachers' experiences of the CPD environment. I found that school influences on participation and outcomes are significant, with examination-linked accountabilities influencing teachers' choices. Social aspects of CPD are important; however, there are limited opportunities during CPD or within the school environment for teachers to develop practice through reflection and experimentation.

Drawing perspectives together, it was evident that the environment for science teacher CPD looks different to different groups of interviewees, even though often described in literature as though it is a single entity. Policy for science CPD undoubtedly offers opportunities which are not available for many other school subjects; however, policy influencers', local providers and teachers described different priorities and purposes for CPD and different success measures.

The role of schools in determining access to CPD and providing environments for teacher development is often overlooked in policy and provision, with the result that teachers' overall CPD experiences are typically ad hoc rather than planned and coherent.

8.2 Implications for practice

My research findings suggest areas for consideration for policy influencers and CPD providers within national programmes, including the UH Centre for STEM Education. It appears that economic and workforce rationales for CPD lead to policy that focuses on: shortage subjects, such as physics; particular key stages, particularly public examination level; and CPD as a solution to specific problems. My research findings suggest that challenges for policy influencers are to: more clearly justify their commitment to CPD for all science teachers and the value of this; extend advocacy for CPD more broadly; and consider ways that policy influence might embrace the nature of CPD process and its outcomes.

Local providers operate in a marketised CPD environment. This leads to a restricted offer, which does not always meet local needs. The challenge for local providers is to

find ways of balancing contractual performance targets with provision that extends across age ranges and subjects and reflects characteristics of effective CPD including: credible facilitators with proven classroom experience; time for teachers to share practice; immediate classroom relevance; a focus beyond public examinations; and ways of embracing situated influences on teachers' development.

The key role of schools' role in determining access to CPD and providing contexts for teacher development is overlooked in policy influence and provision. To address this, policy influencers might consider ways of embracing school leaders' perspectives and encouraging their support for more coherent CPD experiences. Local providers, too, might consider ways to encourage school leaders' support for a broader science CPD offer and provision that embraces situated influences on teachers' development. Policy influencers and providers might consider ways that wider education policy developments, such as the early careers framework or proposed changes to initial teacher education, might enable teachers' participation in science CPD at and between different career stages to be more coherent and less ad hoc.

Table 8.1 shows how the areas for consideration that are suggested in this section address research findings.

Table 8.1: research findings and suggested areas for consideration by policy influencers and local providers

Finding	Suggested areas for consideration	
	Policy influencers	Local CPD providers
Influential stakeholders and government see science CPD as an economic and workforce solution – focusing policy on particular subjects, groups of teachers and success indicators.	Ways of extending the breadth of advocacy for CPD across age ranges and subjects.	Ways of extending the CPD offer across key stages and science subject specialisms.

There are potential tensions between workforce solution and CPD entitlement perspectives. The case for science CPD isn't always justified.	Ways of strengthening the rationale for science CPD, including as a professional entitlement for all science teachers.	
Much policy and provision for science CPD is not underpinned by: - perspectives on effective science teaching and learning; - models for teacher change or effective CPD approaches; - the DfE standard for professional development.	Ways that advocacy for science CPD might take account of effective approaches. Ways that policy influence for CPD might connect with stakeholders' positions on science learning and teaching.	Ways that provision is based on models for effective CPD and teacher development.
The role of schools in policy influence, determining access to CPD and providing environments for CPD is often overlooked in policy and provision.	Ways that school leaders might contribute to policy and ways the school landscape influences policy enactment.	Ways of working with and through schools to extend participation and maximise impact, for example, through opportunities to develop practice through experimentation and reflection during CPD and within school contexts.

Teachers' CPD experiences are ad hoc.	Ways of advocating the potential benefits of CPD in support of science teachers' continuous professional learning journey and exploring links with related policies, such as for initial teacher education and the early career framework.	Ways of connecting CPD provision with wider policy frameworks.
Teachers value social aspects of CPD, credible facilitators and immediate classroom relevance.		Provision characterised by: credible facilitators with proven classroom experience; time for teachers to share practice; immediate classroom relevance; time for experimentation and reflection.

8.3 Limitations and reflections on the research process

I carried out research with the science education community as an insider. As explored in Chapter 3, this presented both opportunities, such as access to research participants and rich conversations, and constraints, with possible influence on interviewees' accounts and potential bias. Interviewees' comments suggest that they perceived me in different roles depending on previous interactions and my organisational context.

As an insider, I bring to research my own views, with potential influence at each stage of my research. I became more aware of this possibility as research proceeded, and

in some cases my thinking changed. Burnard et al. (2018) describe intertwining identities, arguing that there is no clear boundary between insider and outsider research, rather a balancing act, an in-betweener identity that is fulfilled by researching professionals. I recognise the fluidity across identities that I brought to research and grappled with different ways of understanding my position in relation to people whom I interviewed.

I described in Chapter 3 how the epistemology, theoretical perspective, methodology and methods that underpinned my research informed each other. My research was based on a small sample – reflecting the constructivist ontology and time available. Participants' views were no less valid for this, however. They provided a lens through which to consider the environment and the small sample, which might be considered a limitation in a positivist study, was valid in relation to my stated approach. My field work commenced more than a year before writing this final chapter of my thesis. Fifteen months on, early interviews are both clear – I can recall specific phrases – and distant. Re-reading transcripts over time has been an important means of staying connected to interviewees' accounts. I notice, however, that over time as my thinking has developed, I have interpreted data somewhat differently.

Participant teachers were drawn from a restricted group. They are CPD believers or seekers (Wellcome Trust, 2006; Varga-Atkins et al., 2009) who believe in CPD and either had had good experiences or perhaps sought particular provision. My study didn't include teachers with other starting points, for example not believing in CPD or feeling less positive about its value; research participants were drawn from a restricted group.

My research coincided with the 2020-21 COVID-19 pandemic. As described in Chapter 3, this led to changes in my approach to field work, for example, using remote rather than face-to-face interviews. Whilst not necessarily a limitation, the response to the pandemic is likely to have long-lasting effects on education provision and CPD. I described in Chapter 1 how the way that science is perceived in society over time influences the school science curriculum (Millar and Osborne, 1998; Dillon and Manning, 2010). It will be interesting to track whether the high profile of science

during the pandemic, and particularly the biological sciences, has an impact on the place of science in the future school curriculum and the way that it is perceived by young people and wider society.

The response to the pandemic has changed the environment in other relevant ways including: how science is taught; the place and nature of practical work in remote or socially distanced schooling; and the way that attainment in science is assessed at ages 16 and 18. CPD for science teachers has transitioned to on-line, and CPD providers are learning about the opportunities and constraints of this. Changes such as this, and the influence of the pandemic on my own work and research circumstances, remind me that the perspectives gathered through research and my interpretation of them are subject to a myriad of influences prevailing at a particular time. My findings are a temporary settlement of knowledge. The environment that I explored is rapidly changing; knowledge arising from the research is limited by this as well as the research process and is influenced by my position within the changing environment (Shacklock and Smyth, 1998).

