Challenges to Pedagogical Content Knowledge in lesson planning during curriculum transition: a multiple case study of teachers of ICT and Computing in England.

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Challenges to Pedagogical Content Knowledge in lesson planning during curriculum transition: a multiple case study of teachers of ICT and Computing in England

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Abstract

Challenges to Pedagogical Content Knowledge in lesson planning during curriculum transition: a multiple case study of teachers of ICT and Computing in England.

In September 2014 the new National Curriculum programmes of study for Computing became mandatory in England, replacing Information and Communications Technology (ICT) as a school subject and introducing Computer Science into schools. This posed a challenge for in-service ICT teachers without Computer Science subject knowledge: teachers needed to develop both subject and pedagogical knowledge to make the transition from teaching ICT to teaching Computing.

This multiple case study explores teachers' perceptions of the curriculum change and how they have responded in practical and pedagogical terms to planning lessons aligning with the new programmes of study. Nine teachers participated, each of whom had been teaching ICT pre-2014. The study used semi-structured interview questions while teachers engaged in lesson-planning activities, captured mostly using desktop-sharing via internet telephony. A modified version of Shulman's pedagogical reasoning framework and Pedagogical Content Knowledge (PCK) facilitated analysis of teachers' pedagogic practices in lesson planning.

The study shows teachers' concerns about the lack of clarity surrounding the curriculum change, and the lack of access to suitable professional development (CPD). Most highlighted the primacy of programming and Computer Science at the expense of Information Technology and Digital Literacy, the other two strands of the new curriculum.

The study also shows the dynamic nature of lesson planning. Knowledge deficits slowed down the fluency of teachers' lesson-planning processes, but the use of lesson materials created by others helped them to develop PCK. The term *transitional pedagogical reasoning* has been used to describe the process by which unfamiliar but necessary concepts are assimilated into the pedagogical reasoning process while the teacher develops sufficient subject knowledge and PCK.

Recommendations have been made for Computing curriculum policies to recognise and promote Computing pedagogy. This understanding should underpin initial teacher education in Computing, CPD for in-service teachers, and strategic development of the subject in the longer term.

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Declaration

This thesis is my own work and no part of the materials contained in it has previously been submitted for a degree in this or any other university.

Statement of copyright

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My friends, current and former colleagues and fellow students – so many special and cherished people. I hope you know what you mean to me.

Thank you all for being there for me.

Dedicated to the memory of

Diane Bailey-Ginever

1943-2018

Chapter 1 Introduction

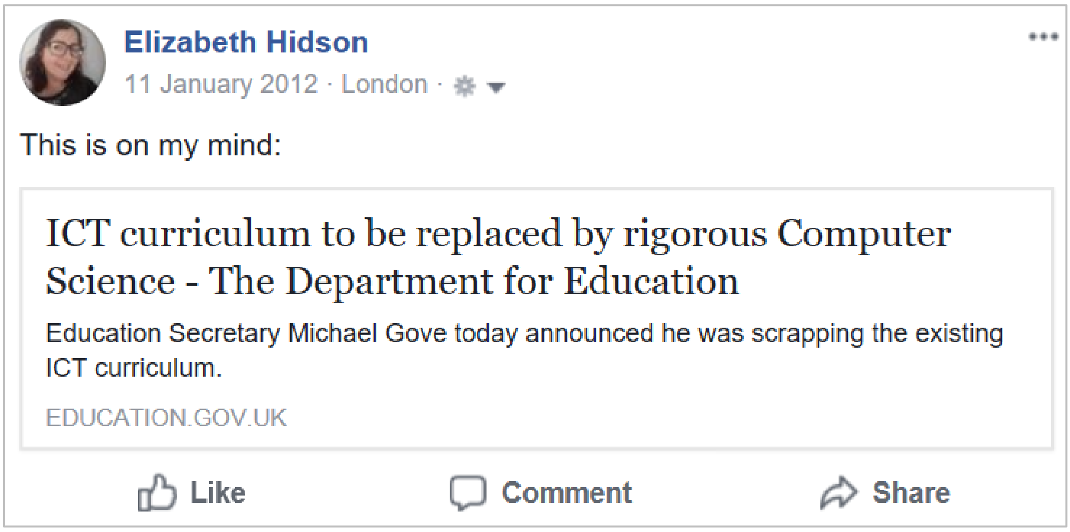

Figure 1.1: Social media post in reaction to curriculum announcement on 11/01/2012

1.1 Background to the study

The proposal to disapply the English National Curriculum programmes of study for ICT was announced on 11th January 2012. It is fair to say that some form of change had been expected, but the sudden announcement at the 2012 BETT (British Educational Training and Technology) Show by the then Education Secretary Michael Gove was surprising in its assumptions and scope. The social media post in Figure 1.1, above (Hidson, 2012), is indicative of the surprise and concern shared by ICT teachers as the news filtered through.

As an interim measure during the announced curriculum review, from September 2012 to September 2014 ICT as a National Curriculum subject would remain compulsory, but schools would no longer have to follow the existing programmes of study. In February 2013, the government proposed to officially replace National Curriculum ‘ICT’ with ‘Computing’ at all four Key Stages, incorporating Computer Science across the full age range for the first time. The new programmes of study for Computing at Key Stages 1 to 4 were published in September 2013, becoming statutory in England from September 2014.

1.2 Overview

This multiple case study explores the perceptions and professional knowledge of experienced teachers of Information and Communications Technology (hereafter ICT) following the disapplication of ICT as a National Curriculum (NC) subject in England and its replacement with Computing from 2014. Specifically, the study seeks to understand how teachers’ professional knowledge in Computing was developed and deployed in order to plan lessons, given that the majority of teachers did not have undergraduate Computing qualifications, and would have trained during the IT /ICT subject era.

The opening chapter introduces the study. The first section discusses the introduction of ICT in the National Curriculum and considers how the shift from ICT to Computing has informed the focus of this study. The next two sections discuss the rationale for the study and its research aims. Thereafter, my researcher positionality and interest in the topic are introduced prior to outlining the structure of the thesis.

1.2.1 Context of the study

This study is located in the broader context of Computing Education in English primary and secondary schools, specifically the teaching of Computing (formerly ICT) as an English National Curriculum subject. The introduction of ICT into the National Curriculum, and the variety of terms used to describe it are discussed, followed by an examination of the drivers for the introduction of Computing. Extracts from a series of programmes of study documents illustrate the shift in foci.

1.2.2 ICT in the National Curriculum

In an international comparison of Computing in schools, Sturman and Sizmur (2011) pointed to the problematic terminology around the discrete subject areas of ICT and Computing, with a wide range of labels used, ranging from Information Technology and Informatics to Computer Studies and Computer Engineering Technology (Sturman & Sizmur, 2011). Additionally, the “absence of a strong research base” (Hammond, 2004, p.30) and the lack of a ‘Pedagogy of IT’ (Brosnan, 2000) has led to misconceptions about the subject. The Royal Society ‘Shutdown or Restart’ report (2012) advocated rebranding the existing UK ICT curriculum to ‘Computing’ and its disaggregation into three parts: Digital Literacy, Information Technology and Computer Science (The Royal Society, 2012). Computing was subsequently introduced, Wing’s model of computational thinking was referenced (Wing 2006) and Computer Science and programming were foregrounded (see Figure 1.2, below (DfE, 2013, p.1)).

The national curriculum for computing aims to ensure that all pupils:

- can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation
- can analyse problems in computational terms, and have repeated practical experience of writing computer programs in order to solve such problems

Figure 1.2: Aims from the 2013 Computing programmes of study

Although the existing programmes of study did not preclude aspects of Computer Science being taught, they were less explicit about programming than earlier versions: see Figure 1.3, below, from the 1989 HMSO report on Information Technology from 5 to 16 (HMSO, 1989, p. 26).

70. While it is not envisaged that all pupils would undertake the detailed study of a programming language they should understand the concept of a computer program as a set of instructions. This understanding can be promoted by the use of certain drawing or control packages where a sequence of moves can be 'saved up' and executed together. The contribution of particular instructions to the whole can be examined without discussing in detail the underlying algorithm. Some pupils will have acquired a detailed knowledge of programming by using computers at home or by specialist study at school. It is important to take account of what will be a much greater divergence in attainment than is often found in other areas of the curriculum so as not to frustrate interested pupils.

Figure 1.3: Objective (iv) 'Simulation and Modelling', HMSO 1989

In the HMSO report, computer programs and algorithms were discussed, in comparison to Figure 1.4, below, from the 2004 update of the National Curriculum (QCA, 2004, p. 90), which allowed for a broader interpretation.

Developing ideas and making things happen

2 Pupils should be taught:

a to develop and explore information, solve problems and derive new information for particular purposes [for example, deriving totals from raw data, reaching conclusions by exploring information]

b how to use ICT to measure, record, respond to and control events by planning, testing and modifying sequences of instructions [for example, using automatic weather stations, datalogging in fieldwork and experiments, using feedback to control devices]

c how to use ICT to test predictions and discover patterns and relationships, by exploring, evaluating and developing models and changing their rules and values

d to recognise where groups of instructions need repeating and to automate frequently used processes by constructing efficient procedures that are fit for purpose [for example, templates and macros, control procedures, formulae and calculations in spreadsheets].

Figure 1.4: Developing Ideas strand from 2004 version of the ICT programmes of study

Mee (2014) examined the "broad and almost universally applicable themes" of the previous IT/ICT programmes of study, a point which was acknowledged by the Royal Society (p. 46) but not by the then education secretary Michael Gove, who, in his landmark disapplication of ICT speech in January 2012 deemed the existing curriculum to be a "roadblock", arguably demonstrating a significant lack of understanding about either the existing curriculum or its organic avenues for development.

1.2.3 The change from ICT to Computing

The Royal Society had previously reported that only 4,600 out of a total estimated population of 18,400 teachers of ICT in the secondary (11-18) sector possessed both relevant first degree and teacher training qualifications (Royal Society, 2012, p. 72) in order to teach ICT as a subject. The number with qualifications in Computer Science was unreported but can be assumed to be a subset of the reported ICT figure. The curriculum change therefore created the need to upskill not just the majority of secondary-sector ICT teachers, but also, albeit to a lesser extent as it was only one subject amongst many the teachers would have to deliver, the estimated 209,500 primary school teachers (DfE, 2015) charged with teaching Computing as part of the statutory National Curriculum provision for children up to the age of 11.

This heralded a period of immense curriculum change as principles of Computer Science, computational thinking and programming replaced the former focus on 'ICT capability' a construct elaborated on more fully in a study by Brosnan (2000) and Barnes and Kennewell (2018). ICT capability was described by the Qualifications and Curriculum Authority as "not only the mastery of technical skills and techniques, but also the understanding to apply these skills" (QCA, 2007, p. 121). The switch in emphasis from the use and application of tools to the principles of "information and computation, how digital systems work, and how to put this knowledge to use through programming" (DfE, 2013a, p. 1) meant that, in many cases, teachers started from scratch, planning and resourcing for an entirely new academic discipline, undergoing intensive upskilling and navigating pedagogical uncertainty during the transition from ICT to Computing.

ICT as a subject had previously suffered from the "absence of a strong research base" (Hammond, 2004, p.30) arguably in part because of problematic terminology around the discrete subject areas of ICT and Computing, with a wide range of labels used internationally, ranging from Information Technology and Informatics to Computer Studies and Computer Engineering Technology (Sturman & Sizmur, 2011; Woollard, 2018). Misconceptions about the status of ICT as a skillset rather than an academic subject meant that as far back as 2005, Woollard concluded that "much is to be determined regarding the curriculum structure and pedagogic order" for Computing (Woollard, 2005, p.192).

At a time when Computer Science pedagogy is still a critical question for CS Education research internationally (CSTA, 2013) the current study is important in order to contribute to the educational research agenda developing around the new statutory Computing programmes of study in England. Sentance, McNicol and Dorling (2012), who were involved in research around the challenges of upskilling ICT teachers through their involvement with the Computing at School grassroots organisation concluded that "there is a need in the UK for teachers to have confidence at an academic level to teach Computer Science; however professional development relating to pedagogy must not be ignored" (2012, p. 85). The current study is situated in precisely this nascent research space. It is an area that is both conceptually and theoretically interesting.

1.3 The rationale for the study

Interest in the topic arises from the researcher's background as an ICT teacher. Broader senior leadership duties before, during and beyond the curriculum shift necessitated direct experience of managing the change at classroom, departmental and whole-school levels, giving rise to an academic curiosity about teachers managing these multiple demands. The objective of this proposed study is to understand how experienced ICT teachers have adapted their professional practices during the transition from teaching ICT to teaching Computer Science, computational thinking and programming, approaching the topic with a perspective born of direct experience. The aim of this study is to explore the ways teachers' pedagogical practices have developed, in order to contribute to the nascent educational research agenda around the statutory Computing programmes of study in England.

1.4 Research aims

The overarching research goal is to understand how experienced teachers of ICT (now teachers of Computing) have responded to the changes in professional knowledge and pedagogical practice necessitated by the new curriculum. The aim of the study is to explore the ways that teachers plan their Computing lessons in order to understand how they are 'filling in the gaps' in their subject knowledge and how they are developing pedagogical strategies for the new curriculum. The new programmes of study centre on Information Technology, Digital Literacy and Computer Science as three core areas, with particular emphasis on Computer Science and programming. Given that serving ICT/Computing teachers may have a relative deficiency in their Computer Science and/or programming subject knowledge, the changes will have required teachers to upskill to varying degrees whilst in post in order to teach these elements.

Arguably, the locus of teachers' professional knowledge and skill is at the level of classroom practice, and can be conceptualised using Shulman's (Shulman, 1986, 1987) Pedagogical Content Knowledge construct (hereafter PCK). This suggests that it is during the lesson planning process that teachers draw on their various professional knowledge bases in a process of pedagogical reasoning to inform their classroom practice. In doing so, they demonstrate PCK as they seek to transform subject matter knowledge for the purpose of teaching it to students in a way that students will understand. PCK in Computer Science teaching is recognised as crucial for its success, but remains under-researched (Brown et al., 2013; Crick, 2017; Hubwieser, Magenheim, Muhling, & Ruf, 2013; Waite, 2017).

The objectives of this study are to explore the lesson planning processes of a sample of ICT/Computing teachers with varying backgrounds and levels of subject knowledge and expertise relating to the teaching of Computer Science and programming. This will contribute to the understanding of the professional and pedagogical development of Computing teachers. It will allow exploration of the variation in approaches and the impact of teacher beliefs on the nature of PCK (Coe, Aloisi, Higgins, & Major, 2014) and planning, instructional decisions and classroom practices (Jimoyiannis & Komis, 2007). It will also allow for a further theoretical development of Shulman's work on PCK as it relates to the objective conditions of practice changing so much that "those pedagogies that depend on practice will necessarily have to change" (Shulman, 2005, p.59).

1.5 Research questions

In this study my overarching aim is to understand in-service teachers' perceptions of the transition from teaching ICT to teaching Computing under the new statutory 2014 National Curriculum in England programmes of study for Computing at Key Stages 1 to 4 and to explore their application of professional knowledge and skills through planning Computing lessons under the new curriculum. Subsumed within this are the following aims:

- To explore participants' perceptions of the curriculum change and its impact on their teaching.
- To explore how different participants address the Computing subject knowledge requirement, given their differing entry routes to teaching ICT and that all pre-2014 teaching in England was within an IT or ICT curriculum framework.
- To investigate the extent to which the concept of pedagogical content knowledge and its enactment through pedagogical reasoning (Shulman 1986, 1987) can be applied to understand the processes involved in planning lessons during the transition from ICT to Computing.

Research questions and sub-questions:

1. How do participant teachers perceive the ICT to Computing curriculum change?
    a. What are participant teachers' perceptions of the ICT and Computing curricula?
    b. What are participant teachers' perceptions of the transition from teaching ICT to teaching Computing?
    c. How do participant teachers perceive the subject-specific professional development available to them during the transition?
2. How do participant teachers approach the planning of Computing lessons?
    a. How is PCK enacted through pedagogical reasoning when participant teachers plan Computing lessons?
    b. How is the Computing subject knowledge requirement being addressed by different participant teachers to enable them to plan lessons?
    c. To what extent do participant teachers draw upon subject-specific sources and resources to enable them to align their planning with the programmes of study?

1.6 Researcher positionality

As a graduate of a combined honours Information Technology and English Literature degree, I began my Information Technology PGCE course in September 1999, just as new curriculum changes were being made and the subject was renamed ICT. My colleagues and I had a light-hearted moment when we joked that, as holders of a PGCE in IT, we were not qualified to teach the new subject: 'ICT'. This memory resurfaced with the disapplication of ICT and introduction of Computing from 2014. Once again, there was a perception of disenfranchisement, only this time the changes were far more drastic and I, along with other ICT teachers I was in contact with, realised that we would need to significantly upskill to be able to make the transition to teaching many of the Computer Science and programming expectations of the new Computing curriculum.

At this stage, having progressed professionally from ICT teacher to head of department, assistant headteacher and then deputy headteacher, with experience as an ICT Lead Practitioner and Advanced Skills Teacher (AST) and with an MA in ICT in Education, I had significant experience of supporting colleagues with curriculum change and professional development. This time, however, the subject knowledge requirement changes were significant, and the pedagogical demands in relation to the teaching of programming surfaced. My concern as I supported struggling colleagues to adapt to change left me with questions about professional knowledge and pedagogical practice. As I took the step out of school into my doctoral studies, I considered that academic research would allow me to address these concerns theoretically and empirically, and they became the research aims of this study.

In light of this, the current study brings my professional experience to bear on the need to explore and illuminate the professional knowledge and pedagogical practices of teachers attempting to make the transition from ICT to Computing. The research was developed in the hope of standing as a marker in the history of Computing Education in England, but also in the hope of contributing to the literature on developing pedagogical practice in the teaching of Computing as a new English National Curriculum subject.

1.7 Outline of the chapters

The literature review (Chapter Two) begins with a brief overview of the intersectional space in which this research is situated, that of curriculum change and attendant changes in teacher knowledge. Shulman's concepts of pedagogical content knowledge (PCK) and pedagogical reasoning are explored and established as the framework for understanding teachers' professional knowledge. Specific literature from the field of Computing Education is presented to contextualise the 2014 curriculum change and provide a stimulus for later discussion of the findings. Chapter Three discusses the methodological approach to developing this multiple case study and describes the digital methods selected for data collection. It also presents the approaches to transcription, coding and data analysis.

Chapters Four and Five present the findings of the study, with each chapter focusing on one research question and its associated sub-questions. Case descriptions, tabulated summaries and thematic cross-case analyses are used to present findings in relation to participants' perceptions of the curriculum change and also to illustrate findings in relation to their approaches to planning lessons. In order to connect the analysis and discussion of the findings to the data which support them, I have taken a holistic approach to discussing issues drawn from the participants' dialogue, actions and wider documentary evidence. This has the additional benefit of focusing on the insights gained from practitioners, which have the potential to be revelatory because of the lack of current research into this area. I use Webb's (2002) adapted model of Shulman's (1986, 1987) pedagogical reasoning and PCK frameworks as a lens with which to view teachers' professional knowledge and practice influenced by their ideas, beliefs and values.

In the final chapter (Chapter Six), I summarise the findings, discuss their implications and make suggestions for further research.

Chapter 2 Literature Review

2.1 Introduction

Following on from the context of the study discussed in Chapter One, the purpose of this chapter is to provide an overview of the literature which has shaped the research questions and sub-questions of the current study. The study aimed firstly to investigate in-service teachers' perceptions of the transition from teaching ICT to teaching Computing following the 2014 curriculum change, and secondly to explore the teachers' application of their professional knowledge and skills through planning Computing lessons that aligned with the new programmes of study.

The chapter is divided into two sections. In the first section, the main areas of the literature that relate to the study are outlined, and relevant research located within intersections of the topics is examined. In the second section, literature reporting on and responding specifically to the context of the 2014 change in UK Computing Education is appraised in order to locate the current study within the contemporary debates and provide a stimulus for the later discussion of the findings.

Although a wealth of literature exists in the areas of curriculum and curriculum change these areas will not be analysed in detail and are only referred to in a limited thematic way in order to advance towards the point at which the specified topics intersect in the current study.

2.2 Curriculum and change post-1988: The National Curriculum

A key theme arising from the field of curriculum theory is that of knowledge (Bernstein, 1971; Cullingford & Oliver, 2001; Kelly, 2009; Oliver, 2001; Young, 2013). Bernstein's pre-National Curriculum era seminal work on educational knowledge defined 'curriculum' as "what counts as valid knowledge", 'pedagogy' as "what counts as valid transmission of knowledge" and 'evaluation' [to wit: 'assessment'] as "what counts as a valid realization of this knowledge on the part of the taught" (Bernstein, 1971). Bernstein's definitions provided conceptual building blocks for the current study, which investigates teachers' responses to a specific curriculum change in 2014. This is set within the wider national educational policy context of the English National Curriculum established by the 1988 Education Act. Although Young (2013) pointed to a post-National Curriculum crisis in curriculum theory, arguing that it had lost "its primary object—what is taught and learned in school" (2013, p. 105), he maintained that "the struggle over schooling has always has been a struggle for knowledge" (2013, p. 115). Ample research exists in the fields of curriculum theory and curriculum change, but the National Curriculum-era literature operates from a conception of curriculum that is prescribed for schools and teachers rather than being determined by them. Kelly (2009) characterised these ongoing curriculum changes post-1988 as "central political control of the school curriculum" (2009, p. 2). The National Curriculum, which has experienced multiple revisions since 1988, currently sets out the programmes of study and attainment targets "for all subjects at all 4 key stages. All local-authority-maintained schools in England must teach these programmes of study" (Department for Education, 2013), the majority of which were introduced for first teaching from September 2014.

The curriculum, or certainly the current English National Curriculum, exists as a set of mandatory 'subjects', each prescribed by 'programme of study' documents, in what Bernstein (1971) would define as a 'collection' type of curriculum. In addition, the subjects can be considered (in Bernstein's terms) to be strongly or weakly 'classified' in relation to the boundaries between the contents of each subject and strongly or weakly 'framed' in the way in which each subject is taught or assessed. Young (2013) argued that school subjects are recontextualized from academic disciplines. In this sense, they provide educational continuity and, although simplified in the school context, subjects are recognisably part of an overarching discipline to which a learner can gain access. Young further argued that,

> the link between subjects and disciplines provides the best guarantee that we have that the knowledge acquired by students at school does not rely solely on the authority of the individual teacher but on the teacher as a member of a specialist subject community." (2013, p. 114)

The crux of the issue as it relates to the current study is that one subject (ICT), arguably a relatively weakly classified branch of the overarching discipline (Computing) was, in effect, swapped with a more strongly classified branch of the overarching discipline (Computer Science), leading to a situation whereby the majority of in-service ICT teachers could not be considered as members of this specialist subject. Young further stressed the importance of teacher knowledge in relation to pedagogy within the schooling struggle:

> "Pedagogy… refers to what teachers do, and get pupils to do; however, teaching is not just a practical activity …Teaching depends on both the knowledge that teachers have of their subject, the knowledge that they have about individual pupils and how they learn—and the knowledge that informs what they require their pupils to do" (2013, p. 111).

Although political control of the National Curriculum has now been in place for thirty years, the current study is located within a problematic situation which, according to Kelly, continues to exist whereby the architects of National Curriculum policies refuse to take any account of research into the role of teachers. Kelly further stressed the '"make or break" role that teachers have in all curricular activities, even in relation to those which "originate outside their schools" (2009, p. 2). Clear warnings have emanated from curriculum theorists about hasty policy decisions and the impacts of an imposed curriculum (Cullingford & Oliver, 2001) and the subsequent potential differences between the 'planned' versus the 'received' curriculum (Kelly, 2009). A key finding for Alwan (2006) from a synthesis of educational change research, citing Markee, (1997) and Fullan and Hargreaves (1992) was that "curriculum change challenges teachers' existing skills" (2006, p. 51), although this might be better expressed as 'curriculum change challenges teachers' knowledge and skills' in respect of the current study. The importance of teachers' knowledge and pedagogy in relation to curriculum change constitutes a significant educational issue, and one that is at the heart of the current study.

2.3 The pedagogy of ICT as a subject

Building on section 1.2.2 and 1.2.3, which outlined the position of ICT as a subject in the National Curriculum and its replacement by Computing as a subject, it is necessary to highlight the niche of work concerning the pedagogy of ICT as a subject. A key paper by Crawford (1998) pointed to the inherent contradiction between the behaviourist approach that he saw as dominating teaching in English state secondary schools and the inherently constructivist approach which he saw as the only workable method for teaching IT. However, recognising the difficulty of a theoretically pure constructivist approach, and building on work by Selinger (1997), which suggested that the constructivist strategies for developing pupils' cognitive and metacognitive strategies were not currently situated in the IT community of practice, Crawford argued for a pragmatic, minimalist approach in developing a constructivist model of teaching IT. Crawford called for additional research to develop a new pedagogy for teaching IT that would be "theoretically sound; and that guides teachers in using constructivist approaches" (Crawford, 1998, p. 2). Crawford further highlighted the problems of the lack of teachers specifically trained to teach IT, and the rapid and unpredictable development of IT. This meant that IT teachers had difficulty maintaining the subject knowledge "needed to construct behaviourist programmed learning materials … except where the focus of these is very narrow. (Crawford, 1998, p. 8).

Decrying the paucity of research into the pedagogy of ICT as a subject, Kennewell, Parkinson and Tanner (2000) focused primarily on the development of ICT capability (discussed earlier in section 1.2.3) as the core pedagogical structure of ICT. They distinguished "two main paradigms or cultures of specialist ICT teaching: the *academic* culture and the *capability* culture" (2000, p. 108) suggesting that an academic ICT culture separates the theoretical and the practical, whereas a capability ICT culture is more in line with the constructivist approach suggested by Crawford (1998). The capability culture is characterised by collaborative, practical approaches that encourage higher-order skills and concepts, enabling the development of schemata and mental models about computer systems.

Later, Webb and Cox (2007) described the evolution of the ICT curriculum, and pointed to the introduction of the national Key Stage 3 ICT Strategy in 2002, which contained " schemes of work, lesson plans, teaching materials and advice on teaching and learning strategies" (2007, p. 3). Webb and Cox characterised the pedagogical intention of the Key Stage 3 ICT Strategy as "a spiral curriculum in which learners gradually tackle more complex tasks that are scaffolded to develop the ICT skills, knowledge and understanding; problem-solving strategies; and thinking skills that they need" (2007, p. 3). By 2009, the alignment of ICT capability, social constructivism and the national ICT strategy were explicit in ICT teaching handbooks, such as Simmons and Hawkins (2009) and Kennewell, Connell, Edwards, Hammond and Wickens (2007).

By the time of the disapplication of ICT in 2012, it is reasonable to suggest that the pragmatic, minimalist principles put forward by Crawford, which had played out to varying degrees as a focus on ICT capability rather than basic skills and been enacted through the approach of the Key Stage 3 ICT Strategy were the dominant, yet under-researched pedagogical principles underpinning ICT as a subject.

2.4 Teacher knowledge

In his influential 1986 article, Shulman decried the lack of focus in research and policy on the domain of teacher knowledge, citing a historical shift towards teacher effectiveness as a primary benchmark of teacher standards. Shulman maintained that, in the effort to identify effective teaching processes that led to improved academic attainment, the content of the teaching had become relatively unimportant and asked "where did the subject matter go?", describing its absence as "the missing paradigm" (Shulman, 1986, p. 5,6). Shulman's response to this research "blind spot" (p.7) was to suggest the need for a framework to describe the domain of content knowledge in teaching. He proposed three initial categories: a) subject matter content knowledge, b) pedagogical content knowledge and c) curricular knowledge, summarised in the table below.

Table 2.1: Representation of Shulman's (1986) three categories of teacher knowledge

Subject Matter Content Knowledge	Pedagogical Content Knowledge (PCK)	Curricular Knowledge
-The amount and the organization of knowledge in the mind of the teacher -Content can be represented and theorised in various ways -The teacher's subject matter content understanding in relation to the discipline	-Subject matter *for teaching* -Aspects of content most germane to its *teachability* -Representations: analogies, illustrations, examples, explanations, demonstrations -Understanding of what makes the learning of specific topics easy or difficult	- [educational] programs designed to teach particular subjects and topics -Instructional materials: texts, software, programs, visual materials, films, demonstrations etc. -Understanding of the characteristics of the materials

In his 1987 work, Shulman expanded from the original three categories to seven, thereby including general pedagogical knowledge as well as knowledge of learners, of educational contexts, and of educational purposes (see Figure 2.1, below). He continued to consider pedagogical content knowledge (PCK) of "special interest" as it represented "the blending of content and pedagogy" (Shulman, 1987). This "rich, new understanding of teachers' knowledge" (Aubrey, 1997, p. 9) premised on the idea of "pedagogical reasoning [placing] emphasis on the intellectual basis for teaching performance rather than behaviour alone" (Shulman, 1987) acted in opposition to the primacy of classroom management criteria over "the adequacy or accuracy of the ideas transmitted" (Shulman, 1987), a situation arguably as recognisable now as in the 1980s.

Central to the current study is the Computer Science subject knowledge expectations placed upon in-service teachers of ICT in light of the 2014 curricular shift, uncannily suggesting a reprise of Shulman's question: "how does the teacher prepare to teach something never previously learned?" (1986, p. 8). Figure 2.1, below, represents Shulman's fundamental categories of teacher knowledge, which will be operationalised in this study.

Categories of the Knowledge Base

If teacher knowledge were to be organized into a handbook, an encyclopedia, or some other format for arraying knowledge, what would the category headings look like?[4] At minimum, they would include:

- content knowledge;
- general pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter;
- curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers;
- pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding;
- knowledge of learners and their characteristics;
- knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures; and
- knowledge of educational ends, purposes, and values, and their philosophical and historical grounds.

Figure 2.1: Shulman's (1987) seven categories of teacher knowledge

Co-located with the literature around Shulman and PCK was a field of research surrounding the incorporation of technology as a teacher knowledge base. The work based on Mishra and Koehler's TPACK framework (Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2009; Mishra & Koehler, 2006), which was built on Shulman's PCK, looked specifically at teachers' integration of technology into pedagogy. This was encapsulated in a conceptual framework of Technological Pedagogical Content Knowledge (TPACK). Ostensibly, this has relevance to the current study because teachers would also be integrating technologies into their teaching of the Computing curriculum. However, the current focus was specifically on teachers' content knowledge in relation to teaching Computing and Computer Science, meaning that study of their knowledge of technology and its integration, although interesting, was beyond the scope of the current study.

2.4.1 Critiques of PCK

As well as gaining a following of teacher educators and researchers for whom "Shulman's ideas about teacher knowledge… made sense" (Abell, 2008, p. 1405), PCK as a construct has been critiqued for its inherent ambiguities (Marks, 1990), teacher-centredness (Banks, Leach, & Moon, 2005) and lack of consensus amongst researchers (Settlage, 2013). However, criticisms of PCK suggesting that knowledge is static (Banks et al., 2005) have been widely contested by PCK researchers who posit PCK as dynamic knowledge (Abell, 2008; Kind, 2009; Nilsson, 2008; Nind, Kilburn, & Wiles, 2015; Park & Oliver, 2008; Seymour & Lehrer, 2006; Şimşek & Boz, 2016). It has also been defended against criticism of its lack of explanatory power (Abell, 2008; Berry, Friedrichsen, & Loughran, 2015; Kind, 2009; Seymour & Lehrer, 2006) although Abell (2008) allowed that "most PCK research in science education is based on small-scale studies that are descriptive in nature" (2008, p. 1412), a situation she cited as changing due to the advent of some large, longitudinal studies involving PCK. It is recognised that issues surrounding methodology and portrayal of knowledge are constant themes in research into teacher knowledge (Chan & Yung, 2015; Loughran, Mulhall, & Berry, 2004; Marks, 1990).

Kind (2009) comprehensively reviewed the various criticisms of Shulman's model and found some of the early critiques around vagueness and lack of theoretical background "fair, given that PCK was devised in principle before any research was undertaken that provided supporting evidence"(2009, p. 11). She also noted that the different models developed by researchers using PCK "point to Shulman's views being rather simplistic - one common feature is that… researchers seem to agree that PCK is more complex than he implied originally" (2009, p. 11), and therefore different researchers have added different components to Shulman's original model. These additional components have been collectively described as "amplifiers and filters" (Berry et al., 2015, p. 31) and include concepts such as teacher beliefs, orientations, prior knowledge and context, aspects which have been recognised for their impact on student outcomes (Coe et al., 2014). In addition, Feldman (1996) sought to introduce a social aspect to what he termed as Shulman's 'cognitive model', asking how "teachers' knowledge can be generated in their social milieu" (1996, p. 6) a call examined in the later section on collaborative aspects of PCK.

Whilst healthy debate about PCK is key to its longevity as an area worth researching, or perhaps, with a nod to Shulman, to its *researchability*, the key viewpoint that sustains Shulman's work on teacher knowledge as the underpinning construct for the current study comes from Gunstone (2015), who summarised the work of the 2012 PCK Summit (BSCS, 2012) and concluded that he was,

> "struck again by the clear recognition that the value of the construct of PCK lies in its potential to represent powerful ideas not otherwise represented in our lexicon of teacher knowledge and expertise" (Gunstone, 2015, p. 252).

Conceptualisation of teachers' professional knowledge and expertise has again been lacking in the most recent curriculum change: the current study seeks to address that gap.

2.4.2 Developing Pedagogical Content Knowledge

Arguably, there is a minimum level of content knowledge required as a precursor to begin developing PCK, therefore in-service teachers without sufficient content knowledge in Computer Science will lack the level of PCK gained from previous teaching experience. In this sense, they may be starting almost from scratch with some aspects of the curriculum and may revert to novice teaching strategies as their overall PCK is reduced by the subject knowledge deficit. This can be linked to the theme within the literature on teacher knowledge that focuses on 'novice' and 'veteran' teachers. However, whilst Computer Science is a new discipline for many, the PCK gained as teachers of ICT could be useful in linking the old subject to the new. Although PCK is not multi-disciplinary as a construct, the underpinning pedagogical strategies developed through working within the ICT Education field may have a facilitating role. The recurring theme relating to the personal nature of PCK is of interest because it seems logical to assume that experienced teachers' previous teaching backgrounds will have relevance to their approach to planning to align with the new programmes of study.

2.4.3 Novice and veteran teachers

Significant research has been carried out into the development of PCK, a prime consideration in the current study. Although much research has been done investigating the development of PCK in beginning teachers, or 'novices', and those for whom the subject matter is new (Achinstein & Fogo, 2015; Depaepe et al., 2015; Gudmundsdottir & Shulman, 1987; Mulhall, Berry, & Loughran, 2003; Nilsson & Loughran, 2012; Park & Oliver, 2008; Rusznyak & Walton, 2011; Van Driel, De Jong, & Verloop, 2002), there exists a small branch of PCK research that takes experienced or 'veteran' teachers as its focus (Lee & Luft, 2008; Park & Chen, 2012; Park & Oliver, 2008), often through the lens of professional development (Rozenszajn & Yarden, 2014) or by focusing on their involvement in the development of curriculum materials [to wit: 'resources'] (Juang, Liu, & Chan, 2008).

Although Gudmundsdottir and Shulman (1987) posited that the difference between novice and veteran teachers is 'manifested as PCK', a position echoed by Park and Oliver (2008), there seems to be a consensus that novices have limited PCK (Achinstein & Fogo, 2015) and that it must be developed over time (Lee & Luft, 2008) through repeated experiences in the classroom (Appleton, 2008; Van Driel et al., 2002) and long term immersion (Juang et al., 2008).

Novice teachers draw on 'received knowledge' (Gudmundsdottir & Shulman, 1987) gained through prior experiences. Having formerly been the pupil, they must learn to become the teacher and find ways to transform their received knowledge for teaching purposes. Several studies have found that participants often lacked subject knowledge (Achinstein & Fogo, 2015; Gudmundsdottir & Shulman, 1987; Van Driel et al., 2002) and that their practice could be characterised by short-term coping techniques as they tried to stay out of trouble and progress through the curriculum (Gudmundsdottir & Shulman, 1987). Developing PCK therefore requires mastery of a substantial level of content knowledge (Achinstein & Fogo, 2015; Depaepe et al., 2015; Nilsson & Loughran, 2012), but it is clear that content knowledge alone is insufficient for the acquisition of PCK. With a lack of PCK, novice strategies can involve teaching as 'telling' rather than representing knowledge in a teachable way (Halim & Meerah, 2002). An overtly didactic approach is evidence of limited PCK because learning to teach a subject needs to focus on learning about the way that students learn (Nilsson & Loughran, 2012), although as Etkina (2010) pointed out, veteran teachers can also be didactic, echoing Van Driel et al's (2002) discussion of knowledgeable, experienced teachers who lack PCK. It therefore follows that PCK does not develop spontaneously, that different teachers will develop in different ways and that study of its development is therefore useful. The core issue is that subject knowledge affects PCK. The question remains as to whether experienced teachers' existing pedagogical knowledge can be useful in a situation where they suddenly lack subject knowledge?