8.4 Suggestions for further research

Whilst some of the issues that I drew out from the literature reviewed in Chapter 2 are reflected in my findings, other literature perspectives were less evident. I had envisaged, for example, that my research would uncover richer data than was the case about ways that CPD policy and its enactment were underpinned by models of effective science teaching and effective CPD. It would be interesting to explore this gap.

Systemic and institutional perspectives of science teaching, learning and curriculum rarely surfaced during interviews, nor did consideration of how teachers develop their practice. Constructs of effective practice, be it for student or teacher development, when they did emerge, rested with individuals and varied. More granular research, particularly about individual teachers' development and experiences of CPD, which are often absent in research, could provide insight into how their beliefs, practice and professional identity develop.

My research took a broad look at the environment for science teacher CPD. In doing so it revealed some inconsistencies within and between tiers. The environment is complex and there is scope to learn more by taking a deeper look at the different tiers through gathering perspectives from: different policy-influencing STEM stakeholders, for example examination boards; other CPD providers, including ones that do not benefit from government-funded programmes; and science teachers less persuaded about subject CPD – the sceptics and agnostics (Wellcome Trust, 2007). Further exploration of interactions between tiers would extend understanding of the influences on CPD policy, provision and participation. The nature and influence of schools as contexts for subject professional development is a rich area for future research. Gathering school leaders' perspectives, would also be an interesting follow-up to my research findings.

Recent and forthcoming developments which are relevant to my research questions and findings include: changes in the architecture of the education environment with the introduction of teaching school hubs (DfE, 2020b); reduced government and stakeholder funding for national science CPD programmes from April 2021; the extension of induction and support of newly qualified teachers into their second year of teaching through an early career framework (DfE, 2019); a new suite of professional qualifications from 2021 (for example, DfE, 2020c); and the unknown future impact of the COVID-19 pandemic. It will be interesting to explore the interface of policies concerned with generic teacher development CPD with policies for science CPD as they are enacted.

As described earlier, the transition of CPD from face-to-face to remote delivery as a response to the COVID-19 pandemic is likely to have long-term implications for CPD pedagogy and the activity of local providers, bringing opportunities, for example more flexible timing and challenges such as building local networks in an open, online environment – another area for future research.

8.5 Final reflections on and from the research process

The first chapter of my thesis sets the scene and describes the rationale for my research into the environment for secondary science teachers' CPD as it relates to my professional experience and role, and the wider science education context. In Chapter 2 I explore literature perspectives on: ways that science teaching and science teacher effectiveness are envisaged and linked to the purposes of science education; ways that teacher development and effective CPD are understood; and dimensions and implications of the wider educational context for secondary science teaching. Each of these areas informed my research approach as outlined in Chapter 3 and provided perspectives that were helpful in providing a broad basis to locate my research and interpret my findings in Chapters 4, 5 and 6. I chose in Chapter 7 to draw on different models, perspectives and standpoints from the literature to conceptualise and interpret data. In this concluding chapter I have summarised my answers to my research questions, outlined opportunities and constraints arising from research as a researching professional (Burnard et al., 2018; Cunningham, 2018), suggested ways that my findings might impact on my practice, and proposed possible areas for consideration for wider policy, practice or research.

Through the process of research, I have refined my professional theories about CPD and the position of providers such as the UH Centre within a self-improving school-led system and have gained insight into how policies, practice and broader societal influences interact and influence my own immediate working environment and the wider environment for secondary science teachers' CPD more generally.

EdD Reflective statement

The EdD journey

In drafting this final reflective statement, it has been interesting to look back on the reflective statement that I wrote in 2017, at the end of first year of the EdD programme. I recognise key features that have continued to underpin my learning – such as social aspects of the EdD, my on-going interest in science teacher development, new challenges from undertaking research as a practitioner, and gains in skills, confidence and insight to education research and science education.

The foundations of professionalism course introduced new perspectives to help me reflect on science education during different phases in my working life including: the ever-changing national curriculum; the national strategies for science; the growth of the profile of the national science learning network; and my involvement in varied science education policy influencing groups. It also drew attention to some wider aspects of my experience: the dwindling role of local education authorities; the emergence of the specialist schools movement, an early stage of the self-improving school system; the role of higher education in national continuing professional development (CPD) programmes; and the links between initial and continuing professional development. The foundation of professionalism module shone a light on the tensions and contradictions that underpin the neoliberal education context and managerial interventions in the twenty-first century. I applied these to my reflections on science education and science teacher professionalism in my module assignment on: 'Ways in which the focus on science education in England in the twenty-first century impacts on professionalism, with particular focus on programmes for continuing professional development for science teachers'.

The methods of enquiry courses nudged EdD participants into new territory as we were invited to position ourselves as researchers. The courses introduced perspectives on social science research which ran counter to my background of undertaking and teaching scientific enquiry. First-hand insights gained from process

of piloting data gathering (an unfamiliar role in a familiar school setting), analysis and reporting helped me to better understand the basis of a social science approach to research and was a useful introduction to new protocols, considerations and identity.

I chose for the methods of enquiry courses and institution focused study (IFS) to focus on a particular CPD programme that I was involved in. Externally funded, it was a rare opportunity, with school leaders' support, to design and implement a long-term programme of CPD for chemistry teachers. The creativity involved, along with the enthusiasm and commitment of participant teachers, and the sense of its impact, set it apart from many of the other initiatives that I was involved in at the time. Exploration of its long-term impact and, in the IFS, of how a CPD programme could act as a change environment for teachers' knowledge and practices had direct relevance to my work and possible value more widely in identifying characteristics that could be built into other CPD programmes.

I drew from the methods of enquiry and IFS courses and assignments understanding, confidence and a toolkit of practical approaches that were useful in the thesis stage of the EdD and will be for future research. My interest in science teachers' professional development was reflected in the exploration in my thesis of the environment for secondary school science teachers' continuing professional development in England. In this, I brought together strands of my professional experience and interest, as well as theoretical perspectives from the foundations of professionalism course and research perspectives from the methods of enquiry courses. This final stage of the EdD has contributed to development in my thinking about my professional context and role which will inform my future practice.

Reflections on learning

My professional role is concerned with adult learning, so it is unsurprising that, at the same time as reading and undertaking research into teacher development, I was interested to reflect on the way that the EdD programme enabled my own learning.

The taught courses provided a mix of expert input, social interaction with a diverse, richly experienced group of participants and milestones that scaffolded and

prompted progression through learning tasks. Learning and reflection was facilitated by the pedagogy of the courses as well as structured situations such as tutorial groups and was enhanced by the research training programme. The EdD framework includes many of the elements identified in literature as effective in supporting teacher CPD: relevance, social interaction operating over time, practical experience of implementing new approaches and reflection on this, and expert input. Each of these, at different times, facilitated my learning.

Teacher CPD facilitators are seen as adding credibility to CPD: they bring first-hand experiences, and their expertise is located in practice. Input to the programme by people at different stages of their EdD journey was similarly credible and valuable. Their experiences and research strategies were useful bases for reflection about personal approaches.

Research and learning in the IFS and thesis stages of the EdD programme were more independent than in earlier stages. Taught sessions were less frequent and transitioned to on-line during after the first COVID lock down. Remote contact with peers didn't fully compensate for face-to-face interactions. During the thesis stage, feedback, encouragement and discussion during regular supervision sessions and meetings with two course colleagues offered huge support to my learning and progress. Formative feedback in both these contexts was helpful, and I envisage it as preparation for peer review during later research.

Participants were encouraged throughout the EdD programme to become more critical readers and many of us have practised a new genre of writing. Navigating UCL technologies to access resources, learning communities and research logs and to upload assignments has provided a reminder of both the opportunities and challenges that institutional information technologies present to teachers and learners.

Course participants were encouraged to keep a research journal to capture our reflections. On-going thoughts, prompts, reminders, suggestions for possible reading, useful words and research themes noted at ad hoc times in my research journal

illustrate how the EdD programme and research were intertwined with professional and home life. At the thesis stage, my research log enabled me to draw thinking across the overall EdD programme and was useful in a way that I hadn't envisaged would be the case at the start.

Reflections on research

Interviewees were generous throughout my fieldwork and I enjoyed learning about their experiences and ideas. As was the case with my IFS, issues of bias, insider research and generalisability were relevant to my thesis, bringing into practice theoretical aspects of the taught courses as I exploited opportunities and recognised tensions that arose from conducting research within my professional field. It has been interesting to reflect on the dual identities of researcher and education professional and to ponder the extent to which each influences the other.

Throughout the EdD programme, tangential but linked to my main area of focus, as I have read more widely and undertaken research, I have increasingly noticed a gap between educational research and practice. The language, conventions and codes of educational research do not always enable easy access by practitioners, whose perspectives are often absent from literature. This also has implications for practice as I consider ways to increase the extent to which the pedagogy and content of CPD programmes are research-informed, and ways of facilitating easier access by science teachers to research.

I noted in my November 2017 reflective statement that I was curious about the impact of electronic communication on professional learning, communities of practice and professionalism. One of the consequences of the COVID-19 pandemic was that CPD rapidly transferred online from the start of the first lockdown in March 2020. Face-to-face CPD hasn't resumed at the time of writing in February 2021. The rapid and dramatic change in context illustrates the temporary nature of knowledge that a study such as mine generates. My research commenced pre-pandemic and asked questions about an environment which subsequently changed. At times, I was

thoughtful about the possibility that I was researching a time gone by and likely not to return.

Conducting a small-scale qualitative study during a pandemic

My field work was interrupted for two months at the start of the pandemic in March 2020. This meant a loss of momentum. Initial interviews became increasingly distant as the first lock-down proceeded. I listened to them again as I progressed other aspects of the research, for example, initial analysis of early interviews, to maintain a sense of purpose and connection to data which it was clear would be gathered over a longer time period than planned. This was a period of reflection, also, about where things were, the changing wider context and how to proceed.

The public language of the pandemic was dramatic, with frequent references to a 'time of crisis', these 'difficult times' and the 'challenges faced'. An early publication by the Chartered College of Teaching, *Education in times of crisis: the potential implications of school closures for teachers and students*, (Muller and Goldenberg, 2021) the establishment by the Association of Science Education of a 'Coronovirus hub', with a stated aim to respond to 'the global emergency', and the House of Commons Education Select Committee inquiry into the impact of COVID-19 on education and children's services were examples of organisational responses that reinforced the seriousness of the situation. Yet the sense of crisis and alarm wasn't reflected in the teachers' interviews. The only clues about the unusual circumstances were the fact that they now took place on-line, and the teachers' descriptions, before formal interviews began, about how teaching and their work differed from previously.

Daily government briefings during the pandemic featured science and scientists of high profile. Data, graphs, tables, charts, measures of cases, rates of transmission, deaths and, subsequently, vaccination rates were central to the coverage of the situation. Drawing on my background in science, I was interested in the way that data and science were used (in many instances with almost unquestioned authority, even if not wholly understood or well represented) and curious about patterns and trends.

In different roles, I have argued for the importance of scientific literacy for all: the value of this now was highlighted, albeit in unwelcome circumstances. As a novice researcher, I was drawn to contrast and reflect on the qualitative approach that I was pursuing, as I sought at one stage, with some difficulty, to recruit six teachers, with the quantitative way in which science and scientific research, with enormous sample sizes, were being applied to describe and understand the developing situation. The comparisons between social science research and positivistic science approaches which were introduced in the EdD methods of enquiry courses were much in evidence.

The pandemic continued to be a backdrop for much of the thesis stage of my EdD. It presented challenges and necessitated adaptation in data gathering approaches, and impacted on formal and informal learning opportunities as EdD and other research development programme courses became remote rather than face-to-face. However, the space for thinking, reading and writing generated through three periods of lock down has been beneficial and reminded me of the challenge and importance of allocating time to professional learning in busier circumstances.

Reflections on familiar and different contexts

I began my EdD in 2016, a return to UCL where I studied for my first degree, in Zoology, and subsequently a PGCE at the Institute of Education – which then was a separate institution. The warmth and colour of Bloomsbury in autumn was the backdrop to the start of each of these three very different learning opportunities. A career in science education lay ahead when studying for a BSc and a PGCE: my stance for each was forward looking. I came to the EdD with a range of professional experience in the field of science education and hoped to be able to reflect on this as much as to look forward. The hectic pace of professional life and the seemingly endless stream of science education initiatives have, on many occasions, mitigated against standing back, taking stock and making sense of the science education environment and my role within it. I hoped that the EdD would facilitate this and provide opportunity for new learning and practice, including through research. It has done both and more.

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Appendix 1 Participant invite note

E-mail header: Research into the policy environment for secondary science teachers' CPD

Dear *name of individual*,

I am carrying out research into the policy environment for secondary science teachers' continuing professional development (CPD). The research is part of an EdD course at the Institute of Education, University College London and is separate from my role at the Centre for STEM Education at the University of Hertfordshire.

I aim to gather different perspectives on national programmes for science teachers' CPD by interviewing people involved in different ways: policy influencers, local school led CPD programme leaders and CPD participants. I plan during the 2019 – 20 academic year to interview 18 – 20 people to learn about their perspectives.

I am contacting you to invite you to take part because *name of organisation* is much involved in national programmes of CPD for secondary science teachers, with significant on – going interest and influence.

If you are willing to take part, the interview will take about 40 minutes, and can be at a venue that you chose, at a time that is convenient to you. I will let you know beforehand about broad areas for discussion.

With your permission, I will audio-record then transcribe the interviews. The content will be saved securely. I will provide you with a transcript of your interview, so that you can check for accuracy. You can withdraw at any time. The research will be reported in a thesis which I will write as part of the EdD course in which participants will not be named or described in a way that could lead to identification, unless you expressly do not wish this to be the case. In the longer-term, I hope that learning from the study will inform the development of policy for science teacher CPD.

If helpful, I am happy to discuss the research project and any questions that you have. If so, please suggest times and a contact number for me to telephone. Otherwise,

please let me know by e-mail by *date* whether you are willing to take part or would prefer not to.