Experienced teachers are generally accepted as having more extensive, specialised knowledge bases (Lee & Luft, 2008; Park & Chen, 2012; Rozenszajn & Yarden, 2014) and being able to see the bigger picture and patterns (Gudmundsdottir & Shulman, 1987; Rusznyak & Walton, 2011). They are able to interpret multiple significant contextual clues (Mulhall et al., 2003; Rusznyak & Walton, 2011) and draw simultaneously from multiple domains (Lee & Luft, 2008) when planning and teaching. However, these views infer a reasonably stable longitudinal situation, such as might be expected when a teacher teaches the same subject, perhaps in the same school, over an extended period of time. The realities of teacher mobility or being required to teach additional non-specialist subjects are potentially disruptive scenarios which can interfere with an experienced teacher's PCK. Teaching outside one's specialism therefore limits PCK as the teacher may not have the content knowledge for effective PCK for other topics or disciplines (Appleton, 2008; Gudmundsdottir & Shulman, 1987; Mulhall et al., 2003). Kind (2009) maintains that "a teacher with well-established, good PCK relating to one specialist subject experiences uncertainty and hesitation when faced with teaching new, unfamiliar subjects" (p. 23), for example a Biologist teaching Chemistry, or in the case of the current study, ICT teachers teaching Computer Science, citing examples in the literature suggesting that this can cause experts to revert to novices in some aspects of their practice.

2.4.4 The personal nature of Pedagogical Content Knowledge

Teachers bring an array of background characteristics and experiences to their professional role. It is reasonable to expect that these would shape their teaching practices in potentially explicit ways. In relation to PCK, various authors have characterised it as being unique or personal to each teacher (Etkina, 2010; Lee & Luft, 2008; Rozenszajn & Yarden, 2014) or even as idiosyncratic (Aydin, Demirdogen, Nur Akin, Uzuntiryaki-Kondakci, & Tarkin, 2015; Mulhall et al., 2003; Nilsson & Loughran, 2012; Park & Chen, 2012). Nilsson and Loughran (2012) developed the idea of idiosyncrasy more fully as they proposed that the 'enactment' of PCK is the moment at which teachers integrate the different constituent components of PCK. They further held that each component is developed as a result of different experiences and knowledge and is therefore idiosyncratic, quoting one of their pre-service science teacher participants to support this idea: "That the students don't understand is no longer a problem for me as I now consider that you as a teacher can explain things in a thousand different ways" (Nilsson & Loughran, 2012, p. 716). The idea that each teacher could explain the same concept multiple ways is a clear route back to the differences that inform their individual PCK, which could be inspired by background-specific or context-specific experiences.

The differences in PCK are felt to be difficult to explain (Baker & Chick, 2006) but various researchers have linked them to subject knowledge (Aydin et al., 2015; Depaepe et al., 2015; Gudmundsdottir & Shulman, 1987; Halim & Meerah, 2002; Lee & Luft, 2008; Nilsson & Loughran, 2012; Van Driel et al., 2002). The majority of these studies involved pre-service teachers, where differences in subject knowledge were likely to be at their most observable

(Van Driel et al., 2002) and make the most difference during lesson planning (Rusznyak & Walton, 2011). Depaepe, Torbeyns, Vermeersch, Janssens, Janssen, Kelchtermans, Verschaffel and Van Doorenet's (2015) comparison of prospective elementary and lower secondary teachers used a pencil and paper test of CK and PCK, which suggested a "positive linear relationship between CK and PCK" (2015, p. 89), which is helpful in supporting the notion of subject knowledge being a significant factor in differences between teachers' PCK. One study which focused on experienced teachers (Park & Chen, 2012) gives a tantalising sense of the differences as the four Biology teachers in their study taught at the same school, using the same materials and similar lesson plans, thereby controlling at least for content and the subject knowledge to deliver it: a common situation in secondary school subject departments. Park and Chen found that the teachers integrated components of PCK in different ways and concluded that teacher beliefs and background regulate this process. In an earlier paper, Park and Oliver (2008) proposed that teacher confidence and belief in their own abilities should be considered as components of PCK. These concepts are critical in the current thesis study. It is logical to assume that at times of curriculum change, teachers' confidence in themselves as well as their subject knowledge may be less secure and therefore impact on PCK. It follows therefore, that teachers' ideas, beliefs and values impact on their processes of pedagogical reasoning.

2.5 Lesson planning

The process of lesson planning is, at its simplest level, thinking about what to teach, how to teach it, and to whom. Equally, it covers the range of "things that teachers do when they say they are planning" (Clark & Yinger, 1987, p. 86). Clark and Yinger maintained that "planning is challenging to study because it is both a psychological process and a practical activity"(1987, p. 86). In terms of the current study, both aspects are of interest as the teachers' planning is disrupted by recent significant curriculum changes, and therefore the teachers' perceptions, thought processes and actions are all relevant. In their review of research on teacher planning, Clark and Yinger cited an earlier study reported in their 1979 studies of teacher planning (Clark & Yinger, 1979) whereby different types of planning were undertaken for different purposes, such as unit planning and daily planning at elementary [primary] school level. Individual lesson planning from unit plans, which is more central at secondary school level, would logically seem to parallel daily planning for primary school teachers in its functional importance. Clark and Yinger (1987) reported that few studies had attempted to describe teacher planning as it occurs naturally in all its variety, as well as pointing to the prevalence of think-aloud methods for accessing teachers' thought processes, providing a clear methodological rationale for the direction of the current study.

The term 'lesson resources' is generally understood as curriculum materials (Clark & Yinger, 1979; Evens et al., 2015; Van Driel, Verloop, & De Vos, 1998) either created by the teacher or pre-prepared materials that can be taken and re-used by a teacher. A wealth of materials for Computing have been made available through Computing At School as well as multiple other resource providers (Brown & Kölling, 2013; Pye Tait Consulting, 2017c; Weatherby, 2017). A worksheet or PowerPoint presentation about how to create programming loops, for example, would save a teacher having to create those resources from scratch.

Interestingly, the National Curriculum era has coincided with the expansion of international work on teacher knowledge, despite, or perhaps partly because of the situation whereby at times even the lesson plans and materials as well as the curriculum have been centrally dictated, as with the QCA Schemes of Work for ICT (Barnes & Kennewell, 2018; QCA, 2007). Moving forward, contemporary handbook-type publications exist which aim to generalise the process and aid with "structuring the cognitive and conceptual work you need to undertake to plan for effective teaching and learning" (Savage, 2015, p. 5), usually aimed at beginning teachers who need to develop their skills in lesson planning and pedagogy generally. Very recent relevant work has linked PCK to the importance of lesson planning for Computing in secondary schools post-2014 (Lau, 2017), the key focus for the current study.

2.5.1 Lesson planning: private versus public PCK

Looking at the development of PCK through lesson planning is to examine the point at which content knowledge has to be transformed for teaching purposes. It follows that a teacher will plan a lesson that they think they can teach. The current study looks at Computing teachers' PCK in lesson planning. Lack of CK or PCK in the resulting lessons will derive from events such as an unanticipated topic being encountered in the lessons, for example where a student question leads the discussion to an area of knowledge that the teacher doesn't possess, or a programming challenge that the teacher cannot solve, and therefore the PCK strategies are different. In addition, it is useful to examine the collaborative aspects of planning, including access to online communities of practice, (where learners participate and move toward full participation in the sociocultural practices of a community (Lave & Wenger, 1991)), as significant support, and sources of resources for use in lessons, can be acquired through engagement with social media and internet repositories.

The lens of PCK allows the examination of the transformation of teacher knowledge in order to teach particular content to particular students at a particular time. There is consensus that this is located in classroom practice (Gess-Newsome, 2015; Mulhall et al., 2003; Park & Chen, 2012), which encompasses both the private PCK as used in prospective lesson planning and the PCK in practice that can be observed as the teacher interacts with their students. It may be useful to consider these two faces of PCK as private PCK and public PCK. A lesson is essentially the dynamic public manifestation of that which has been planned in private. Traditionally, lesson observation records episodes that are visible to the observer. This can be problematic as a non-specialist observer may not be attuned to the nuances of the specialist teacher's knowledge and expertise. In high-stakes observations, such as those undertaken for teacher appraisal, job interviews or performance management, there may not be an opportunity to unpick the complexity underpinning the process. The process of lesson planning, however, can be slowed down and each structure and concept examined for fitness for purpose. Lessons can be planned by one or by several practitioners together and allow access to the richness of the PCK (Rozenszajn & Yarden, 2014) involved in the process, in what Rusznyak and Walton (2011) would term space for "pedagogically reasoned choices" (p. 272) as opposed to an instrumentalist description of classroom practice.

Lesson planning can therefore be conceptualised as an expression of PCK (Juang et al., 2008): a fertile cognitive, reflective and experiential space where a teacher plans a lesson to bring together the complexities of the contextualised students and the content or concept they need to learn. "Planning" seems an inadequate word for this powerful process, but it is the professional term used and runs the continual risk of being devalued as a form of component assembly without due consideration of the professional knowledge and skill required. The actual process of lesson planning is widely accepted as a way of developing PCK (Achinstein & Fogo, 2015; Etkina, 2010; Halim & Meerah, 2002; Rozenszajn & Yarden, 2014). Lee and Luft (2008) maintain that the lesson plans and supplementary materials they collected from experienced teachers helped them to understand how PCK was represented in the lesson plans. They also used lesson observation as a data source for their study, taking the teachers' actions as representations of their PCK. The use of other data capture methods for the study of PCK seems vital as, according to Park and Chen

(2012) reliance on lesson observation alone provides limited insight into teachers' PCK. However, it is possible to further the argument by pointing out that examining either the lesson or the lesson planning process without the teacher's input and reflection is like watching a video with the audio channel muted. The teacher's voice must be accorded significant weight if their pedagogical reasoning process is to be fully understood.

2.5.2 Collaborative lesson planning and communities of practice

Two of the main ingredients of PCK are content knowledge and knowledge of students, either generally as in 'a Key Stage 3 pupil' or specifically as in 'the pupils in my top set Year 9 class'. Deficits in other knowledge bases, such as assessment knowledge or curriculum knowledge, may also be present, but a lesson that needs to be prepared must focus primarily on the topic and the students. A solitary teacher will need to access some kind of external resources in order to plan the lesson. Collaborative lesson planning is generally accepted to be a beneficial practice (Achinstein & Fogo, 2015; Appleton, 2008; Aydin et al., 2015; Etkina, 2010; Juang et al., 2008; Mulhall et al., 2003; Park & Oliver, 2008; Rozenszajn & Yarden, 2014), allowing access to another teacher's experience and PCK. For less experienced teachers, working with more experienced teachers in the form of an educative mentoring role (Aydin et al., 2015) can develop PCK (Achinstein & Fogo, 2015) as mentors take the role of a critical friend (Appleton, 2008) and suggest specific developmental actions (Van Driel et al., 2002), or support with curriculum knowledge issues (Gudmundsdottir & Shulman, 1987) in the form of a cognitive apprenticeship (Etkina, 2010). However, this type of approach is resource-intensive, requiring a suitable mentor and protected time in a busy school situation.

A common departmental approach is the planning and resourcing of schemes of work, curriculum documents that, as Mulhall, Berry and Loughran (2003) suggest, "tend to represent the teaching of a topic in an undifferentiated form as certain content to be learned and understood, and activities that might engage students" (Mulhall et al., 2003). While Mulhall, Berry and Loughran find that this is often limited to 'what works', Park and Oliver (2008) find positivity in a co-constructed approach. They see teachers as knowledge producers, not knowledge receivers, as they take materials and adapt them to suit their own purposes: "teachers are not simply doers; those who realize what others have planned" (Park & Oliver, 2008, p. 280). With PCK as the heart of teachers' professionalism, there can be no 'off-the-shelf' solution. There is however, a gap, an unheard commentary that is part of any shared lesson resource. This meta-information is the key to PCK: the results of the reflective process of planning a specific lesson for specific students.

What works for one teacher with their class may work differently for another teacher, for a multiplicity of reasons. The idea of using successful teachers' PCK to develop others (Mulhall et al., 2003) has long been an aspect of the focus on PCK development. Juang's 2008 study of a collaborative school-based curriculum development strategy, which resulted in a knowledge base of lessons plans is an example of the benefit of a collaborative community of practice. Online repositories would have been in their infancy in 1998 when Van Driel aspired to "prevent[ing] every teacher from reinventing the wheel" (Van Driel et al., 1998) but it is clear that the affordances of technology that allow access to knowledge bases (Juang et al., 2008), forums and online resources such as those available through the Computing At School organisation (Crick & Sentance, 2011; Weatherby, 2017) create communities of practice (Lave & Wenger, 1991) that can evolve into personal learning networks (PLNs) for teachers. Small departments and individual teachers may need to turn to the wider professional community for informal support and mentoring. Several studies have highlighted examples of mentors belonging to multiple communities of practice (Achinstein & Fogo, 2015; Etkina, 2010; Rozenszajn & Yarden, 2014), citing them as environments of sharing ideas and critically evaluating new notions (Rozenszajn & Yarden, 2014). A study that investigated online personal learning network experiences through the analysis of survey data (n=732) of U.S. schoolteachers reported that participants described their PLNs as "diverse and multifaceted networks of people, communities, tools, platforms, resources and sites" (Trust, Krutka, & Carpenter, 2016, p. 54). In addition, Trust, Krutka and Carpenter concluded that personal learning networks helped participants meet specific pedagogic needs as well as moving towards new conceptions of their professional identities, precisely the challenge for the teachers in the current study. It is worth considering the extent to which such communities can play a key role in the development of PCK for teachers such as those in the current study, who needed rapid upskilling.

2.5.3 Evidencing and measuring Pedagogical Content Knowledge

In this section various studies are reviewed to see how PCK is evidenced and/or measured in order to gain an understanding of methods used to research PCK. Thus far, getting as close as possible to teachers' authentic practice and reflections seems key to understanding PCK. Rigorous research requires appraisal of the various benefits and limitations of using methods such as video, surveys, questionnaires, PCK organisers, interviews and test instruments to evidence and measure PCK. Although it has been shown that PCK can be evidenced categorically, it also requires interpretation. Whether specific levels of measurement can be applied in a positivist sense, or whether statistical analysis can be useful is a valuable line of enquiry.

Having achieved a broad consensus from the field that PCK is a useful construct for describing teachers' professional knowledge and skill (Aydin & Boz, 2012; Evens et al., 2015; Kind, 2009; Lee, 2007), the reported difficulty of evidencing and measuring PCK means that it remains a fruitful avenue for research as its precise nature remains empirically uncertain (Krauss et al., 2008). It has been argued that teachers' training and daily practice does not require or routinely foster the articulation of PCK (Alonzo, Kobarg, & Seidel, 2012; Loughran et al., 2004; Loughran, Mulhall, & Berry, 2008) but that pre-service teachers who have been exposed to the idea of PCK in their training can recognise it in themselves and in others (Bertram & Loughran, 2012) even when others lack the language to describe their practice in terms of PCK (Loughran et al., 2008). This means that PCK can be studied in terms of what a pre-service or in-service teacher reveals implicitly or explicitly about their practice through a variety of methods designed to capture what they do or what they say about what they do. Alonzo described these methods as,

> reflect[ing] PCK as it is used in practices associated with teaching [such as observations, or as] practices that are further removed from the classroom – such as interviews and paper-and-pencil assessments. (Alonzo et al., 2012, p. 1216).

Regardless of the method of data collection, arguably the key factor is the operationalisation of PCK in the various studies: the difficulty in translating PCK concepts into measurable variables.

2.5.3.1 Evidencing through observation

It has been shown that PCK can be recognised by interpreting teachers' practice in relation to a variety of PCK components. Depending on the model of PCK being used as an interpretive lens, this will usually involve a process of capturing evidence of a teacher demonstrating PCK components in situ. Direct classroom observation is used widely to capture such evidence (Chan & Yung, 2015; Park, Jang, Chen, & Jung, 2010; Prescott, Bausch, & Bruder, 2013), and routinely recorded through audio (Van Driel et al., 1998) or video (Alonzo et al., 2012; Chapoo, Thathong, & Halim, 2014; Nilsson, 2008; Seymour & Lehrer, 2006). Alonzo, Kobarg and Seidel (2012) suggested, however, that a negative impact of merely observing lessons is that teachers do not need to articulate their tacit form of knowledge. Loughran, Mulhall and Berry argued that,

> observations can provide only limited insight into a teacher's PCK, because it is partly an internal construct—thus we must ask teachers to articulate their PCK (2004, p. 373),

suggesting that observations are often coupled effectively with semi-structured interviews. However, while Rohaan, Taconis and Jochems (2009) agreed that PCK is not entirely expressed through teachers' behaviour in lessons, they also contended that "teachers may only use a small portion of their PCK in the observed situations" (Rohaan et al., 2009, p. 330). Extending this idea, Alonzo, Kobarg and Seidel contended that multiple approaches are needed to fully capture teachers' PCK (Alonzo et al., 2012) which ties in with the prevalence of the case study methodology (Chan & Yung, 2015; Chapoo et al., 2014; De Jong & Van Driel, 2004; Ibrahim, Surif, Arshad, & Mokhtar, 2012; Van Driel et al., 1998) for the study of PCK.

2.5.3.2 Evidencing through planning

Following on from the idea of practices associated with teaching, lesson planning regularly features in the study of PCK (Chan & Yung, 2015; Chapoo et al., 2014), usually as one of an array of methods used (Goodnough, 2006; Marks, 1990; Park et al., 2010). Lesson planning as the primary focus of a study is relatively rare, although Van Der Valk and Broekman (1999) made use of the Lesson Preparation method, asking pre-service teachers to plan a lesson as if they were to teach it the next day and to explain their thinking in an interview. Similar approaches by Atay, Kaslioglu and Kurt (2010), Nilsson (2008) and de Jong and Van Driel (2004) required prospective teachers to plan, implement and review a teaching activity. Providing lesson plans for pre-service teachers to analyse formed part of Prescott, Bausch and Bruder's (2013) Teacher Education Lesson Plan Survey (TELPS), which aimed to move towards a more standardised approach to identifying PCK. Although Prescott, Bausch and Bruder found that "lesson plans are suitable objects to disclose PCK" (Prescott et al., 2013, p. 45) this approach, which attempts to balance open interview questions with test-like standardisation was successful in a theoretical sense but was not rooted in the participants' own practice. This point was further addressed by Prescott, Bausch and Bruder in their future plans to see whether this knowledge translated into the participants' own lesson plans.

'Lesson Study' as a distinct methodology involves joint planning, as with Nilsson's (2014) study aiming to develop experienced teachers' PCK through collaboration, a conceptual approach echoed in various studies involving two complementary instruments: Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) (Bertram & Loughran, 2012; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Loughran et al., 2004, 2008; Williams & Lockley, 2012). A CoRe represents the aspects of PCK most attached to a specific content area, captured through the use of a tabular template with guiding questions. Its partner, the PaP-eR, is an "engaging portrayal of the elements of PCK that are being illustrated for the reader" in a lesson (Loughran et al., 2001). The use of an over-arching medium-term planning tool will be familiar to teachers, but the CoRe PCK approach explicitly linking planning with students' understanding will be less familiar. Loughran, Milroy, Berry, Gunstone and Mulhall saw this approach as a blueprint for practice, but found the notion of one standard yardstick of PCK untenable (Loughran et al., 2001) preferring instead to collect a CoRe and several PaP-eRs together into a Resource Folio that represented PCK around a specific topic (Loughran et al., 2008). In this proposal, the folio becomes both a source of PCK as well as an outcome of PCK, offering a wealth of possibilities for the teaching profession. The various studies assembled here seem to give the impression of incremental development leading to eventual best practice, which is laudable, but if PCK is to be a useful construct, then a need remains to study it in critical situations. Some remaining threads to be followed up ask difficult questions such as whether PCK can be used in remedial situations: can struggling teachers improve their practice rapidly and effectively by understanding their own PCK; can PCK ever be useful in a situation of curriculum change or disciplinary shift? It may be that finding ways to measure PCK can provide insights into its rectification.