Many thanks *Signature and UCL contact details*

Appendix 2 Consent form: in-person interview

Institute of Education

UCL

Research into the policy environment for secondary school science teachers' continuing professional development (CPD)

Consent form

Background

The long-term aim of this research project is to better understand the policy environment for secondary school science teachers' CPD. Perspectives of national policy makers, local school-led programme leaders and CPD participants will be gathered through a number of interviews. My research is being undertaken as part of an EdD course at the Institute of Education, University College London and is not part of my role at the Centre for STEM Education at the University of Hertfordshire.

Interviews

- Interviews are likely to take 30 – 40 minutes.
- The interview content is confidential.
- Broad areas for consideration will be provided before the interview.
- Interviews will be audio-recorded, and the recording will be stored securely.
- A transcript of the interview will be provided to you, so that you can check for accuracy.

Participation

- You can withdraw at any time, without reason. If so, any data gathered, for example interview recording, will be destroyed.
- Data gathered in this study will be stored anonymously and securely using password-protected software.
- In any outputs resulting from the research, you and your organisation will not be named or described in a way that could identify you.

Consent

If you agree to participate in this study, please complete this consent form and return to Sue Sissling at the address below.

	Yes	No
I have read and understood the information about the research and have had the opportunity to ask questions about it.	☐	☐
I understand that if any of my words are used in reports or presentations they will not be attributed to me, and that all efforts will be made to ensure that I cannot be identified.	☐	☐

UCL Institute of Education
20 Bedford Way, London WC1H 0AL
+44 (0)20 7612 6000 | enquiries@ioe.ac.uk | www.ucl.ac.uk/ioe

IOE LONDON

I understand that I can contact Sue Sissling and withdraw from the project at any time, and that if I choose to do this, any data I have contributed will be destroyed and not be used. ☐☐

I consent to my interview being audio-recorded and understand that the recordings will be stored anonymously, using password-protected software and will only be used for specific research purposes. ☐☐

I understand that data gathered in the research will be stored anonymously and securely using password-protected software. ☐☐

_____

Name Signature

Date

Researcher contact details:

Sue Sissling

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Appendix 3 Consent form: remote interview

Research into the policy environment for secondary school science teachers' continuing professional development (CPD)

Consent form

Background

The long-term aim of this research project is to better understand the policy environment for secondary school science teachers' CPD. Perspectives of national policy makers, local school-led programme leaders and CPD participants will be gathered through a number of interviews. My research is being undertaken as part of an EdD course at the Institute of Education, University College London and is not part of my role at the Centre for STEM Education at the University of Hertfordshire.

Interviews

- Interviews will be conducted remotely via Microsoft Teams or Zoom
- Interviews are likely to take 30 – 40 minutes.
- The interview content is confidential.
- Broad areas for consideration will be provided before the interview.
- Interviews will be audio-recorded, and the recording will be stored securely.
- A transcript of the interview will be provided to you, so that you can check for accuracy.

Participation

- You can withdraw at any time, without reason. If so, any data gathered, for example interview recording, will be destroyed.
- Data gathered in this study will be stored anonymously and securely using password-protected software.
- In any outputs resulting from the research, you and your organisation will not be named or described in a way that could identify you.

Consent

If you agree to participate in this study, please complete this consent form and return to Sue Sissling at the address below.

	Yes	No
I have read and understood the information about the research and have had the opportunity to ask questions about it. **YES**	☐	☐

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I understand that if any of my words are used in reports or presentations they will not be attributed to me, and that all efforts will be made to ensure that I cannot be identified. ☐ ☐

I understand that I can contact Sue Sissling and withdraw from the project at any time, and that if I choose to do this, any data I have contributed will be destroyed and not be used. ☐ ☐

I consent to my interview being audio-recorded and understand that the recordings will be stored anonymously, using password-protected software and will only be used for specific research purposes. ☐ ☐

I understand that data gathered in the research will be stored anonymously and securely using password-protected software. ☐ ☐

_____

Name Signature

Date

Researcher contact details:

Appendix 4 Interview schedule policy influencer

1. Please describe your role in relation to continuing professional development for secondary science teachers in England.
2. Please describe your organisation's role in relation to CPD for secondary science teachers.
    a. What is the current rationale for involvement?
    b. How has this changed over time?
    c. What factors have influenced changes?
3. How does the role or rationale fit into the wider landscape for CPD for secondary science teachers?
4. How does the organisation understand or conceptualise CPD?
    a. Thinking about specific examples of CPD programmes, how is the purpose envisaged?
    b. What models of professional learning are embedded?
5. Is a particular type of CPD, for example face-to-face or school-led, seen as more useful or effective than others?
6. How are your CPD programmes informed by or aimed at promoting a particular view of good science teaching?
7. How are your CPD programmes informed by or aimed at promoting a particular view of the secondary science curriculum or learning in science?
8. How does the organisation judge whether its support for CPD for secondary science teachers is worthwhile?
    a. What does success look like?
    b. Is there a long-term plan or ambition?
9. In summary, some key points about CPD for secondary science teachers that have emerged during this interview are ……
10. Are there other points that would help me to understand your or the organisation's perspectives about CPD for secondary science teachers?

Appendix 5 Interview schedule local CPD provider

1. Please describe your role as a local CPD lead.
    a. What is your background in education? How did you come to this role?
2. Please describe how your school/organisation operates in relation to local CPD for science teachers.
    a. What is the rationale for its involvement in provision of science CPD?
    b. How has the role changed over time?
    c. What factors have influenced changes?
3. How do you understand national policy for science CPD?
    a. How does the school / college / SLP role fit into the wider landscape of CPD for secondary science teachers?
    b. How does the national approach for the network or national policy influence local delivery?
    c. Can you describe examples of tensions between your local approach and national policies or approaches?
4. Thinking about the CPD that your school / college / SLP offers:
    a. What is the overall purpose?
    b. Are particular types of CPD more useful or effective than others?
    c. What models of professional learning are embedded?
    d. Is the CPD programme informed by or aimed at a particular view of good science teaching?
    e. Is the CPD programme informed by or aimed at promoting a particular view of the science curriculum or learning in science?
5. How do you judge whether your involvement is in CPD for secondary science teachers is worthwhile?
    a. What does success look like?
    b. Is there a long-term plan?

6. In summary, some key points about the way that the school /college / SLP fits into the landscape for science CPD that have emerged during this interview are ……
7. Are there other points that would help me to understand your or the school /college or SLP's perspectives about CPD for secondary science teachers?

Appendix 6 Interview schedule teacher (CPD participants)

1. Please briefly describe your role and experience as a science teacher.
2. Thinking about participation in CPD, please describe examples of science CPD that you have taken part in. *Clarify date, provider, duration.*
    a. What led to you taking part?
    b. What factors personal to you influence your attendance at CPD?
    c. What school factors influence your attendance at CPD?
3. Thinking about your experience of CPD, please describe features of effective CPD.
    a. What was the outcome?
    b. What led to this?
        i. Is this your general experience of CPD?
4. Thinking about the range of CPD that is available for secondary science teachers:
    a. What CPD programmes are you aware of?
    b. What do you think is the reason for these and others such as …… *suggest others not mentioned?*
    c. What kind of science teaching or science teachers do you think these CPD programmes are supporting?
5. What beliefs do you bring to your science teaching?
    a. About the curriculum or your role as a teacher?
    b. How has this been supported through CPD? or changed? or challenged?
6. You have suggested during the interview that … *about your experience* … and … *the range of CPD for science teachers* …
7. Are there other reflections or comments about your experience and understanding of national policy and programmes for CPD for science teachers, or areas that we haven't discussed?

Appendix 7 Interview summary form

Interview summary form

With: Date: Venue:

Main issues and / or themes from the interview

Main information gathered or not gathered in relation to research questions

Other things that were salient, interesting, illuminating or seemed important

New questions/ areas to explore emerging from the interview

Appendix 8 Ethics approval application extracts

Institute of Education

UCL

Doctoral Student Ethics Application Form

Anyone conducting research under the auspices of the Institute of Education (staff, students or visitors) where the research involves human participants or the use of data collected from human participants, is required to gain ethical approval before starting. This includes preliminary and pilot studies. Please answer all relevant questions in simple terms that can be understood by a lay person and note that your form may be returned if incomplete.

Registering your study with the UCL Data Protection Officer as part of the UCL Research Ethics Review Process

If you are proposing to collect personal data i.e. data from which a living individual can be identified **you must be registered with the UCL Data Protection Office before you submit your ethics application for review**. To do this, email the complete ethics form to data-protection@ucl.ac.uk. Once your registration number is received, add it to the form* and submit it to your supervisor for approval. If the Data Protection Office advises you to make changes to the way in which you propose to collect and store the data this should be reflected in your ethics application form.

Please note that the completion of the UCL GDPR online training is mandatory for all PhD students. The link is here: *https://www.ucl.ac.uk/legal-services/ucl-general-data-protection-regulation-gdpr/gdpr-online-training*

Section 1 Project details			
a.	Project title		The policy environment for secondary school science teachers' continuing professional development in England: policy makers' and practitioners' perspectives.
b.	Student name and ID number (e.g. ABC12345678)		Susan Sissling
c.	***UCL Data Protection Registration Number**		Z6364106/2019/10/95 Date issued 11 October 2019
c.	Supervisor/Personal Tutor		Professor Michael Reiss
d.	Department		Curriculum, Pedagogy and Assessment
e.	Course category (Tick one)	PhD ☐	EdD ☒
		DEdPsy ☐	
f.	**If applicable,** state who the funder is and if funding has been confirmed.		
g.	Intended research start date		November 2019
h.	Intended research end date		June 2021

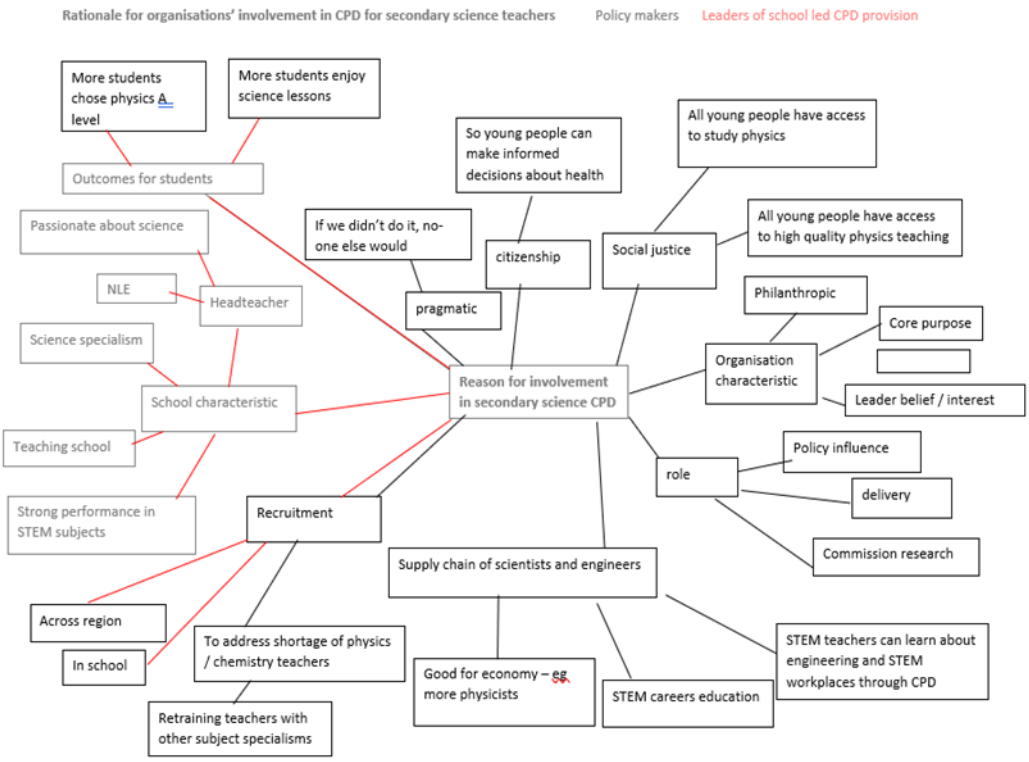
November 2018

Reviewer 1		
Supervisor/first reviewer name	Michael Reiss	
Do you foresee any ethical difficulties with this research?	Feedback provided by me has been satisfactorily taken into account	
Supervisor/first reviewer signature	[redacted]	
Date	2 Oct 2019	
Reviewer 2		
Second reviewer name	Jacek Brant	
Do you foresee any ethical difficulties with this research?	This is a well-considered form that I approve.	
Supervisor/second reviewer signature	[redacted]	
Date	2/10/19	
Decision on behalf of reviews		
Decision	Approved	☒
	Approved subject to the following additional measures	☐
	Not approved for the reasons given below	☐
	Referred to REC for review	☐
Points to be noted by other reviewers and in report to REC		
Comments from reviewers for the applicant		

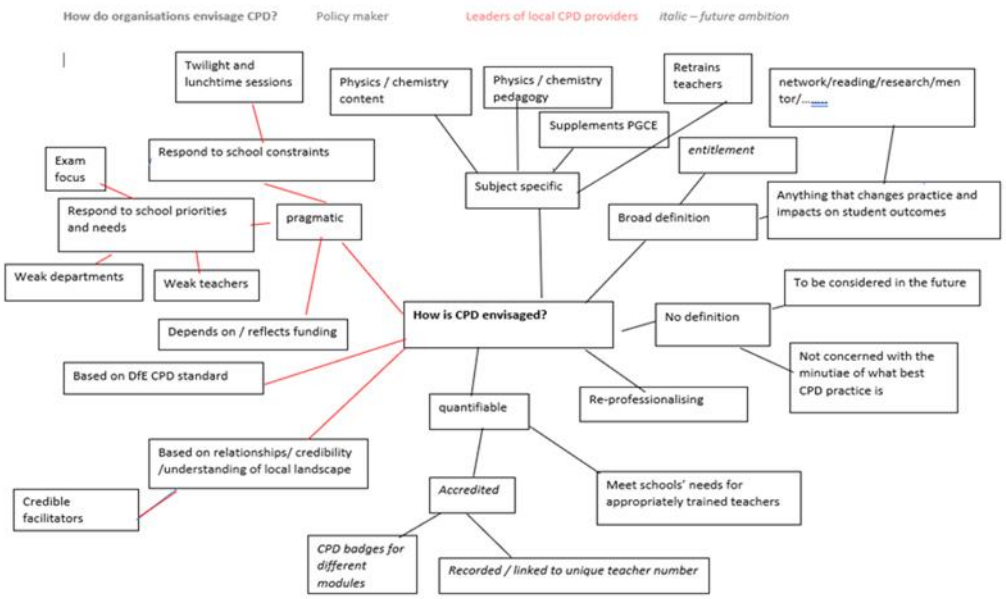
Once it is approved by both reviewers, students should submit their ethics application form to the Centre for Doctoral Education team: IOE.CDE@ucl.ac.uk.