2.5.3.3 Measurement

PCK has emerged from the literature as a complex construct, with multiple contributory components. Given that it is a form of knowledge, it can be no surprise it has also emerged as something that is difficult to measure in a positivist way. However, various studies have attempted to design instruments to capture or measure PCK through the use of multiple choice questions (Maat & Zakaria, 2014; Manizade & Mason, 2010; Rohaan et al., 2009), Likert scales (Abdullah & Halim, 2010), by using survey methods (Prescott et al., 2013) and also through the use of pencil-and-paper tests (Juttner, Boone, Park, & Neuhaus, 2013; Krauss et al., 2008). Park, Jang, Chen and Jung developed their quantitative study of high-school Biology teachers' PCK by using a correlational design involving a rubric for lesson observation judgments (Park et al., 2010). Table 2.2: Sample sizes of studies focused on measurement of PCK, below, lists sample sizes in cited studies where a test instrument was used with active participants, as opposed to being developed by them.

Table 2.2: Sample sizes of studies focused on measurement of PCK

Authors	Type of instrument/test items	Number
Maat & Zakaria, 2014	Multiple choice questions	N=254
Prescott et al., 2013	TELPS survey of lesson plans	Germany (N=173) Australia (N=83)
Rohaan et al., 2009	Multiple choice questions	A (N=34) B (N=101)
Krauss et al., 2008	Open ended	N=198
Juttner et al., 2013	Short answer, open-ended and ranking	N=158
Abdullah & Halim, 2010	Multiple choice and Likert	N=50
Park et al., 2010	PCK rubric used to score PCK components observed	N=7

A common feature of the literature around attempting to measure PCK is a call for the potential to study larger sample sizes, working on the premise that a measure developed from a large sample size will have greater relevance for generalisation. Sample size seems, perhaps unsurprisingly, to correlate with methodological approach and a move towards ‘distal information’ (Juttner et al., 2013) often aims for a larger sample size, whereas the ‘proximal’ methods make use of smaller sample sizes, even when attempting to convert PCK into a numerical format. Park, Jang, Chen and Jung (2010) used a rubric with a four-point scale to measure the level of PCK based on observations of the teachers’ teaching and pre/post observation interviews, but with only seven high school teachers, albeit across 33 observations over two school semesters. Although Park, Jang, Chen and Jung reported positive findings, they highlighted the small sample size and recommended replication.

Measuring PCK seems to be a problem partly revolving around asking the right questions in the right way, perhaps because the measures which are easiest to administer are proxy measures of the key constructs of interest (Rowan, Schilling, & Ball, 2001). Rowan, Schilling and Ball concluded that multiple choice questions are of 'limited success' even if they take an approach of one correct answer in short but realistic scenarios. They pointed to scales with low to medium reliabilities and ambiguous face validity and admitted that PCK is multifaceted in nature and left as an open question whether it can ever be measured. Rohaan, Taconis and Jochems (2009) used two groups, totalling 135 respondents to their multiple-choice test. Although they concluded that their content validity was high due to the process of item development, there were still problems during the test construction with formulating "best answer and plausible distracters" (Rohaan et al., 2009, p. 337) because of the complexity of PCK as a construct. Rohaan, Taconis and Jochems concluded that larger samples would allow more sophisticated statistical techniques but, interestingly, also recommended complementary 'qualitative' methods for triangulation. Manizade and Mason (2010) concurred that multiple-choice questions were not ideal for complex constructs because of issues of validity and reliability but attempted to overcome the problems with the methodology to develop test items through the use of repeated rounds of development to achieve expert consensus. Despite efforts to develop tests of PCK, it would seem to be the case that "one cannot pin-point particular PCK items in ways that teacher-testers might like, for the interplay and relationships are too complex to be held still to individually capture and measure" (Loughran et al., 2001, p. 306). It would seem that research into PCK is best operationalised through a conceptual framework which articulates and describes the complex work of teachers.

2.5.4 The model of pedagogical reasoning

Whilst PCK and the attendant categories and components of knowledge have been the focus of much research, fewer studies make explicit reference to the later model of *pedagogical reasoning* (see Figure 2.2, below for Shulman's original presentation), the process through which Shulman suggested that PCK is translated into practice (Alonzo et al., 2012).

TABLE 1
A Model of Pedagogical Reasoning and Action

Comprehension

Of purposes, subject matter structures, ideas within and outside the discipline

Transformation

Preparation: critical interpretation and analysis of texts, structuring and segmenting, development of a curricular repertoire, and clarification of purposes

Representation: use of a representational repertoire which includes analogies, metaphors, examples, demonstrations, explanations, and so forth

Selection: choice from among an instructional repertoire which includes modes of teaching, organizing, managing, and arranging

Adaptation and Tailoring to Student Characteristics: consideration of conceptions, preconceptions, misconceptions, and difficulties, language, culture, and motivations, social class, gender, age, ability, aptitude, interests, self concepts, and attention

Instruction

Management, presentations, interactions, group work, discipline, humor, questioning, and other aspects of active teaching, discovery or inquiry instruction, and the observable forms of classroom teaching

Evaluation

Checking for student understanding during interactive teaching

Testing student understanding at the end of lessons or units

Evaluating one's own performance, and adjusting for experiences

Reflection

Reviewing, reconstructing, reenacting and critically analyzing one's own and the class's performance, and grounding explanations in evidence

New Comprehensions

Of purposes, subject matter, students, teaching, and self

Consolidation of new understandings, and learnings from experience

Figure 2.2: Shulman's (1987) model of pedagogical reasoning and action

Considering pedagogical reasoning from an ICT-specific perspective relevant to the current study, Webb (2002) followed the trend for enhancing Shulman's ideas by adding a complementary layer relating to teachers' ideas, beliefs and values, based on a conceptual framework by Alexander, Rose and Woodhead (1992), provided in Figure 2.3, below for information, taken from Alexander (1994). Webb attributed part of her rationale for doing so to pivotal evidence on teachers' ideas, beliefs and values influencing practice relating to ICT (Moseley et al., 1999). Webb asserted that much of the knowledge informing Shulman's model of pedagogical reasoning would also provide knowledge for the development of their ideas, beliefs and values. Hence, she maintained the core processes of the pedagogical reasoning model and allowed for other influences on the cycle of processes. By doing so, it can be argued that she made it more useful for the consideration of the broad spectrum of teachers' professional knowledge and skills.

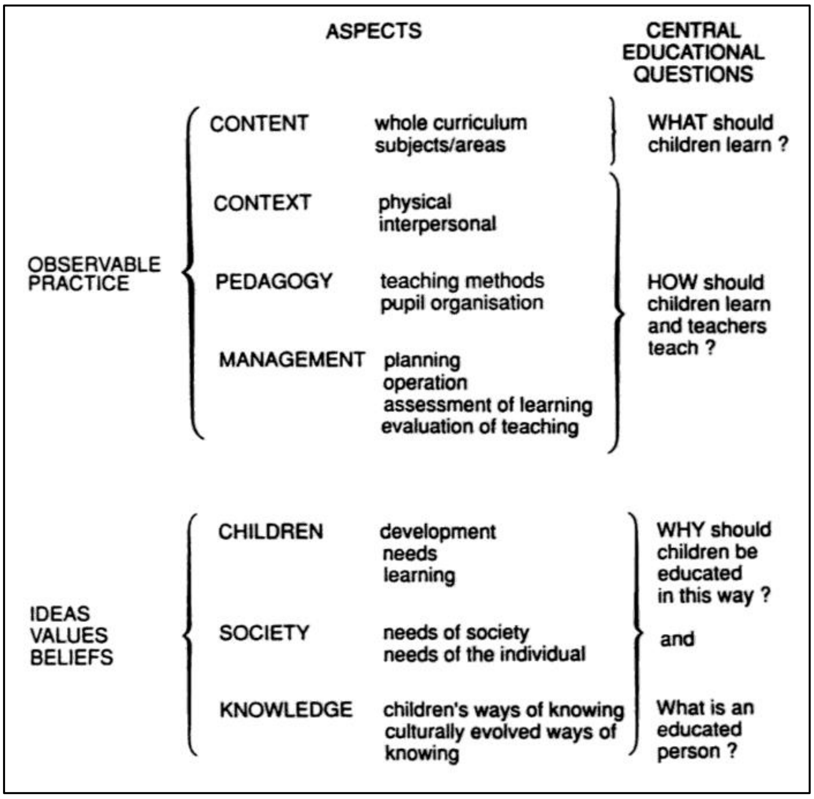

Figure 2.3: Education practice framework (taken from Alexander 1994, p. 18)

Webb graphically represented the main points of Shulman's model of pedagogical reasoning as a cycle of processes in which PCK is used and generated. The model is reproduced in full in Figure 2.4, below. The arrows represent the influence of ideas, beliefs and values on the processes of pedagogical reasoning without detracting from its main purpose. The current study explores teachers' ideas, beliefs and values surrounding the transition from ICT to Computing, and the ways in which these are reflected in the teachers' perception of curriculum change as well as in their professional practices.

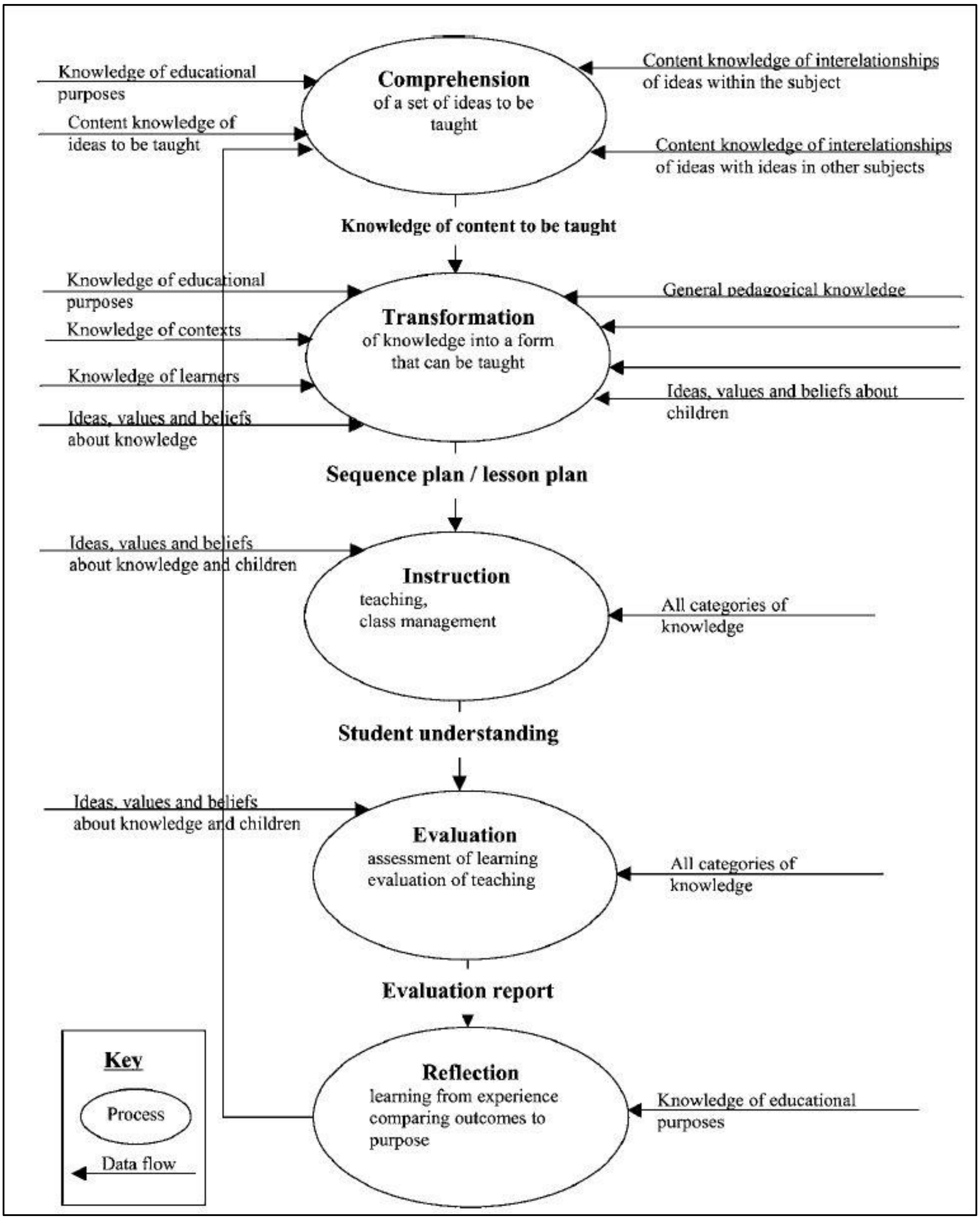

Figure 2.4: Webb's (2002) model of pedagogical reasoning (based on Shulman, 1987)

In addition, Webb represented the process of transformation (located within the second process oval in Figure 2.4) separately, as shown in full in Figure 2.5, below. She highlighted that transformation of knowledge by the teacher "occurs not only prior to the instructional process… but also through instruction and during evaluation" (2002, p. 241), pointing to the lesson planning process as a crucial location for pedagogical reasoning and the use and the development of PCK.

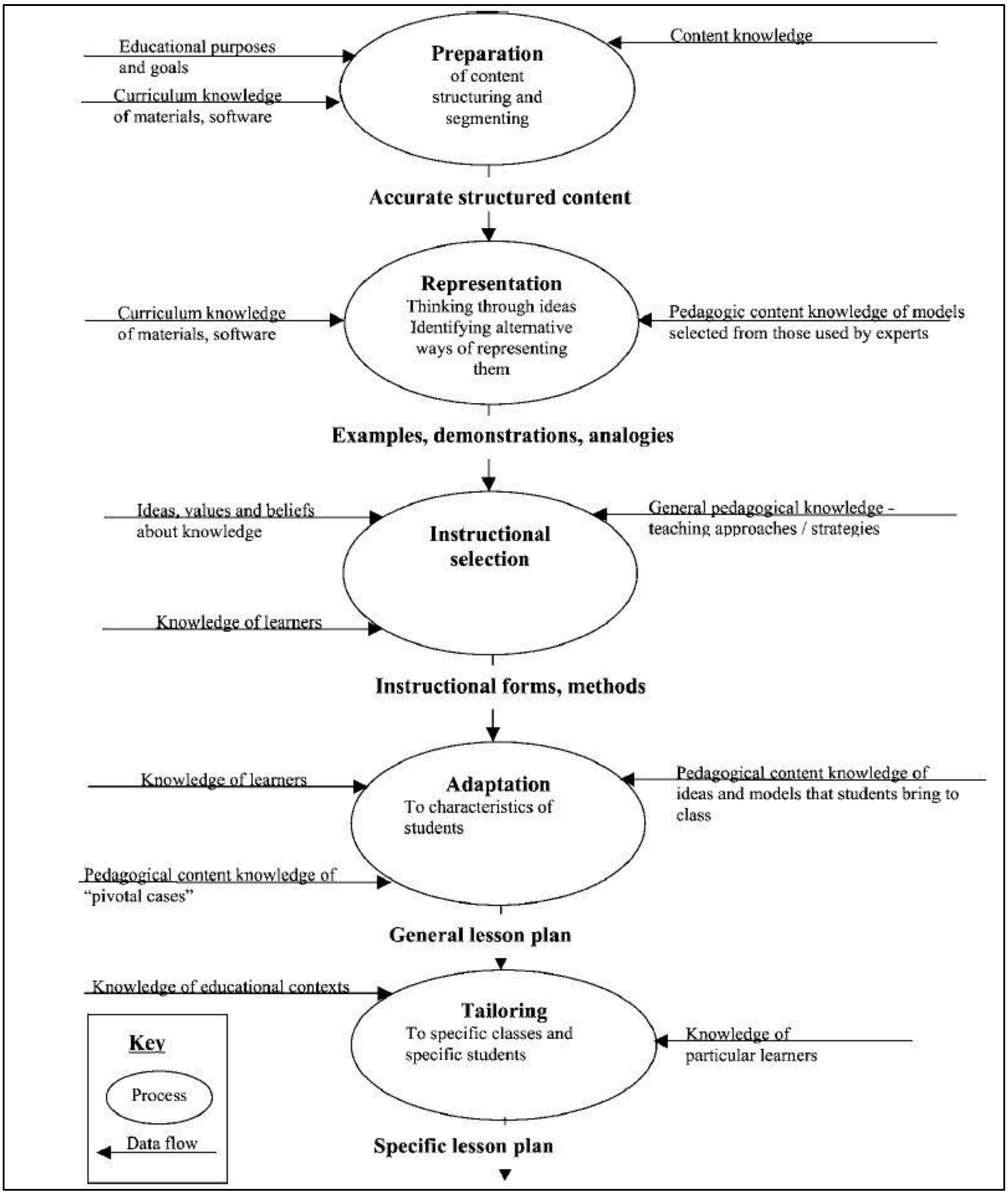

Figure 2.5: Webb's (2002) model of transformation (based on Shulman, 1987)

Visualising the key principles of the process of pedagogical reasoning in this way serves two purposes. Firstly, it allows insight into the general processes undertaken every day by teachers planning lessons, as each sub-process can be understood in relation to other parts of the process. Secondly, it allows the processes to be operationalised thematically and interpreted through professional interpretive lenses. Whilst the diagrams may lack presentational finesse, they act together as a suitable starting point for the identification of functional themes in teachers' professional practices, whilst being open to the inclusion of other influences, internal and external, that might have a bearing on the process of pedagogical reasoning.

2.6 Contemporary issues in Computing Education

In this section, literature reporting on and responding specifically to the context of the 2014 change in Computing Education in England is appraised in order to locate the current study within the most relevant contemporary debates and provide a stimulus for later discussion of the findings.

The English National Curriculum change involving the shift from ICT to Computing from 2014 is recent enough that much of the research is still emerging. This is evident in the current dearth of reporting of contemporaneous studies in England beyond those undertaken by existing academics in the field and a small number of postgraduate researchers. Considerable debate exists (Crick, 2017; Passey, 2017; Webb et al., 2017) around the future direction of studies needed in the area of Computing in the UK, with broader debate continuing to occur elsewhere in the UK about the implications of introducing Computer Science and coding (Barnes & Kennewell, 2018; Hinchliffe, 2016; Perry, 2015) into national curricula.

At the Computing at School annual conference in June 2017, Sentance reported on themes in Computing Education from 2004 to 2014 based on earlier work with Selby (Sentance & Selby, 2015). She presented details of post-2014 research by doctoral students currently underway in the UK (Sentance & Brown, 2017), of which the current study was one of only ten highlighted, evidence of the “known issue …[of] a lack of UK capacity for computer science education research, with small clusters at a few institutions across the UK” described by Crick (2017, p. 17) and echoed in the Royal Society report of 2017 (Royal Society, 2017).

Sentance and Selby reported on the prevailing major research themes in peer-reviewed papers on Computing Education in schools and higher education pre-2014, as shown in Table 2.3, below. These main themes continued to be addressed post-2014, albeit with a more specific focus on Computing at school level in light of national and international curriculum change trends. Some of the key research informs the thematic basis of the next section.

Table 2.3: Themes in Computing Education (from Sentance & Selby, 2015, p. 8)

Common topics	School	HE	All
Outreach	15%	0%	4%
Course	14%	22%	20%
Pedagogy	13%	17%	17%
Curriculum	12%	5%	7%
Programming	12%	12%	11%
Inclusion	6%	3%	3%
Assessment	6%	9%	7%
Computational Thinking	4%	1%	2%
Learner characteristics	4%	5%	5%
Specific topics in CS theory	1%	7%	7%
Motivation	1%	4%	3%

2.6.1 Extra- and cross-curricular activities

Outreach, as reported here, generally described the outcomes of higher education (HE) institutions delivering Computing-related outreach programmes in schools. Post-2014, a common theme in this general area included studies of extra-curricular and enrichment activities designed to stimulate interest in aspects of the new curriculum and simplify teachers' efforts to engage with the programming requirements of the new programmes of study. With the exception of one Randomised Controlled Trial (RCT) of after-school Code Clubs for ages 9-11 undertaken by NFER on behalf of Code Club UK, which showed unsurprising improvement in coding skills and confidence (as with an earlier Code Club survey-based study (Smith, Sutcliffe, Sandvik, Keynes, & Sandvik, 2014)), but no additional evidence of impact on computational thinking (Straw, Bamford, & Styles, 2017), studies tended to be smaller-scale and exploratory. Although the Straw, Bamford and Styles study referred to issues of pedagogy on the first page, it was clear later that "outcomes for teachers and schools [were]… not a key focus of the evaluation" (Straw et al., 2017, p. 6) and mentioned that some teachers had struggled to deliver the code club. They suggested that this was because of lack of knowledge of the languages, contrasting with the conclusion that setting up and delivering a Code Club was relatively straightforward "even for those staff with no prior experience of coding" (2017, p. 7).

2.6.2 Computational thinking and creativity

The concept of game-making using game-authoring software in addition to coding has been suggested as an area where the ceiling can be "pushed higher" to develop deeper knowledge (Henrique De Paula, Valente, & Burn, 2014, p. 66) but requiring less specialist programming knowledge on the part of teachers. The authors proposed that game-making could foster computing-related principles and competences, but in an inter-disciplinary way, with the potential for embedding Computing more deeply within and across the curriculum. A study by Johnson (2014) designed to help students think more deeply about the underlying principles of game design also suggested that computer game authoring might be one path to developing units of work to support the new Computing curriculum, "especially for teachers and pupils who have little prior knowledge of the field" (Johnson, 2014, p. 5). Connected as this line of enquiry is to a broader theme of creativity and computational thinking, as explored by Savage and Csizmadia (2018), it acts as an incentive to move the debate away from coding skills in isolation to an approach with a deeper rationale, and one based more securely on the knowledge and skills needed during the transition from ICT to Computing.

2.6.3 Programming and pedagogy: the teacher's perspective

Whilst programming as a research theme was and continues to be consistently published (Davenport, Hayes, Hourizi, & Crick, 2016; Zarb & Hughes, 2015), post-2014 the emphasis seems to have moved towards the pedagogy of programming (Avis, 2014; Davenport et al., 2016; Selby, 2015; Sentance & Csizmadia, 2017a; Waite, 2017) and in some cases, with a specific link to pedagogical content knowledge and the PCK of programming (Avis, 2014; Griffin, Pirmann, & Gray, 2016; Qian & Lehman, 2017; Yadav, Berges, Sands, & Good, 2016), recognising that to be a good programmer is not enough to be a good teacher of programming. Although the Griffin, Pirmann and Gray study focused on two teachers in two different kinds of schools in the USA, it allowed a detailed exploration of their choices of "pedagogies, curricula, and technologies; their techniques for balancing problem solving with creativity; and their means of establishing social norms" (Griffin et al., 2016, p. 465) as they taught Computer Science courses. Their study focused on these different types of teacher knowledge, beyond subject knowledge or programming skills, that contributed to effective teaching of Computer Science but also highlighted that "pedagogical approaches for enacting curricula in one school setting may not be effective in another" (2016, p. 461). In the comprehensive literature review of pedagogy in teaching Computer Science in schools carried out for the Royal Society report (Pye Tait Consulting, 2017b), Waite (2017) concluded that “consideration should be given of teachers' perceptions and understanding of pedagogy” (2017, p. 41), citing a 2013 study of fostering Computer Science PCK through reflection on the activities of planning and teaching (Buchholz, Seli, & Schulte, 2013) with a stated aim of helping student teachers to see themselves as “future teachers who are researchers of their pupils’ learning processes” (2013, p. 15) in contrast to focusing on their subject knowledge alone.

In England, a very recent chapter has re-invigorated the debate around teachers’ perspectives on the development of Computing as a subject, returning curriculum enactment to the foreground with a timely reminder that:

> …any curriculum specification is going to be mediated by cultural practices at school and classroom level; those involved in implementation bring their own values, beliefs, attitudes and behaviours (Barnes & Kennewell, 2018, p. 28).

Barnes and Kennewell’s study used CHAT (Cultural Historical Activity Theory) to evaluate and analyse the perceptions of Welsh teachers of the development of ICT capability through their teaching. What is most striking from the findings when seen through a post-2014 lens is the stark reminder of the metacognitive value of ICT capability that was widely undervalued and ultimately discarded along with the ICT curriculum in England. Brosnan (2000) argued that ICT capability in the National Curriculum (1999; 2004) occupied a ‘third way’ between constructions of ICT as a tool and ICT as a set of skills, with insufficient attention given to developing pupils’:

> “… initiative and independent learning, with pupils being able to make informed judgements about when and where to use ICT to best effect, and to consider its implications for home and work both now and in the future” (2004, p. 89).

It is arguable that ICT capability as a construct could have been reclaimed and repurposed along with the curriculum to provide a segue into Computing and computational thinking.

In a similar vein, Waite (2017) reported mixed evidence on the effectiveness of the unplugged approach to teaching Computing, whereby concepts are taught through embodied practice without the use of computers. The approach was popular with teachers for developing their own knowledge and understanding, and that of their students, through the use of analogy and practical activity (Sentance & Csizmadia, 2015, 2017a). Waite reported a risk of primary school teachers migrating to teaching computational thinking through unplugged activities rather than through programming, calling for “the role of computational thinking in primary computing [to] be reviewed" (2017, p. 44). This seems additional evidence of a potential metacognitive gap in teachers' confidence with computational thinking in relation to programming, as well as a reminder of the influence of teachers' values, beliefs, attitudes and behaviours in curriculum enactment. In addition, Weatherby's (2017) study of Computing teachers' participation in online communities of practice confirmed that computing teachers' background characteristics impacted on their preparedness for teaching Computing.

2.6.3.1 Assessment

Given that the third aspect of Bernstein's (1971) definition of curriculum was 'evaluation', which we would currently interpret as 'assessment', a high level of interest remains in the assessment of Computing. With the development of Computing and Computer Science GCSEs and A Levels as high-stakes assessments in English schools, evaluation of student learning is a key concern for teachers (Ghumra, 2014) as it revolves around assessment of Computing knowledge as well as programming skills. Ghumra's participants felt significantly unprepared for assessment under the new curriculum order. Giordano, Maiorana, Csizmadia, Marsden, Riedesel and Mishra's review of the current status of resources for Computer Science assessment pointed to a variety of "instruments, question banks, tests, and tools" but highlighted the lack of use of existing repositories (Giordano et al., 2015, p. 122) in their development of a prototype collaborative national platform for assessment. Bradshaw (2018), however, pointed out the overarching constraints felt across the profession because of the high-stakes nature of assessments via awarding bodies, which impact heavily on teachers' assessment knowledge and planning for learning.

Kallia's (2017) review of assessment in Computer Science courses undertaken for the Royal Society aimed to apply research findings to Computing assessment in UK schools and found that assessment research tended to be focused on approaches, design and development of assessment instruments, automated tools for assessment and other instruments for assessing learning. Whilst Kallia's review focused on academic research, it lacked a critique of the UK's high-stakes assessment culture, which would have been useful in considering how the findings of her review might be positioned to inform and influence the assessment practices laid down by awarding bodies and their regulator. This has particular relevance due to the stringent nature of assessment practices in Computing and Computer Science GCSE, very recently the subject of national attention for malpractice in online discussions and sharing of solutions for the non-examined practical programming controlled assessment accounting for 20% of the GCSE course (Ofqual, 2018). The situation from January 2018 forward is that the practical programming element of the GCSE will no longer count towards a student's terminal mark, leaving only a traditional paper-and-pen terminal examination and no assessment of practical programming skills. This outcome raises a serious concern about the validity of current approaches to the assessment of programming and Computer Science.

2.6.3.2 Learner characteristics

Although the current study focuses on teachers' knowledge and skills in the transition from ICT to Computing, this by no means affects the centrality of students to the work of teachers. A key knowledge base for teachers has been shown to be knowledge of learners, both generally and specifically. Pre-2014, inclusion, motivation and learner characteristics were three areas of research in Computing Education, and they remain important post-2014. Research on students tended to involve their cognitive, conceptual and affective aspects (Asad, 2016; Johnson, 2014; Sentance, Dorling, & McNicol, 2013), their interest in Computing and reasons for continuing to study it beyond Key Stage 3 (Payne, 2014) and their differing needs with regards to inclusion (Shelton, 2018). Most relevant to the current study, however, is research surrounding students' knowledge, conceptions and misconceptions with regards to learning programming (Qian & Lehman, 2017), another vital knowledge base for teachers in regards to their developing PCK for Computing. Qian and Lehman, in their comprehensive literature review on this area, highlighted a key area contributing to students' difficulties with programming as being "teachers' poor content knowledge" (Qian & Lehman, 2017, p. 10) citing the problem of teachers with weak content knowledge teaching 'rules' rather than 'reasons', leading to the formation of incorrect mental models. It is evident that, in order for teachers' knowledge to improve, both their subject knowledge for programming and their application of this to understanding their students' difficulties need to be addressed through professional learning:

> we believe that developing and enhancing instructors' PCK, including their knowledge of student misconceptions and ability to apply effective instructional approaches and tools to address difficulties, is vital to the success of teaching introductory programming (Qian & Lehman, 2017, p. 18).

2.6.3.3 Space for professional learning

Significant calls for continuing professional development and suggestions for professional learning and knowledge sharing (Brown & Kölling, 2013) for teachers were a feature of publications around the time of the curriculum change (Brown et al., 2013; Royal Society, 2012; Sentance, Humphreys, & Dorling, 2014; Sentance et al., 2012) and have continued to be a focus for the Computing Education academic community (Webb et al., 2017). Issues around teachers' perspectives and understanding of concepts (Davenport et al., 2016; Kallia & Sentance, 2017; Sentance & Csizmadia, 2015), need for support (Sentance et al., 2014), professional recognition through teacher inquiry (Sentance, Sinclair, Simmons, & Csizmadia, 2016), certification (Sentance & Csizmadia, 2017b) and ongoing development of pedagogy (Sentance & Waite, 2017) have been major themes.

Solutions such as massive open online courses (MOOCs) (Vivian, Falkner, & Falkner, 2014), along with professional development networks (Cutts, Robertson, Donaldson, & O'Donnell, 2017; Ericson, Guzdial, & McKlin, 2014) have been researched with a view to understanding the development of teaching practices through online communities (Go & Dorn, 2016; Preston, Allen, & Allen, 2018; Trust et al., 2016; Weatherby, 2017). Weatherby's (2017) findings are of relevance to the current study as some teachers reported significant changes to their professional practices as a result of engaging specifically with the CAS online community.

2.6.4 The Royal Society Report 2017

The influential Royal Society Report of 2012, entitled '*Shut down or restart? The way forward for computing in UK schools'* (Royal Society, 2012) has been widely considered as one of the catalysts for the shift from ICT to Computing as an English National Curriculum subject. The succeeding five years have seen immense change, the implications of which have yet to be fully realised or reported on. The Royal Society commissioned a further report, published in November 2017: *'After the reboot: computing education in UK schools'* (Royal Society, 2017) in order to provide "a snapshot of the changes that have taken place since 2012" (2017, p. 7) and to examine the impact of these changes along with the presentation of a number of challenges. Several of the literature reviews undertaken as part of the compilation of the report have been reviewed separately, above (Crick, 2017; Kallia, 2017; Waite, 2017).

The report summarised that "computing education across the UK is patchy and fragile" (2017, p. 4), addressed themes of curricula, teacher knowledge and confidence, professional development needs, gender imbalance, and the need for further research into pedagogy, assessment and Computing the UK. As the report was pubished after all of the data for the current study were analysed and reported, some of the key findings and recommendations will be addressed in later chapters, where they have particular relevance.

2.7 Chapter summary

The overarching themes of curriculum change and its impact on the subject and pedagogical knowledge of the in-service teachers tasked with its implementation were the key drivers for the current study. Teaching and learning with and about technology and its computational foundations occupies a specialised pedagogical space requiring disciplinary knowledge and technical skills well beyond the requirements of the previous curriculum order. The professional experiences of teachers as they adapted their pedagogical strategies in order to teach Computer Science, computational thinking and programming provided a fertile area for research.

From the literature, key themes have emerged that hold particular significance for the current study. From the field of curriculum theory, it is clear that conceptions of curriculum (Bernstein, 1971) and drivers for curriculum change (Kelly, 2009) are contested sites where research and political ideologies intersect and remain in dispute. Theorists assert that the role of teachers has been diminished within these processes (Kelly, 2009). Despite a wealth of research into teacher knowledge and pedagogy (Shulman, 1986, 1987), insufficient attention has been paid to this as a locus for professional development (Sentance et al., 2012) necessary to encourage effective Computing education in the UK (Royal Society, 2017) and ensure secure teacher professional practices (Rusznyak & Walton, 2011). Translating these debates into the field of Computing education reveals a gap in the knowledge at their intersection, and it is this gap that the current study seeks to operate within through the application of a conceptual framework (Webb, 2002) to the study of teachers therein, and by so doing, to contribute new knowledge.

2.7.1 Research questions

This multiple-case study seeks to address two main research questions, each with three sub-questions, with the intention of exploring teachers' perceptions of the curriculum change and how these teachers have been able to plan lessons aligning with the new curriculum.

1. How do participant teachers perceive the ICT to Computing curriculum change?
    a. What are participant teachers' perceptions of the ICT and Computing curricula?

   b. What are participant teachers' perceptions of the transition from teaching ICT to teaching Computing?
   c. How do participant teachers perceive the subject-specific professional development available to them during the transition?
2. How do participant teachers approach the planning of Computing lessons?
   a. How is PCK enacted through pedagogical reasoning when participant teachers plan Computing lessons?
   b. How is the Computing subject knowledge requirement being addressed by different participant teachers to enable them to plan lessons?
   c. To what extent do participant teachers draw upon subject-specific sources and resources to enable them to align their planning with the programmes of study?

Methodologically, issues of teacher perceptions and professional practices are a good fit with proximal, think-aloud methods that can be mapped to conceptual frameworks. The research design and approaches will be discussed next in the following chapter.

Chapter 3 Research methodology

3.1 Chapter overview

The purpose of this multiple case study was to explore with a sample of teachers their perceptions of the 2014 ICT to Computing curriculum change in schools in England and in addition, their lesson planning processes in the wake of the curriculum change. In particular, the study investigated how teachers already in post were engaging in pedagogical reasoning without either career experience of teaching the Computer Science aspects of the Computing curriculum, or, more commonly, without any formal prior knowledge or qualifications to do so. In seeking to understand this problem, the study addressed two main research questions, each with three sub-questions:

1. How do participant teachers perceive the ICT to Computing curriculum change?
    a. What are participant teachers' perceptions of the ICT and Computing curricula?
    b. What are participant teachers' perceptions of the transition from teaching ICT to teaching Computing?
    c. How do participant teachers perceive the subject-specific professional development available to them during the transition?
2. How do participant teachers approach the planning of Computing lessons?
    a. How is PCK enacted through pedagogical reasoning when participant teachers plan Computing lessons?
    b. How is the Computing subject knowledge requirement being addressed by different participant teachers to enable them to plan lessons?
    c. To what extent do participant teachers draw upon subject-specific sources and resources to enable them to align their planning with the programmes of study?

This chapter presents and discusses the study's research methodology and methods used to address the study's research questions. Matters of sampling, research design and data collection are explained, along with an outline of the methodological rationale in order to situate the decisions made and the way in which the nature of the research questions and the overall study influenced the direction of approach and the research context. Also discussed are ethical considerations in relation to the research as a whole and specifically around the use of digital and video-based methods. The way in which pilot data has explored the utility of video-based methods is discussed, making reference to a forthcoming publication presented in Appendix H: Published article based on pilot data, located on p. 246. The analytical approach forms the latter part of the chapter, bringing transparency to the process of data interpretation by sharing the major stages in the process. Issues of trustworthiness and limitations are then discussed.

3.2 The research context

As the ICT to Computing curriculum change was in effect from September 2014 and was mandatory for all schools in England legally required to follow the National Curriculum, the selected research context could have been any or all local-authority-maintained schools and any or all teachers in those schools teaching ICT to children from 5 to 16. Although my research questions had been formulated in order to explore teachers' responses to the curriculum change, I did not want to limit my focus to one or two schools or to a specific area. From my experience, supported by research carried out by the Royal Society (2017), I felt that secondary-school ICT departments were often small, sometimes with only one lead teacher who would be responsible for planning and resourcing for the department. This arguably had the potential to increase the homogeneity of the planning approach of teachers from any one school. In effect, one lead teacher is likely to direct the department approach to planning, teaching and assessment. Primary schools often adopt a similar approach, with one person as the ICT or Computing lead. This could also have led to increased variation in teacher backgrounds, whereas I felt that it was especially relevant to the research question to locate teachers who had experienced both types of curriculum and who could be selected with certain characteristics, in line with Gobo's (2008) focus on representativeness and making sure that extreme cases are taken into account.

This led to the decision to focus on teachers as the units of analysis and for the research context to be situated in the experiences of the teachers as they carried out their professional expectations by teaching the new curriculum. Each teacher's practice would therefore be its own research setting. In keeping with the social constructivist paradigm, Hammersley and Atkinson discussed the potentially misleading talk of 'studying a setting' and pointed out that "settings are not naturally occurring phenomena, they are constituted and maintained through cultural definition and social strategies" (1995, p. 41) therefore I felt the term 'context' best suited the location of the cases under investigation. I also felt that the systematic selection of the cases within their contexts in order to address the research questions strengthened the credibility of the research.