Appendix 9 Examples of data maps

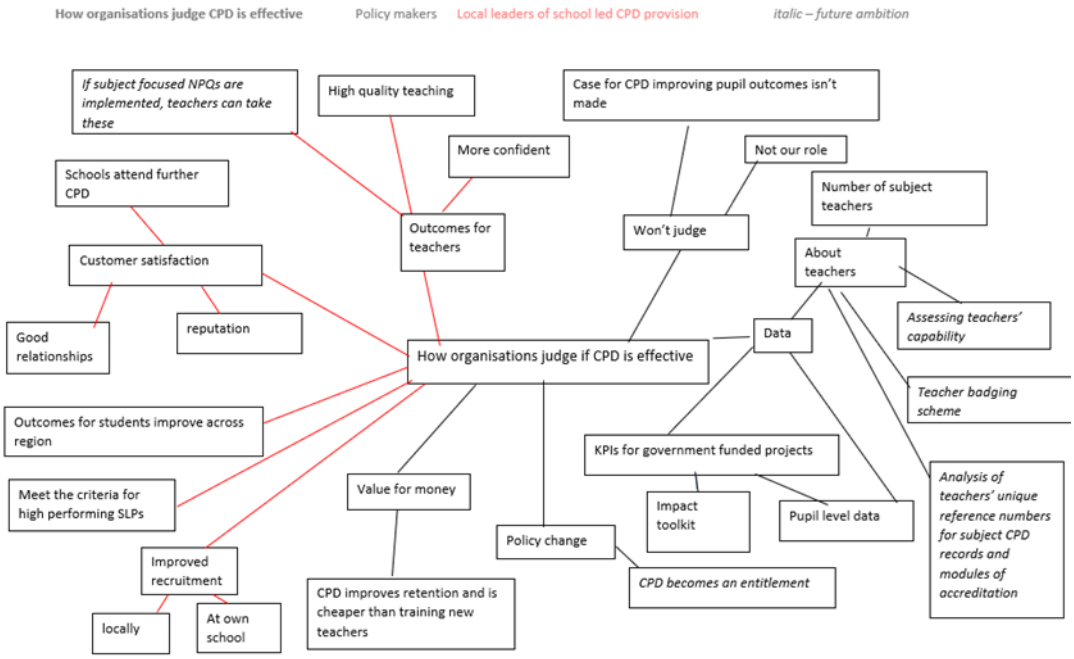
Rationale for organisations' involvement in science CPD



How organisations envisage CPD



How organisations judge CPD to be effective



Appendix 10 Codes for data analysis

Data domains

	How organisation is involved in science teacher CPD
	Why organisation is involved in science teacher CPD
	Landscape
	How CPD is envisaged
	Science teaching and curriculum
	Science teachers

Shaded: only noted in interviews with teachers

Codes: how organisation is involved in science CPD

Organisation (O)	How (H)		
Provide CPD	CPD	build capacity	cap
Work with government	gov	conversation with government / influence/ trusted voice/ policy	inf
		funded by government	fund
Commission research	res	disseminate research	dis
Different for different projects	var		
Changes over time	ch		
Deliver CPD	del		
Fund	£		
Influence curriculum	curr	subject lead	sub
Collaborate	coll		
Informed by personal experience	exp		
Quality assure	qa		
Provide advice	adv	knowledge of schools	knowsch
Project manage	proj		
Involved in ITE	ITE		
Knowledge of schools	knowsch		
Needs analysis	na		
Broker	br		
Build relationships	rel		

Codes: reason for organisation involvement in science CPD

Organisation (O)	Why (W)		
Influence	inf		
Opportunistic	opp		
Organisation position	pos	individual belief/passion	ind
Organisation function / role	func	career/employment chain/economy	car
Workforce development	wf	good subject teachers	subteach
		recruitment	rec ----phys, chem
		retention	ret ----phys, chem
		entitlement	ent
National economy	ec		
Student	stud	equity	eq
		subject uptake	up ---- phys, chem
		career pathway	car
		citizenship	cit
		attainment	att
Leader's passion	lead		
Fits with school position in landscape – TSA, Mat	schpos		

Shaded: only noted in interviews with teachers

Codes: landscape

Landscape (L)			
Workforce	wf	initial teacher education	ITE
		NQT	NQT
		early career framework	ECF
		teacher recruitment	rec --- phys, chem
		teacher retention	ret ----phys, chem
		teacher recognition	rec
		professionalism	prof
		deployment	dep
		census	cen
		subject knowledge enhancement	ske
Economic influence/ value for money	vfm		
Government	gov	policy	pol
School	sch	finance constraint	£X
		accountability	acc -------- Ofsted (Of)
		leaders	lead
		led landscape	loc
		constraint	con
		staff turnover	turn
		staff deployment	dep
Industry	ind		
Changing	ch		
Variety of CPD providers	var		

Shaded: only noted in interviews with teachers

Codes: how CPD is envisaged

CPD (CPD)			
To address deficit	def		
Professionalise	prof		
Make teachers feel valued	val		
Build teachers' confidence	conf		
Entitlement	ent		
Impart expertise	exp		
DfE standard	Dfestand		
Government policy	gov		
Goal specific / measurable outcomes	acc	individual teacher	ind
		school	sch
		workforce	wf
		retention	ret
		student	stud
Process	?	course, conversation, facilitator, research, CPPL, coaching, share good practice, shadow	
		practitioner led	T-T
Subject specific	sub	mastery	mast
		knowledge	know
		pedagogy	ped
		engage teacher with subject	eng
		supplement PGCE	+PGCE
Syllabus focused	syll		
Targeted	tar		
Continuous	cont		
Professional learning	pl		
Value for money	vfm		
Facet of school culture	sch cult		
Changed over time	ch		
Research informed	res		
Facet of department culture	dep cult		
Industry linked	ind		
Build capacity	cap		
Syllabus linked	Syll		

CPD (CPD)			
School focused	sch		
Department focused	dep		
Network focused	net		
Product	prod		
School to school	sch		
Bespoke	bes		

Codes: science teaching and curriculum

Science teaching (t) curriculum (c)			
Science teaching	sci t	using models	mod
		practical work	prac
		improves student outcomes	stud att
		subject knowledge based	sub
		research based	res
Science curriculum	sci curr	practical	prac
		research informed	res
		syllabus driven	syll
		industry linked	ind
		skills based	sk
		change	ch
		school defined	sch

Codes: individual science teacher characteristic, identity, experience

Science teacher (T)			
Ambition	amb		
Subject identity	id	science	sci
		biology	bio
CPD	CPD	experience	exp
		impact	imp
Belief	bel		
Experience	exp		
Weakness	w		
Development	dev		

Shaded: only noted in interviews with teachers

Appendix 11 Example of coded transcript (local provider)

03 February 2020 Transcript

To start by asking you about your role.