Continuing the selective approach to the research context, matters of time sampling had also to be decided. Although planning a lesson may be influenced by many factors and inspiration may occur at any time, based on professional experience I decided that there would be a distinct and observable time period when a teacher would plan what to do in a specific lesson. Whether the planning involved the more routine checking of the scheme of work and ensuring that the teaching resources were accessible, or sitting down to create new resources, I decided that teachers would be able to demarcate a time period for this planning activity. Intending for this to be naturalistic, I specified this as the time I would observe the teachers' processes of lesson planning. I was able to be completely flexible with my availability to observe this process, whether my participants wished to plan their lessons on a Saturday morning in their own home, or during non-contact time at school.

3.2.1 Research participants

As the research questions were not linked to one specific school, region or phase of education, the priority was to gather participants who had experienced the curriculum change. Hammersley and Atkinson (1995) cited various types of informant who have the knowledge required, and may be strategically selected. They categorised these as "informants who are especially sensitive to the area of concern": outsiders, rookies, nouveau-statused or naturally reflective people or as "the more-willing-to-reveal informants": naïve, frustrated, 'outs', 'old-hands', needy or subordinates. Of these, my targeted participants were 'the nouveau statused': those in transition for whom the "tensions of new experience are vivid" (pp. 137-138); serving teachers who had been teachers of ICT (as would be found in secondary schools) or those teaching ICT (as would be found in primary schools) who were now charged with teaching Computing. The initial screening requirements for the participants are outlined below:

Pre-2014 requirements

- Had experience of following the statutory requirements for ICT as a National Curriculum subject prior to the disapplication of ICT in 2012, and / or
- Had experience of teaching NQF Level 2/3 ICT-related qualifications (e.g. GCSE or AS ICT or equivalent).

Post-2014 requirements

- Were currently teaching Computing, ideally using the new Computing programmes of study, and / or
- Were currently teaching Computing/Computer Science NQF Level 2/3 qualifications (e.g. GCSE or AS Computing) accredited for first teaching post-2014.

This implicit but broad purposive sampling (Silverman, 2013) allowed the opportunity to maximise the diversity relevant to the research question and include participants on the basis of assorted characteristics of interest. Taking the approach that any teacher who was previously teaching ICT and was currently teaching Computing might be able to provide useful data and engage in relevant reflective dialogue about their current practice allowed the selection of cases "from as diverse a population as possible in order to ensure strength and richness to the data" (Cohen, Manion, & Morrison, 2007, pp. 114–115). This maximum variation sampling approach meant that, in order to describe differences in subject knowledge, pedagogical practice and evidence of PCK, participants possessing a combination of the following explicit characteristics were sourced:

- **educational phase:** primary, middle/all-through, secondary, NQF Level 2/3;
- **pre-service subject background:** IT/Computer Science/another subject;
- **initial teacher education:** IT/ICT specialism/primary specialism/another subject;

In addition, the research questions were such that they were also open to negative case sampling. I considered that it would be relevant to include any teachers that could be sourced through snowball sampling for whom the change had been welcome and unproblematic, or indeed those for whom the change was a barrier to teaching Computing. I felt this would provide an added richness to the continuum of practice to be explored.

Following receipt of ethical approval (see Appendix B: Ethical approval, on p. 226), I began an ongoing process of participant recruitment, with the aim of gathering a diverse sample. Having become a member of the Computing at School (hereafter CAS) organisation as well as developing a presence in several subject groups on social media, I was able to put out a call for participants across multiple platforms, which resulted in several initial volunteers. I also placed participant information on a research blog I created. I approached the then Head of Research at CAS, Dr. Sue Sentance, and asked her to share my participant call with her social media followers, which she did.

I presented my work at a CAS research working group meeting in London and co-presented a research workshop at the CAS North East Conference in Newcastle and gained several more volunteers. Presenting a poster at the Durham University Postgraduate Researcher poster competition also gained me a volunteer, who approached me to discuss my poster from a teaching perspective and was willing to be interviewed. Remaining within my own set parameters for the participants, I did not proceed with two trainee teachers who volunteered, being focused explicitly on teachers who had experience of both curricula. I was also contacted via my blog by a post-doctoral researcher who wanted to collaborate, but I did not proceed with this contact as they did not meet any of the criteria. I had three teachers drop out – one citing workload pressures, one not replying beyond the initial contact and the other gradually ceasing to respond to contact, despite agreeing times and dates for data collection.

3.2.1.1 Access and informed consent

During the first contact with each participant following their expression of interest in participating in the study, I explained the purposes of the study and provided each one with a copy of the informed consent documents I had developed as part of the ethical approval process. I asked them to read the document and let me have any questions before they signed the consent form. As the level of access needed for most of the participants was outside of teaching time and there was no involvement of pupils, eight of the nine participants proceeded by giving personal consent and offering times that suited their personal work schedule. One participant invited me to school during non-contact time, having discussed it with their headteacher first. Participant names have been anonymised and are listed in Table 3.1, below, along with times, locations and channels used for interviews and planning sessions.

Table 3.1: Participant access times and channels

Participant	Time and location of access	Channels
1. **Alex**	At home	Remote
2. **Ben**	Work at home	Remote
3. **Claire**	Lunch break at work	Face-to-face
4. **David**	At home	Remote
5. **Ellen**	At home	Face-to-face
6. **Faith**	Non-contact time in school	Face-to-face
7. **Glenn**	After school	Remote
8. **Helen**	After school	Remote
9. **Ian**	After school	Remote

On receipt of the participants' informed consent, four clear phases followed in the data collection programme:

- **Phase 1**: Initial exploratory data collection through email and web.
- **Phase 2**: Site visit/meeting/initial interview with participant.
- **Phase 3**: Recording of lesson planning session.
- **Phase 4**: Follow up for fact-checking, copies of documents referred to in the planning session and clarification of points from transcription.

The varying channels of participant recruitment meant that I was able to begin working with the participants on a rolling programme, in the order in which they appear in the table, between February 2016 and January 2017. I proceeded with nine participants (see Table 3.2 below for a summary of participant characteristics).

Table 3.2: Summary of participant characteristics

	ID	Current educational phase	Pre-service subject background	Initial teacher education	Other pertinent information
1.	**Alex**	Secondary	Computing & Business	TeachFirst ICT	Has taught primary and secondary. Head of department. Active on CAS
2.	**Ben**	Primary	Politics & International Relations	Primary PGCE	CAS Master Teacher. School lead. Plans and co-teachers all Computing lessons. Holds GCSE ICT, A Level Computing. BCS Certificate. Active on CAS
3.	**Claire**	Further Education	Information Technology	Post-Compulsory PGCE	MSc in Computing. Taught Level 2 vocational – BTEC, DIDA, ECDL, Key Skills, Functional skills, GCSE ICT resit to 16+ students. Has now left teaching and moved to HE. Did not like changes to L2 qualifications. Not a CAS member
4.	**David**	Key Stage 1-3	Computer Science	ICT PGCE	Trained as a secondary teacher. Moved to primary. Works in all through 4-18 school. Not a CAS member
5.	**Ellen**	Secondary	Business Management	Business PGCE	A Level - Business, geography and general studies. MA in Education. Teaches health and social care, business, IT and computing. Vocational co-ordinator. Attends local CAS events.

	ID	Current educational phase	Pre-service subject background	Initial teacher education	Other pertinent information
6.	**Faith**	Secondary	Management Science – marketing (Maths, marketing, law, computer science)	Maths PGCE	Computer studies O level. Computer science A level. Trained as Maths teacher. Did not enjoy teaching ICT. Now happy to teach Computing. Head of department. Member of CAS – downloads/comments
7.	**Glenn**	Secondary	Vocational route – web developer then Cisco CCNA Networking	IT Technical degree IT PGCE	Master Teacher, Hub Leader, Head of Department Active on CAS
8.	**Helen**	Secondary	Educational Research	IT PGCE	Teaching since 2009. Initially Adult IT Trainer. CAS Hub Leader. CAS Master Teacher. Faculty Director. Head of KS3 Computing, Raspberry Pi Certified Educator, Moderator for GCSE Computer Science. CEOP Ambassador. BCS Certificate. Primary outreach. Active on CAS
9.	**Ian**	Secondary	Civil engineering	Science KS3 & 4 conversion course - PGCE	ECDL in order to offer ECDL. Teaches IT and Science. 10-week evening course at local university on Python and Computer Science, based on CAS syllabus. Active on CAS.

Participant case study narratives are presented in Chapter 4 for transparency, in order to demonstrate “the match between research problems and cases selected” (Hammersley & Atkinson, 1995, p. 45). The diverse backgrounds, routes into teaching and experiences before and after the curriculum change are all factors that frame the participants’ responses used to answer the research questions. In addition, they serve to contribute to the trustworthiness and potential usefulness of the study because they provide authentic accounts of practice to which practitioner-readers can relate.

Theoretically, each single case’s ultimate disposition towards the curriculum change could have been predicted beforehand, but to a varying or contrasting result, based on the preconceived propositions about their background and teaching experience. While the cases were selected with the intention of maximum variation, they do not purport to provide a complete typology of teachers based on background and prior experience, but I would argue that they present a partial typography of the in-service teachers in this study who were faced with responding to the change of curriculum.

Table 3.3: A partial typography of in-service teachers

Participant Description	
B	Non-specialist, generalist primary Computing specialist
C	'Qualified' post-16 Computing specialist
A & D	'Qualified' ICT-trained Computer Science specialist
E	Business-trained non-specialist teaching some Computing
F	'Qualified' Maths-trained secondary Computing specialist
G	Vocational-route 'qualified' ICT-trained secondary Computing specialist
H	Non-specialist ICT-trained transitioning ICT teacher
I	Non-specialist Science-trained transitioning ICT teacher

3.2.2 Data needed

In order to address the research questions, two distinct types of data were needed: perceptual data and contextual information (see Table 3.4). The first research question asked how teachers perceived the curriculum change, so perceptual data were needed to answer this, directly taken from what teachers had to say about the curriculum change, but also indirectly from their actions, documents and artefacts. The second question asked about the planning processes, and contextual evidence of this needed to be gained directly from the teachers' actions, but also indirectly from their perceptual data.

Table 3.4: Summary of data needed

Research Questions	Sub-questions	Data needed
How do participant teachers perceive the ICT to Computing curriculum change?	• What are participant teachers' perceptions of the ICT and Computing curricula? • What are participant teachers' perceptions of the transition from teaching ICT to teaching Computing? • How do participant teachers perceive the subject-specific	• Direct responses from participants, either in the form of answers to specific questions, or relevant comments made • Inferential data from wider sources that either support or

Research Questions	Sub-questions	Data needed
	professional development available to them during the transition?	conflict with direct responses
How do participant teachers approach the planning of Computing lessons?	• How is PCK enacted through pedagogical reasoning when participant teachers plan Computing lessons? • How is the Computing subject knowledge requirement being addressed by different participant teachers to enable them to plan lessons? • To what extent do participant teachers draw upon subject-specific sources and resources to enable them to align their planning with the programmes of study?	• Direct evidence of participant actions as perceived through the lens of PCK and pedagogical reasoning • Direct responses from participants, either in the form of answers to specific questions, or relevant comments made • Inferential data from wider sources that either support or conflict with direct responses

The types of information were distinct from the methods of data collection (see Table 3.5 on p. 55). In order to answer the research questions, a clear decision was made to focus firstly on what teachers ***said*** as one aspect of gathering data, and secondly on what teachers ***did*** while planning lessons. The benefits of this approach were that I could be sure of understanding the participants' perceptions of curriculum change because of what they said, but with the potential of comparing it to what they did and said while planning, allowing any discrepancies to be highlighted.

In addition, focusing on what participants did while planning lessons would allow an understanding of the processes, but again, in relation to what they said about what they did. It was also clear that, beyond the potential to triangulate individual participants' talk and actions, a further level of triangulation would be possible though the use of documents and artefacts contextualising the data over time. Triangulation would be possible by comparing data from each of the methods to assess whether talk, action and artefact complemented or contradicted each other. This is demonstrated in Figure 3.1: Triangulation of data through methods, below. The words of a participant who spoke of taking a particular approach could be triangulated through the observation of their planning and compared against the documentary evidence, such as schemes of work or school publicity materials. I felt that the potential data was therefore adequate to address the research questions and sub-questions. In addition, the data necessary to answer the research questions was a methodological fit with an interpretive approach. Patton (2015, p. 14) asserted that “qualitative findings are based on three kinds of data”, and that these are:

1. in-depth, open-ended interviews;
2. direct observations;
3. written communications.

Patton explicated the types of data under these headings and therefore confirmed that the data I proposed to collect was within the expectations of an interpretive approach.

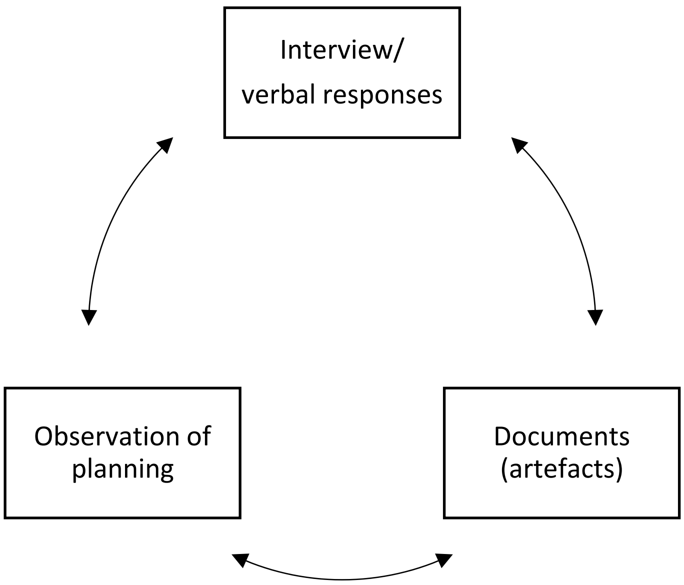

Figure 3.1: Triangulation of data through methods

3.3 Methodological rationale

Methodology refers to the approach taken towards research. Although arguments have been made against the dangers of dichotomous thinking (Pring, 2000), it is generally accepted that approaches to research are situated along an descriptive to causal continuum depending on the type of research question asked.

According to Creswell (2012), conducting a qualitative study involves trying to get as close as possible to the participants being studied so that knowledge can be known through the subjective experiences of people. The positionality of the researcher is key to the qualitative approach as “long-term familiarity with a given social milieu breeds the insider knowledge…necessary to asking questions of informants” (Dempsey 2010, p. 364).

Working on the premise that schooling and curricula are socially, culturally and historically constructed realities (Denzin & Lincoln, 2011), negotiated and maintained by the social interactions of stakeholders in the educational sphere, the current study proceeded from a position of social constructivism. Social constructivism legitimates social interaction as a site of interpretive research and so, to work with ICT teachers to understand how they engaged with re-making their social world as teachers of Computing while at the same time their social world re-made them was appropriate.

In addition, the methodological approach of the study owed much to the direct influence of Shulman (1986, 1987), a proponent of the shift of research paradigms in education towards “well-reasoned, methodologically sophisticated, and logically argued approaches to the use of qualitative methods and case studies” (1986, p. 6) in order to “collect, collate and interpret the practical knowledge of teachers” (Shulman, 1987). In essence, a study that sought to engage with Shulman’s ontological and theoretical framework of teacher knowledge should also be aligned with its methodological approaches in order to do justice to the data that would be generated and interpreted. Focusing on teachers’ processes of planning lessons lent itself to taking a qualitative approach to the development of case studies.

The methodology employed sought to answer the research questions by remaining true to Shulman’s exhortation to “work with practitioners to develop codified representations of the practical pedagogical wisdom of able teachers” (Shulman, 1987) in order to contribute to a case literature and knowledge base for teaching Computing. The teacher participants in this study were ‘able’ in that they were actively transitioning from one curriculum to another and were willing to discuss and share their practice.

Understanding the context around the teachers’ perceptions of what they did required a methodology capable of generating insight into intrasubjective processes (Dempsey, 2010) and reflection about their practice and pedagogical reasoning. Taking a qualitative approach allowed for the development of patterns of meaning rather than starting with a fixed theory (Creswell, 2012) and encourages experimental and multi-voiced texts (Atkinson & Hammersley, 2011). In this sense, listening to the voices of teachers and encouraging reflection and dialogue while they planned lessons was both pragmatic and promising.

3.4 Research design

3.4.1 Multiple case study

Proceeding from an interpretive research standpoint, it was clear that my focus on a small number of participants suggested a case study approach. However, there were several other factors that were important. Firstly, that my research questions focused on what the participants had to say, and also on what they were doing. I wanted the participants' views as well as my interpretations to be represented. In addition, my background in digital and visual methods meant that, where possible, I wanted to use the affordances of video technology to capture rich data.

Using Stake's (1995) definition of intrinsic and instrumental cases to define the purpose of the case study, where intrinsic case study is the term for capturing the case in its entirety for a full understanding and instrumental case study is the term for understanding an aspect, concern or issue of the case, the purpose of this study is instrumental in that it sought to understand specific issues through the case.

In seeking to work with multiple participants, the research design was therefore a multiple case study aiming to identify, explore and analyse perceptions and pedagogical practice resulting from a significant curriculum shift. Yin (1994) maintained that the evidence from a multiple case study "is often considered more compelling, so the overall study is regarded as being more robust" (p. 45) than that of a single case. Using Creswell's (2012) characteristics of case study research as a guide, multiple sources of data were identified, providing a thorough picture of the cases, context and themes. Table 3.5 summarises the types of data needed to answer the research questions, following on from Table 3.4, and distils the data collection methods into three clear types: interview, observation and documentary evidence. Each of these is explored separately below and is represented in Figure 3.3 on p. 62.

Table 3.5: Methods to collect data

Data needed	Data collection methods
Direct responses from participants, either in the form of answers to specific questions, or relevant casual comments made	Semi-structured interview questions
Direct evidence of participant actions as perceived through the lens of PCK and pedagogical reasoning	Observational data of lesson planning
Inferential data from wider sources that either support or conflict with direct responses	Documents and artefacts

3.4.2 Semi-structured interview(s)

Arguably one of the key methods in qualitative data collection, semi-structured interview questions were planned for use with participants. Kvale (2007) offered a useful approach to developing an interview guide which retains flexibility. Having an interview guide also allows for “comparison between cases” (Bryman, 2012, p. 472). The semi-structured interview guide (see Appendix E: Semi-structured interview guide 1, on p. 238) showed the *a priori* themes from the literature review upon which the questions were based, as well as providing prompt questions aiming to cover as much ground relating to the research questions as possible. The data from the interview questions were able to provide material to answer the first research question relating to the curriculum change and some of the second research question relating to planning Computing lessons. The flexibility of this approach meant that the protocol did not have to be strictly applied if an answer had already been provided through other means. There are limitations on “how much can be learned from what people say” (Patton, 2015, p. 27) and so, in order to fully understand the complexities of the situation, observation of the planning process was a fruitful way to proceed.

3.4.3 Observation of lesson planning

3.4.3.1 Visual ethnographic approach

An ethnographic approach to research is employed in different ways by different researchers, but with a shared focus on the activities of people in a given field, and the social meanings of those activities. This results in multiple data collection techniques, but with a key focus on presenting an authentic portrayal of their activities and perceptions.

Nind, Curtin and Hall (2016, p. 140) pointed out that ethnography "makes visible the many ways in which individuals do not exist alone and how their positions and agency in communities of practice influence their experience in these communities". Although this study involved teachers in separate schools, the teachers were effectively part of a distributed professional community of practice of Computing teachers, evidenced by their shared understandings of the need to plan lessons.

In addition, researcher positionality needs to be discussed in relation to the methodological approach. Although I did not spend extended periods of time in each of the schools, as a former ICT teacher I was familiar with the culture and society created by the expectation of the role of the teacher of ICT. Using a blend of approaches to develop case studies allowed me to observe the participants' practices and processes when planning lessons. The benefits of this approach allowed me, as per Pink, Horst, Postill, Hjorth, Lewis and Tacchi (2016), to watch what the participants were doing through the Skype shared desktop or via in-person recording. This placed me in a digital workspace with the teachers who were happy to work in this way, while physical co-location with others, either in school or out of school allowed insights into practice that were immediately familiar to me.

Inspired by Thomas' (2011) discussions of the nature of teachers as reflective and therefore also phronetic practitioners, my approach offered "understanding presented from another's 'horizon of meaning', but understood from one's own" (Thomas, 2011, p. 31) and was well suited to the study. Teachers demonstrate practical judgment, practical wisdom and common sense as they teach, often in ways that are not immediately obvious, requiring detailed examination of their practices in order to unpick the meaning in the data. As a researcher, I needed to be attuned to what worked on a pragmatic level. This meant responding to the teachers' preferences and being open to "shifting from physical co-present interviewing to remote modes" (Weller, 2015, p. 2). I chose to anchor my approach in the research questions being asked, thereby allowing for a certain amount of flexibility with the methods.

The need to 'see' things more clearly invited a visual methodology, allowing a 'new view' with the luxury of meta-analysis and reflection (Lyle, 2003). Video offers rich visual vignettes, a multimodal series of moving images with attendant audio, situated in context, albeit offering a restricted view, but one that is far more detailed than just field notes or still images. The use of video as a method to examine teachers' practices fit into the research design as a major data component, with planned triangulation against other sources. Video was used to record all live contact with the participants, either physically co-present (via iPad) or remotely through internet video calling (Skype). Video data relating specifically to planning provided material of participants' practices to inform the second research question.

3.4.3.2 Internet video calling and shared desktop

The use of video calling in research is a relatively recent phenomenon and one that can be seen as a 'methodological frontier' (Weller, 2015). Skype was offered to participants as an interview medium, and for some was an effective way to proceed. As all of the participants had taught ICT and were perhaps more technologically confident than would otherwise be expected, this opened up the potential to be more creative. The ability to record the interview was made possible using software tools for video recording and streaming (Evaer and Open Broadcaster), which integrated easily with Skype. One benefit of this approach is that it generates abundant data that can be revisited, "enabling a richer focus on the minutiae" (Weller, 2015, p.41). The video data collected became a rich visual record of the lesson planning processes as well as an accurate record of all utterances.

Figure 3.2 illustrates the desktop sharing method. The participant and researcher connect through an internet call. This enables two-way dialogue between the researcher and participant. Video can be enabled by each party. The participant chooses to share their desktop, which can then be observed and recorded by the researcher. In practical terms, the recording can be started by the researcher as soon as the connection is made, which will then record all audio and video during the session. Once the desktop is shared, the video stream of the participant is minimised and can be hidden to avoid distraction. The researcher has full access to viewing everything on the participant's computer desktop, which enables the researcher to observe all actions. The participant engages in two-way dialogue with the researcher, or in a think-aloud explanation of what they are doing.

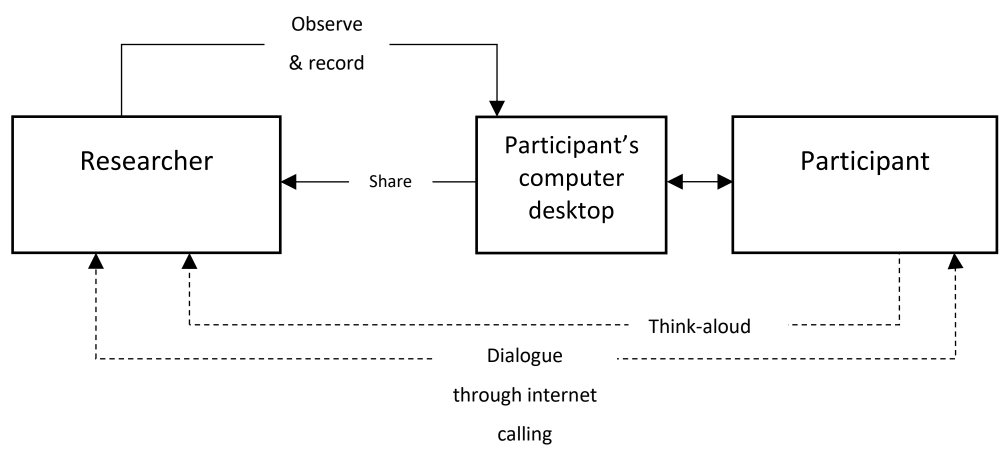

Figure 3.2: Model of desktop sharing method

In this study, the actions observed through the desktop-sharing method included participants creating lesson artefacts and resources, locating saved materials for re-use or review, use of internet search engines to locate text or multimedia information, and trialling methods for use in the classroom, such as developing a programming technique in advance of teaching it to the class. One additional action taken by participants was that of illustrating something they had referred to by locating it in their own archives or on the internet, allowing an insight into wider influences and practices than might otherwise have been gleaned through the sole use of interview questions.

Early on in data collection, despite assuring teachers that I did not wish to alter their lesson planning processes in any way, the first two participants talked throughout their remote recording session – explaining what they were doing, what choices they were making and providing rich, fascinating insights into the process. This negated the use of video-stimulated interviewing originally intended, as so much of the ground was covered and did not require revisiting to explain it. Additional review of the literature confirmed that a think-aloud protocol was an appropriate method to use when studying an individual's interactive thoughts (Reitano, 2006) and potentially countered some of the concerns raised by Nind, Kilburn and Wiles, that "the role played by the video in stimulating recall and reflection was smaller than anticipated" (Nind et al., 2015, p. 6), which had been a concern in the pilot process undertaken. From that point onwards, think-aloud became the method instead of video-stimulated dialogue.

3.4.3.3 Video-stimulated interviews

A video-stimulated interview method (hereafter VSRRD) was originally planned to elicit teachers' tacit knowledge of their own PCK in their lesson planning by jointly observing excerpts and engaging in recall, reflection and dialogue. Video offers rich audio-visual data, albeit within the physical restrictions of the visual frame. An additional limitation of this method, raised by Kind (2009) is that it relates only to the PCK evident in the probe material. It was anticipated that triangulation and comparison to the literature would allow as full as range of "PCK snapshots" (Kind, 2009, p. 30) as possible within the scope of the study.

As part of the research design process for the pilot, it was necessary to examine key features from a selection of studies using video as an interview prompt (Dempsey, 2010; Jones et al., 2009; Lyle, 2003; Moyles, Hargreaves, Merry, Paterson, & Esarte-Sarries, 2003; Nind et al., 2015). This was essential for confidence in the nuances of the method. Although different research agendas and interpretive frameworks impacted on the way the method was used, the use of video was central to each. A shared reflective, dialogic experience between researcher and participant, which seemed to be the key to more recent developments in the method, was reported by Jones, Tanner, Kennewell, Parkinson, Denny, Anthony, Beauchamp, Jones, Lewis and Loughran (2009) as being absent in the VSR strand. Jones, Tanner, Kennewell, Parkinson, Denny, Anthony, Beauchamp, Jones, Lewis and Loughran (2009) and Nind, Kilburn and Wiles (2015) recommended giving the participant time with the video in order to select episodes, whilst Moyles, Hargreaves, Merry, Paterson and Esarte-Sarries (2003) promoted video ownership as residing with the participant. The Nind, Kilburn and Wiles (2015) full VSRRD strand had the most consonance with the proposed case study methodology as they emphasised that any and all aspects of the interview could be analysed to provide additional detail.

Table 3.6: Common approaches to the use of video-stimulated interviews

Acronym	Title	References
SR; video-SR, VSR	Stimulated Recall; Video-Stimulated Recall	(Lyle, 2003)
SRI	Stimulated Recall Interview	(Dempsey, 2010)
VSRD	Video-Stimulated Reflective Dialogue	(Jones et al., 2009; Moyles et al., 2003)
VSRRD also known elsewhere as VSRR	Video-Stimulated Recall, Reflection and Dialogue	(Nind et al., 2015)

VSRRD therefore offered the best opportunity to “read the pedagogical environment critically” (Nind et al., 2015, p. 14) as well as to focus on the thinking behind the action. It fit in with the case study design as a vital data collection opportunity, allowing triangulation against other sources of data as described in the data collection matrix (see Appendix D: Data collection matrix, on p. 234). However, the VSRRD approach was soon side-lined because of the early participants’ willingness to engage in think-aloud practice. It remains in this section because the option to revisit video with participants was open to me until the end of the data collection process but was only used with one participant in order to clarify some details rather than in its full form. In essence, this was more a case of member checking for verification, but through the use of video snippets.

3.4.4 Documents and artefacts

Given that we “may not always appreciate the nature and significance of a case until we have subjected it to detailed scrutiny” (Bryman, 2012, p. 71), it was important for the trustworthiness, credibility and rigour that appropriate and intensive methods of data collection were employed. The use of documents in research works well alongside other methods (McCulloch, 2012). McCulloch (2012) cited the example of interviews with teachers about their curriculum and pedagogic practices being compared with policy documents (p. 213), which was suitable to this study. In order to build up a full picture of the context of each teacher, the following data were collected and used for triangulation and cross-case comparison. They are expanded in the full data collection matrix (see Appendix D: Data collection matrix, on p. 234).

UK policy documents relating to computing available publicly

These were needed in order to contextualise changes to the official presentation of ICT and Computing to trace the process of the curriculum policy changes.

School website and policy documents relating to Computing available publicly

These provided examples of the way that Computing was outwardly presented by 'the school'. Authorship of these documents was a related query. It was anticipated that these would provide "potential connections and disconnects between policy and practice" (see Hine, 2015, p. 88).

Computing department promotional material e.g. newsletters, competitions, posters

Documents produced for promotion of the department and subject area were deemed likely to offer insight into the way the subject was perceived and promoted by the participants' Computing departments.

Computing department schemes of work, lesson plans and teaching resources

These showed how the new curriculum was being received, interpreted and transformed into practice by teachers and provided evidence of the subject's translation into teaching practice, in essence, Kelly's (2009) "planned curriculum" versus the "actual or received" curriculum (p. 11). Schemes of work evidenced the department's interpretation of the curriculum, whereas lesson plans evidenced the individual teachers' interpretation of the scheme of work, which was often different again. Teaching resources included artefacts such as slide decks, handouts, worksheets, hyperlinks to online material: anything located or created to be used in the planned lessons.

Communications with teacher (e.g. email) and relevant encounters at the case study site

Any and all communications between the researcher and the participant (or their colleagues) were judged as potentially eliciting comments that could contribute to the study. These were in the form of email exchanges, social media messages or expressed in the form of project memos (see Richards, 2014), which were added to the study's hermeneutic unit in Atlas.ti 7.

Teacher CVs / education and training

As teacher background was relevant to participant selection and cross-case comparison, it was necessary to gain this information in order to contextualise the participants' responses and dialogue.

Field notes from classrooms (including environment and displays)

Field notes are a valuable source of data. Classroom displays are particularly interesting sources of evidence of practice over time, especially when student work is displayed, what Jewitt (2005) would describe as "a material instantiation of pedagogic discourse" (Jewitt, 2005, p. 309), further evidence of how a teacher mediates 'official' government and school discourse. Where a school was visited as part of the data collection process, field notes were captured as well as video footage.

3.5 The data collection process

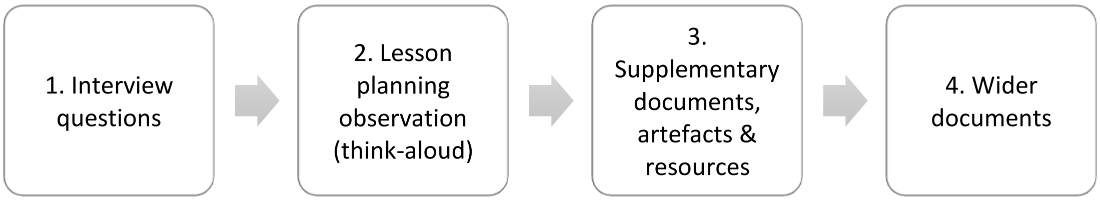

Figure 3.3: Data collection (repeated for each case)

3.5.1 Pilot study

An initial pilot study was undertaken as part of the research design process, as well as successive small-scale pilot interviews in order to trial recording via Skype, different versions of third-party recording software and video-stimulated interviews using the recorded lesson planning footage as the stimulus material. These were successful in confirming that the procedures worked on a technical level, and a reliable combination of recording technologies was found.

While coding the pilot data, it was noted that the high level of technology-related knowledge and competence of teachers of ICT and Computing led to a number of reflections on technology and specifically on video in relation to their professional practice. Themes relating to school leadership began to emerge which were beyond the scope of the research questions of the main study but were sufficiently interesting to warrant separate exploration. The resulting paper, presented in Appendix H: Published article based on pilot data, on p. 246 (Hidson, 2018), explores video-enhanced lesson observation as a source of multiple modes of data for school leadership.

3.5.2 Lesson planning observations

'Planning lessons' in the current study describes a range of time-bound activities related to preparing learning activities for a specified timetabled teaching group. Tangible outputs from this process could include a written lesson plan, a slide deck, handouts, worksheets, stimulus materials, textbook references, software or web-based resources as the teacher deemed suitable for the lesson. Relevant copies of these were collected from the teacher as data. The participants were recorded while planning, whether in person by the researcher or remotely through digital communication technologies e.g. Skype's shared desktop and web cam data streams, which were simultaneously recorded by third-party software. The resultant video, regardless of collection method, provided data for thematic coding and analysis.

Although it may have been useful to observe the teacher teaching the planned lessons, this was not feasible given time, syllabus and geographical constraints. Teacher self-recording and sharing of lesson video had been trialled in the pilot phase and was discounted as a method because of issues with filmic choices and poor camera work exacerbating the limitations of the video footage. This example of 'secondary research material' (Eric Margolis & Pauwels, 2011) meant that I would have been dealing with material produced by someone else. This is not ideal, as during the pilot phase, it was a source of immense frustration that I was unable at times to see potentially significant episodes that could be partially heard in the background. The analytical focus (Eric Margolis & Pauwels, 2011) was significantly hampered by this pragmatic decision. In addition, the focus on the pedagogical reasoning process meant that I considered this data was best captured during the lesson planning process, emphasising teacher voice and action: literally "making meaning from authenticity" (Jackson & Mazzei, 2009, p.5).

3.5.3 Semi-structured interview protocol

The interview questions used with the eight participants currently teaching were grouped into sections relating to background, teaching, curriculum change, the subject, planning and provision of examples. A slightly different version was used with the teacher who had moved to Higher Education. Both versions are provided in the appendices as Appendix E: Semi-structured interview guide 1, on p. 238 and Appendix F: Semi-structured interview guide 2, on p. 239. Table 3.7 maps the interview questions to the research questions and sub-questions in order to indicate the extent to which the interview questions provided data to answer the research questions. With many of the questions having the potential to provide data for multiple research sub-questions, I was satisfied with this data collection instrument.

Table 3.7: Research questions / interview questions matrix

	Research Questions					
	1. How do participant teachers perceive the ICT to Computing curriculum change?			2. How do participant teachers approach the planning of Computing lessons?		
Interview Questions	1a	1b	1c	2a	2b	2c
1	x	x	x			
2	x	x	x	x		
3	x	x	x	x	x	
4	x	x	x	x	x	
5	x	x	x	x	x	x
6	x	x		x	x	x
7	x	x	x	x	x	x
8	x	x	x	x	x	x
9	x	x	x		x	
10	x	x	x		x	x
11			x		x	x
12	x	x		x	x	x
13	x	x	x	x	x	x
14	x	x	x	x	x	x
15	x	x	x	x	x	x
16			x	x	x	x
17			x	x	x	x
18			x	x	x	x
19	x	x		x	x	x
20	x	x	x	x	x	x
21	x			x	x	x
22	x			x		x
23				x	x	x
24				x	x	x
25	x			x		x
26	x			x		x
27	x			x		x
28	x			x		x
29	x	x	x	x	x	x
Tally	**23**	**17**	**18**	**25**	**22**	**24**

3.6 Approaches to data analysis

Atlas.ti 7 was chosen as the software for qualitative data analysis. This allowed for a combination of deductive and inductive coding across a variety of modalities of data resulting from a range of technologies. Tummons (2014) argued that "the use of computer software for qualitative data analysis facilitates rigour and reliability in research" (2014, p. 1), allowing for transparent, consistent, accurate and rigorous data management and analysis. Tummons argues that the use of qualitative data analysis software makes the process of analysis more visible because it is more straightforward to produce detailed accounts. In practical terms, the Hermeneutic Unit (the digital project container in Atlas.ti) is itself a verifiable record of all codes, network views and text queries, which could be opened and demonstrated to an interested party in a way that Tummons would term "persuasive and credible" (2014, p. 14), allowing the trajectory of the conclusions to be verified.

Practically speaking, in terms of thematic analysis Saldaña (2012) suggested a cyclical process of open, descriptive coding followed by closed, analytical coding to narrow down the number of codes by constant comparison in order to begin extensive data analysis. Initial indicative codes (see Table 3.9: Ex ante code list used to approach the data, on p. 72, below) were developed from the literature surrounding Shulman's work on PCK and pedagogical reasoning and relevant studies involving pedagogy in Computing Education, such as those developed by Sentance and Csizmadia (Sentance & Csizmadia, 2015) in a study of teachers' perspectives on successful strategies for teaching Computing.

3.6.1 Transcription

By the end of data collection, the data consisted of a range of interviews, audio and audio-visual recordings, documents, online links and communications. A major decision was necessary in relation to preparing the data for analysis. Although much of the data was in the form of video files and I had a background interest in semiotics and multimodality, I felt that the research questions were such that the voice and experiences of the participants needed to be foregrounded and analysed thematically. Although many options were possible in terms of analysing the interactions within the planning process, for this study I felt that to prioritise the interactions would be to neglect the wider context of the research and the responses and actions of the participants. At a time following a major curriculum change, I felt it important to keep my analysis close to the authentic voice of the participants. Jenks (2011) highlighted that the methodological framework used in the research “will often determine what to transcribe” (p. 3). As such, I decided to transcribe all interviews and planning sessions orthographically and use the line by line representations as the main source of data, but always with the intention and potential to work simultaneously with the original recordings for verification. I expected that I would be able to return to the video to illustrate the nonverbal aspects of some of the findings with still frames lifted (and anonymised) from the video.