I'm a science teacher, first and foremost. I teach science from year 7 to year 13, and I specialise in biology GCSE to A level. I also run the science learning partnership for *name of school*.

How did you come to the SLP role?

Good question .... *laughter* .... At the time the head of faculty was running the science learning partnership and it was too big a job for her, she didn't have the time to do, so she was looking for somebody to help her run it so initially I was bought in as her assistant. Then quite quickly it just developed. I was taking more of a lead role and the head of faculty was taking a step back and her role as head of faculty was getting bigger because they introduced the maths department as well as science, the D&T department and she became an assistant head and I took over the role. It was a natural progression

How did the school become an SLP?

I think they were invited to be an SLP, when they first came out, because we are historically a science specialist school and a very high performing science school, as well.

So, the rationale was to build on the specialist work?

Yes, I think because our department was so strong, and there's strong management. Our attainment is so good in science and our uptake at A level is really strong. We're a girls school as well, and I think as a girls school our numbers in physics A level, and the destinations of our students, we're very, very strong in STEM subjects as a whole.

Does it connect with you teaching school role?

Yes. And we're a maths hub as well. I think because we already had that embedded within our school, we already had that structure, in terms of being a teaching school, we already had those contacts across the region as well. We were used to providing school to school support.

And does it work together, the different bits?

Yes. Absolutely. I think the fact that we have the teaching school as the overarching umbrella and then within that sits the maths hub and the science learning partnership, it does work very, very well. And also out head is an NLE, so we have school-to-school support, we have SLEs, we have maths facilitators, science facilitators. That why we were so gutted we didn't become the computing hub as well. *laughter*

You've got science SLEs

Yes, and they're trained as well through the science facilitators programme for STEM

I see, so is your science work mainly as an SLP or do you do other science CPD?

If there is science support that's needed that comes in from our teaching school, then it would be passed onto us to deliver it. I think there was one school who contacted us via the teaching school and that was actually an SLE that went out and did that work. But, mostly it's though the SLP.

So how would you describe the national landscape for science CPD?

I think there is a lot out there, for people. There is a lot on offer for schools and some schools find it a little bit overwhelming, because they are, not bombarded, but all the examining boards send their flyers, and all their different offers and their e-mails. Then there's companies that run, different businesses, money-making businesses that offer things as well, then there's different bursaries that are offered. There's so much out there. And obviously all the on-line CPD that's available. There's a lot there which is brilliant, and there's a lot of really good quality CPD, which is brilliant, but I think that as individual

teachers, and sometimes as heads of department, it's hard to choose and to know where to go for the best in terms of your own personal, what would be best, most suitable for your school and for your department, and then obviously there's the budget.

It's important

It is really important because in terms of running the SLP, I am trying to sell something. I think what we run is very, very high quality, very high impact and teachers who come on our courses and the school-to-school support we offer, they get a lot out of it and there's a lot of impact from that. However, there is still resistance from the top because, a, it costs money even though it's very good value for money, our courses compared to some of the London courses that are out there, but it's also getting that time out of school, and it's almost that if they don't see that it is something that is essential, like health and safety or radio-activity training, that sort of thing, then to allow somebody to go out for a whole day CPD that's going to end up costing £400 - £500. And if they're missing exam classes as well, it might be even if they did see that they wanted to fund it if you're missing year 11 and year 13, then that's .... you're sacrificing those classes. I know it might only feel like one lesson, but sometimes there's double lessons, so that's two lessons those year 11s are missing, so it's difficult.

It is difficult. You said two things – high impact and high quality, so what would you say that the overall purpose of you CPD is?

That teachers will feel that at the end of it, they have something that is going to help them in the classroom to actually make a difference to their students, but also to their own time, to save them time, in terms of their planning, if it's going to make teachers' life easier and at the same time impact on their students in terms of it could be, it doesn't necessarily have to be attainment even, it might just be engagement of engagement or the students' attitudes to science.

When you plan CPD for those purposes do you think some types are more effective than others?

Possibly. I think very subject specific things are probably ..... have more of an impact and I feel the teachers go away a lot happier and satisfied

Can you give me an example of this subject specificity?

Really specific. For example, a department we gave training on monoclonal antibodies, so very, very specific. And another teacher, and she has done this a lot, a lot of schools want this, where our chemistry facilitator goes in and talks about Mole calculations in chemistry. So it's very specific, but they love it because it's something they have to teach. They don't know what the best way is to teach it and sometimes they don't have the subject knowledge to teach it, so they go away more confident and with some strategies of how to do it in the classroom.

Subject knowledge and pedagogy. Very precise, specific.

It is and we're talking about quite short sessions, about an hour and a half, not day sessions.

What models of professional learning – are people learning because they're hearing an expert? Or doing things? How are the teachers learning?

Both really. It's a bit hands-on. 'This is what I do, what do you do?' A conversation a lot of the time. A lot if the time it's getting them used to sharing good practice as well, in a department because, some departments, our department is so amazing, in terms of our collegiate environment and how we share resources with each other, but all departments work like that. Some teachers are quite, I think some teachers feel a little bit isolated within their department and some teachers feel a little bit precious about their resources and about what they do in the classroom. So I think maybe, it's just initiating that sort of

environment and that 'we can do this together', I'm facilitating this, but actually this is something you could do in every department meeting, because you have the experts here within your department.

So encouraging people to share practice within schools and as well as between school.

Yes

And when you plan CPD, do you think there's a particular model of good science teaching embedded in it?

.... I would say so. It's good teaching, it's not necessarily good science teaching. Good teaching and good science teaching. Hands-on, lots of activities and fast pace good teaching.

And what about .... is there a particular view of the science curriculum or how students learning in science? Does that come across through the CPD?

Yes .... It depends on what the CPD is that you're doing, but a lot if the time it is about actual learning. It's about making it relevant and contextualising it, obviously in that will come literacy and numeracy skills as well. All those things need to be addressed in terms of making students feel successful.

Practical work?

Yes. Hands-on practical work. Yes.

How will you know if your work as an SLP, or your work as an SLP leader, is successful?

Schools come back to us.

That's a good point.

We build up, I think because we are so localised, we build good relationships with our schools. I think the biggest impact you have, although it's not part of our KPIs, the biggest impact is when we go back and work with the same teacher over and over and over again. When we just do a one-off session, I think they're great, they're really good and those teachers will go away with something and they'll find it useful. But in terms of the best impact, so for we had a teacher to go over, and they did all the chemistry PAGs, so they went over in lunchtimes, it was every other fortnight. So they did five sessions and they covered all the PAGs, and that was brilliant because she was able to build up that relationship, that rapport with the department and they were absolutely positive about it and the technicians as well. To have that continuous, that regular contact, the relationship, although it's not our KPI, it does help with the teacher to have that regular support and quite a lot of our teachers will just drop us an e-mail and say, 'Oh have you got any ideas how to do this or how to do that?' and that's why I think we're successful because they can see a value in what we're doing, because they're asking us for more help and more support. They don't see it as help, but they see it as some ideas to share. It's that conversation, it's not us going in and saying we're the experts, we're brilliant at this, we know what we're doing, this is how you should do it, it is a conversation. It's relationships.

I'm thinking about national policy and local relationships. You're making things work for local needs.

Yes, and is it sustainable? That's the thing. Is it something that actually is going to be able to work nationally? And that's the idea of these little hubs, that should be the whole purpose, that you are providing localised, bespoke support. When I talk about the schools that we are building relationships with, I'm talking about through the triple science programme, through STEM Learning, a national programme, they're the schools that we're able to keep going because we've got the funding to keep that relationship going. We're able to keep meeting with them.

Building a relationship

Exactly, whereas if somebody just comes on the one course, sometimes they'll come back and do more courses, but it might be a different teacher from the department, it might not be the same teacher again. But we still have the same links with the schools, but in terms of building that kind of relationship I think it works with the triple schools really nicely. But I don't know if you necessarily get that on the reviews .... I don't know if that's what comes across, sometimes when I'm writing a review at the end of the year and it's all about what have the done and the activities and what impact of that in terms of ticking off these boxes and putting in the numbers, but actually it's more than that.

The relationship. They're coming back to you. You mentioned funding, is it sustainable without funding?

In a word, no, *laughter* because who's going to pay for me to do that? Not just me but all the other facilitators as well to go out there and do that. It's very time consuming, it's the same with time, because of the problem with cover and having days out and half days even, for courses, we are running more twilight sessions, because of that. However, I think that is in terms of the cost of that, is it sustainable because we're having to do lots of twilight sessions rather than a one-day course?

Finances are an aspect

Massive for schools – that will be about the definite decision about whether a teacher will be able to go on a course. It's also an aspect for us.

It's also about the provider as well

Yes – can we provide it

If triple science is a national policy, are there others you engage with?

The Enthuse partnerships which are brilliant, and they're funded through industry. They're amazing. We've got a new one, a new Enthuse partnership that's literally just starting in [redacted] and that is really interesting cross – phase. Their project is all about creating an all through science curriculum from EYFS up to year 11. An amazing project, I'm really excited about it. I think those projects are so good because it's all about collaboration between schools and CPD across those schools.

So most of the work that you do is for STEM Learning. Are there other national policies that you are

Not really .... just the STEM Learning ones really.

So is there anything else that you would like to say about national policy?

I do wonder, I went to a meeting a while ago now, I think last year or maybe the year before at Wellcome Trust and I did wonder, they were doing a pilot in the north, Sheffield I think it was, about how, not just for science, but all subjects, having a minimum of 40 hours in a year of CPD and I wondered what the progress was of that and what the findings were of that. It was quite a while a go and I'm curious about it.

That's about an entitlement for all teachers

Yes, and I wondered how the schools who are taking part in the pilot were funding it and how they were finding the time for teachers to take part in 40 hours a year. That sounds quite a lot.

I think that was about subject specific CPD, which is what you're talking about. Is that hard for people to get release for?

I think so. I personally believe that's the best CPD you can have, subject specific CPD, but unless schools think it's essential that .... it's easier for all us to sit in the hall on the INSET day and all have training on using an EpiPen. That's much easier than arranging for subject specific CPD for each department.

You're talked about courses, school-based support, you've talked about .... staff meetings for a whole science department. Are those the main forms of CPD at the moment?

I'd say so. There's on – line CPD as well, which I haven't contributed to .... STEM Learning have online CPD and we set that as part of a gap task sometimes. So face to face, one-to-one mentoring, we do and some coaching. What we might do, for example, one of our triple schools, the head of science is quite new and quite early on in his career, as well, we've done quite a bit. He's come over, and shadowed our head of science and they sometimes have a chat and also another head of science we've got him with others touch with so they can run some ideas past and ask questions, that sort of thing as well.

So just to finish, the main things that people are asking you for locally are

I would say, secondary schools, are really specific parts of the curriculum in terms of subject knowledge and how to deliver. Fun ways of delivering, some of the more boring parts of curriculum. And required practicals .... not only how to actually do them but also how students can be successful in answering questions on required practicals.

So examinations, GCSE

Yes, exam techniques. Around practical work. And data.

And you mentioned a new head of science. Is there some leadership

Yes – we had a leadership course no-one, I think there was one person booked onto that. Again, it might be that there is a need for it out there, but in terms of people actually coming onto the courses, it's really not .... I think we have almost audited our local schools and set up our programme according to what they've wanted but then when we send it out there, we might just get one or two teachers and then we can't run it. So I think the issue is not necessarily that they don't want it, we are asking teachers what they want, but they just can't get the release time. And I think that's probably even more about exam teachers being released than funding.

I think most teachers. Most science teachers are teaching across the board and will be teaching year 11 or 13, so most science teachers will be teaching exam classes so it's the fact that they're going to miss their exam classes, and the cost of supply and then knowing that, that lesson, because it's a supply teacher, will be a bit of a wasted lesson for the students.

So even though you've done a needs analysis and put a programme on, yet, people still aren't able to come. Your headteacher has leadership connections with other school leaders, does that help at all?

I think that's the way it is. They know what's on offer, locally, we've got our message out there I think and we have a good reputation, they know we're here to help them and support them in what-ever way they want, and they do approach us. But when we say, we can do this, this and this, there are barriers that they hit that means that they're not able to take up the offers that we give them.

So, going back to national policy, that's probably something that .... you said there's loads of science CPD out there and some of it is part of national policy, and even so people aren't able to take part in it.

Even with our triple science schools. Some of those schools would like to go on courses that we're running but can't get the cover, even though it's funded. Even though they don't have to pay for the course. So straight away we can see that it's not an issue with the cost of the course, because there is no cost for the course, it's getting out of school. That's why a lot of the time, with those triple science schools, we're having to go in and do bespoke science CPD during their departmental meetings.

So that would be you, or SLAs or facilitators you trained?

Yes. Our trained facilitators will go in and do twilight sessions, or there was a school recently that had an INSET day, and, in the afternoon, they had some departmental time so we had a two hour slot with them. But mostly it's departmental time. The trouble with departmental time is some schools don't have many departmental meetings. They might only have one a half term, and then to use that whole departmental time, that one time in the whole half term for CPD when there might be other issues they need to do. It's really limited which is why some of our more flexible facilitators are going in at lunchtimes and working with teachers, but then that's their lunchtime. But that's the only time they're able to be .... It's impacting on their well-being as teachers. Pragmatic → consequence

That's really important to understand, that that's the reality of the situation

For some of those teachers who are desperate for CPD, that's the only way they're going to get CPD. That's through the triple science programme, that's funded. We wouldn't be able to do that if it wasn't funded, unless the school was going to pay us.

My sense is that schools haven't got the money to pay for subject CPD, from what you said earlier.

No they don't.

Thank you.