Transcription is not a neutral process. It inevitably involves selection and compromise between what is being transcribed and how it can be represented, especially when transcribing from video. Despite possible concerns around bias and selectivity, Jenks (2011) outlined four fundamental functions of transcription: to represent, to assist, to disseminate and to verify. Firstly, I was confident that the participants’ perceptions and processes could be represented through the transcription of their spoken words, and that any queries could be addressed by returning to the raw video data. Secondly, transcriptions would be helpful in framing the participants’ responses, allowing an accessible level of detail during the process of analysis, complementing but not replacing video data. I concurred that having transcripts would assist not only in the analysis process, but also in the dissemination phase. Jenks’ third function: dissemination, was worthy of consideration from the outset as an accepted and convenient way of sharing data in an accessible format. The chronological nature of video and the time taken to move between sections and then to watch the episode potentially detracts from the point being made. The use of transcription allowed data to be shared in written form for publication, for example in Hidson (2018). Verification, Jenks’ fourth function, meant that I could bring transparency to my work by providing the opportunity for others to engage with and critique my interpretation of the data. Methodologically, I intended to take a thematic approach to analysis, and the rationale is discussed in the next section.

3.6.2 Coding

In this study, I used coding to analyse the data thematically. I took Saldaña’s (2016) definition of a code as,

> a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or attribute for a portion of language-based or visual data (Saldaña, 2016, p. 4)

for the purpose of detecting patterns and applying categories. Although I followed Friese’s (2012) practical approach to using Atlas.ti 7 CAQDAS software to manage the data, Saldaña's systematic approach to coding as an analytical process resonated more fully and I was able to combine both.

Saldaña proposed a two-cycle process of coding: essentially an initial "first draft" followed by a strategic "second draft" based on the learnings of the experience (Saldaña, 2012). He offered 'eclectic coding' as a method appropriate for an initial exploratory technique followed by synthesis of the material into a more unified scheme. Eclectic coding can be used to apply a range of code types, such as descriptive codes, emotion codes, *in vivo* codes and process codes. Working with my research questions to guide my interpretation, I decided that the flexibility of this approach was relevant to the variety of responses from what my participants had to say, what they were doing, and what the wider documentary data would suggest.

3.6.3 Conceptual framework

To begin the process of analysing the data, I kept a data handling log, in which I documented the various stages and decisions involved. I first revisited my conceptual framework and expressed this as a narrative and tabulated the high-level concepts (Table 3.8).

*The new computing curriculum replaced ICT in 2014. In addition to requirements of the National Curriculum, communities of practice, such as CAS, exist to encourage the delivery of Computing, particularly Computer Science. The teacher's background, subject knowledge and existing professional knowledge bases are *challenged* as the new curriculum represents an entirely different discipline for many teachers. In addition, local influences impact what is possible in terms of access to CPD, but also the extent to which the new curriculum can be taught. Teachers plan lessons within the new curriculum, locating, modifying and developing teaching resources, and within an assessment framework, developing their abilities to teach the new subject. This study aims to explore teachers' planning of Computing lessons within this framework, in relation to the lesson 'plan' (the manifestation of the process of pedagogical reasoning) as a site for demonstration and development of professional knowledge.*

Table 3.8: Conceptual framework

External influences	Teacher influences	Local influences	Teacher actions	Outcomes
New computing curriculum Communities of practice e.g. CAS Exam board qualification specifications	Teacher background Teacher subject knowledge Teacher professional knowledge bases	Access to CPD Legacy (ICT) curricula School resources (including hardware and software) School policy	Lesson planning Developing resources Teaching Assessment	Extent of various influences on planning and resourcing lessons 'Shape up or ship out': development of teachers' ability to teach the new curriculum

3.6.4 Data handling

The following section outlines the decisions made at the data handling stages.

3.6.4.1 First cycle coding

Four main stages characterised this part of the data handling process: selecting the data, organising it, creating network visualisations and finally, coding.

Step 1 – selecting the data.

A data matrix was produced (see Appendix G: Participant data matrix, on p. 238) in order to select the types and amount of data to be used from each participant, as this varied. Participant 1 (Alex) had been involved from the pilot stage and I needed to balance his contribution in proportion to the other participants. I took the decision to use only the most recent contributions from Alex, which were planning sessions relating to Year 7 and Year 10 lessons. This was approximately two hours of initial video of his planning processes: all of this was transcribed verbatim. This step meant that I had to remove all the files and codes that had previously been established, in order to clean up the data set.

For participant 2 (Ben) the initial video data was planning for Year 3 and 4 (combined) and totals approximately 2 hours and 20 minutes.

Participant 3 (Claire) was not currently teaching in the FE sector, so her contribution was 90 minutes of audio recording of one semi-structured interview using a list of pre-prepared questions as a guide (see Appendix F: Semi-structured interview guide 2, on p. 239).

Participant 4 (David) was using pre-planned materials that he had created in a previous school and adapted for his current school and the interview and planning session discussed this. The video files total approximately 45 minutes. David provided all his schemes of work but at the start, I decided to only incorporate the overviews rather than every file. The generosity of the participants in sharing digital documents meant that I had an uneven spread in terms of quantity and relevance. The data that have been included are presented in Appendix G: Participant data matrix, on p. 238.

Participant 5 (Ellen) was using materials prepared by her head of department and discussed this in relation to modifying them for her class. The audio and video files totalled approximately one hour.

Participant 6 (Faith) was using pre-planned materials that she had developed for the use of her department. She was refining her plans for the classes she was teaching. The video footage is approximately one hour. A small chunk of video material (approximately 10 minutes) was lost because of technical issues, but once the issue was noticed, those questions were incorporated later in the interview.

Participant 7 (Glenn) was planning GCSE lessons and the video data was 1h 20mins. Towards the end of the interview, he mentioned another lesson he was planning, so we also discussed that. He later sent materials for the second lesson as well. Glenn provided other teaching resources, which were not included in the data matrix.

Participant 8 (Helen) planned an unplugged lesson which she discussed delivering to other year groups as well. The initial video was 45 minutes. Helen provided other resources, which were not included in the data matrix.

Participant 9 (Ian) planned a logic gates lesson. The initial video was 45 minutes. Ian provided other resources, which were not included in the data matrix.

Step 2–organising the data

Each piece of data to be used was prefaced with the participant's initials so that I could group them into document families to make management easier. As I already had some of the documents in an Atlas.ti 7 hermeneutic unit, I reused this hermeneutic unit and deleted documents that were no longer in my data matrix. I went through and imported all the documents specified in the data matrix. All PowerPoint, HTML and Excel files had to be converted to PDF to be readable by Atlas.ti 7. I updated the data matrix to show the filenames for each participant's set of files and renumbered them to run sequentially.

At this point there were 141 files in the hermeneutic unit. I then created families of documents for each participant to facilitate data management.

Step 3- visualising the documents

I then created network views of Faith and David to visualise the documents. Realising that I had been inconsistent in adding descriptions, I went through and put a brief description in the primary document manager comment box for each document so that its contents would be immediately obvious. I then created network views of each participant to visualise the documents. I created a network view of the scheme of work documents for each participant and then exported a Primary Document Family table, showing all the documents and their distribution within the families I had created.

Step 4 - coding

The first coding decision was to code all the interview/planning session transcripts before turning my attention to the resources and other documents in the hermeneutic unit. Given the focus on planning for the new curriculum and the desire to understand how teachers were planning within it, I decided that there would be two main approaches. Firstly, I would take each segment of the participants' speech (which could include responses to questions, wider comments, think-aloud utterances and problem-solving, to name a few) and decide what the main concept/s in the utterance related to. The frame of reference for this was:

1. Descriptive coding of a concept in an open coding approach and naming the code;
2. *In-vivo* codes, using the actual words of the participants;
3. *Ex-ante* codes using existing key words from the PCK and pedagogical reasoning; literature, and the national curriculum keywords. The initial list of 40 can be seen in Table 3.9 on page 72, below.

I systematically coded the data, adding an additional 23 codes and began to add in analytical memos as ideas occurred to me. I created a family of codes for participant Alex as well as a family of *ex-ante* codes, so that I could analyse the different codes and determine which codes were useful for the other participants. When I started coding Faith's data, I realised that Friese (2012) had suggested coding all the speaker segments. I completed this for Faith and went back over Alex and Ben. I created a table of codes as a separate document.

Next steps

At this point I coded the remaining material using the same codes and made a note to go back over the transcripts to see if any of the later codes had a place in the earlier transcripts. This was because I felt that the cumulative effect of reading through the documents and interviews meant that I may have developed my understanding more towards the end of the process than the beginning and wanted to apply that interpretation consistently. I then coded the wider documents, amending any errors during the process. At this point all interviews and sessions were coded, as well as all supporting documents. The basic first cycle was complete, and the code list had risen to 232 codes (see Appendix I: Table of codes, on p. 258).

3.6.4.2 Second cycle coding

The second cycle of coding was characterised by a process of code revision. I started with 232 codes obtained from first cycle coding, which involved beginning with a set of provisional codes – the *ex-ante* codes – and then adding new codes as I coded the files in the hermeneutic unit. By doing this, I moved from 40 initial codes to 232 overall, although nine of these were participant identification codes designed to help segment the data and provide anchors for later analysis.

I did not code video or audio separately, relying solely on the text transcriptions. The rationale for holding back from coding the audio and video was an explicit decision to concentrate on thematic analysis rather than taking a multimodal analytic approach. The nature of the research questions meant that, although video offers "a fine-grained multimodal record of an event" (Jewitt, 2012, p. 2), resulting in rich visual vignettes situated in context, my aim was to frame the video footage as multiple modes of data rather than attempt a multimodal analysis of the meaning within different modal channels. I felt there was sufficient complexity in the data collection and analytic methods to answer the research questions.

I reviewed the codes to delete unused codes. I examined each code, looked at its use in context and then wrote a definition of the code. I began with single-use codes, then moved systematically through codes that had been applied between two and seven times. With some of the lower-use codes, I was able to merge them with other codes. This happened with some of the *in-vivo* codes, such as “irritated by interruption”, which I merged with “feelings”. The full data-handling log was useful as I was able to track back and understand why I had made particular decisions. I also used it to make notes on things to consider, such as linking and grouping particular codes. I found that I was writing very full descriptions in the code descriptor, almost in memo detail and using them to connect with my thinking.

At the end of the second cycle of coding there were now 185 codes and I created a new document to tabulate them A to Z (see Appendix J: Full list of codes, on p. 263).

3.6.4.3 Codes

Using themes from the literature and from the research questions, I developed an *ex-ante* code list – a starter list with which I could begin to approach the data, which can be seen in Table 3.9, below. Although presented here in alphabetical order, the list included explicit codes relating to PCK and pedagogical reasoning. They acted as branches of thinking rather than an exhaustive list.

Table 3.9: Ex ante code list used to approach the data

Ex-ante code list	
Adaptation	Knowledge of students
Assessment knowledge	National curriculum
CAS	Pedagogical knowledge
Classroom context	Planning
Coding	Preparation
Computational thinking	Proforma
CPD	Programming
Curricular knowledge	Progression pathways
Curriculum change	Reflection
DfE	Representation
Differentiation	Resource provider
Digital literacy	Resources – created
E-Safety	Resources – found
Evaluation	Resources – modified
Feelings	Scheme of work
ICT curriculum	Subject knowledge

Ex-ante code list	
ICT Skills	Teacher background
Impact	Teacher beliefs
Instructional selection	Transition from ICT to Computing
Instructional strategies	Unplugged computing

As I began to work with the data, I added *in-vivo* codes and developed new codes based on my interpretation of each segment of data. By the end of the coding process, I had developed 185 codes, of which nine were simply structural participant identification codes, resulting in 176 codes. In reviewing the codes, I categorised them as having the potential to answer aspects of either the first or the second research question, each of which had three sub-questions. However, given the overall complexity of the study, I recognised that flexibility was necessary to give the fullest picture. Table 3.10 and Table 3.11, on p. 74 onwards, show these codes.

Starting to look for patterns

Friese (2012) suggested prefixing main categories and then creating subcategories from this, which I did. One of the things I wanted to do was to look at the quotations that I had coded, in order to get back to my raw data. By using the network diagram feature in Atlas.ti 7, I was able to take an individual code and import its quotations. I found it useful even within the code to arrange the quotations visually into loose themes.

For example, Figure 3.4 shows the network view of the 37 quotations for the CPD code. It is not intended to be a readable example, but rather to show how quotations can be arranged visually using the network view feature. Within this code, there were groups of quotations that created smaller subcategories. Each of these was interesting and warranted individual attention. There was one large collection relating to the costs of CPD – in terms of financial cost, time cost, and an implied cost of not taking the opportunities to upskill if you are a non-specialist ICT teacher trying to convert. This then related to the ‘impact on career’ code and what happens if you don’t upskill or don’t want to upskill.

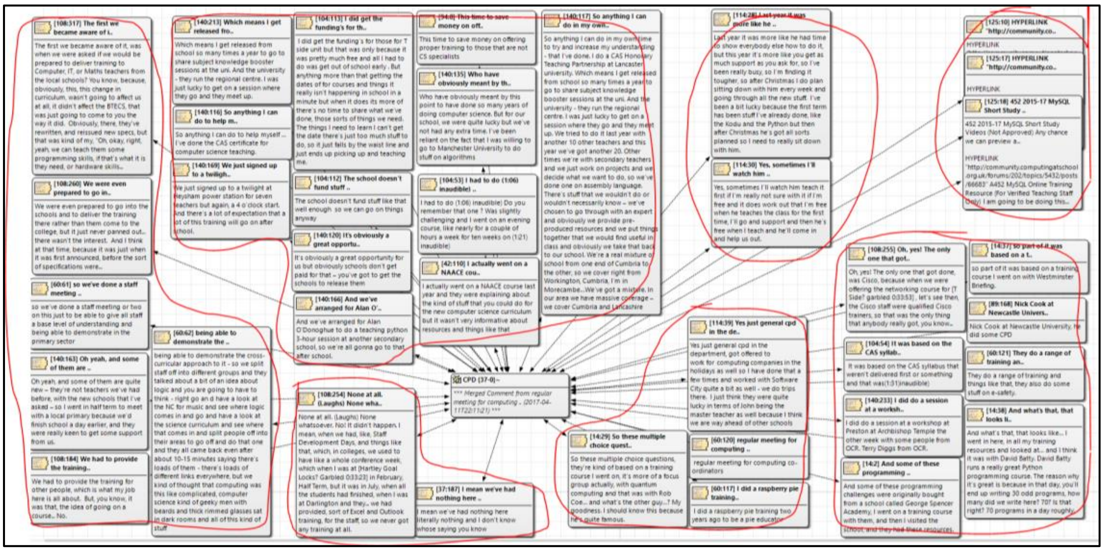

Figure 3.4: Network view of CPD quotations in Atlas.ti 7

Inasmuch as the process of checking of codes was painstaking, it meant that I could see patterns emerging. I was able to develop main categories and subcategories, but also subcategories within the codes. Because of familiarity with the data, I could also link quotations back to participants for a fuller understanding. For example, I knew that the teacher with the Computer Science background was not keen on the training event he had attended and also that he was not an active member of CAS. I could also identify which of these quotes came from ICT teachers transitioning to Computing.

Finally, I created new families of codes based on the main categories, as expressed by capitalised prefixes, for example 'PERCEPTIONS_Computing is different from IT'.

Table 3.10: Final codes, mapped to Research Question 1

Codes mapped to Research Question 1		
Ahead of the game	Imposter syndrome	Qualification currency
Broad curriculum	IT marginalised	Real world skills
CAS_local CAS hub	Jump ship	Staff confidence
CAS_master teacher	KS4 options	Stick to my guns
CPD	Lack of programming skill	Student ability
Challenges	Multimedia	Student interests
change back	National curriculum	Student recruitment
Computational thinking	New content	Subject knowledge
Computing strands	New curriculum	Subject name changes
COMPUTING_Digital literacy	Non-Specialist Teachers	Subject specialism
COMPUTING_E-Safety	PERCEPTIONS_ of computing	Teach myself

Codes mapped to Research Question 1		
Curriculum change Dodged a bullet EBACC Evidence Extra-Curricular Feelings gap in the curriculum Gender Government policy I am on the back foot I do what I do because I have to I trained as a programmer ICT curriculum ICT Skills Impact Impact on career	PERCEPTIONS_Computing is different from IT.. PERCEPTIONS_Lack of CS understanding from SLT Primary curriculum Pushing Computer Science Qualification changes	Teach other subjects Teacher attitudes Teacher background Teacher beliefs this is, I suppose the life of.. Transferable skills Transition from ICT to Computing Uncertainty Upskill staff vocational We still value both subjects Web design Y6toY7_Transition issues

Table 3.11: Final codes, mapped to Research Question 2

Codes mapped to Research Question 2		
Barefoot Computing Build on prior plans CAS Curriculum map Curriculum planning Curriculum tension Detailed planning Engagement Exam boards Exam specifications Exercise books Extension I'm not a very good programmer.. I lost my chain of thought com.. I see why this works but I'm n.. I'm not sure having it all wri.. I've struggled to program this.. integrate what we've learnt pr.. irritated by interruption is this how real programmers p.. learn the syntax off by heart Lesson Study LESSON_PLAN_Proforma Marking Modelling most teachers will beg, borrow… Multitasking now I've got my own misconceptions Objective	PCK Assessment knowledge PCK Pedagogical knowledge PCK_Curricular knowledge PCK_Idiosyncracies PCK_Knowledge of students PCK_nobody teaches the same way twice PCK_Pupil misconceptions PED_REASON_Adaptation PED_REASON_decision PED_REASON_Differentiation PED_REASON_Evaluation PED_REASON_Instructional selection PED_REASON_Instructional strategies PED_REASON_Preparation PED_REASON_Representation PED_REASON_Sequencing Pedagogical influences Planning Planning ahead Planning for assessment Planning for lesson observation Planning interruptions Planning pressure Presentation Pupil attitudes Pupil motivation	Pupil prior knowledge Recap resilient RESOURCE - textbook RESOURCES RESOURCES - booklet RESOURCES - purchased Teacher background CAS_local CAS hub CAS_master teacher CPD Influential people MIT PHYSICAL computing PHYSICAL_MicroBits PHYSICAL_Raspberry Pi Programming Programming languages PROGRAMMING Scratch Programming strategies PROGRAMMING_Coding PROGRAMMING_Errors Progression pathways Social media Support primary Teach myself This is where the teaching network… Unplugged computing

The third phase of work with the codes and code families was essentially a process of constructing theoretical sub-themes, achieved by “connecting and consolidating second-level codes and at the same time, abstracting from the evidence contained in the data” (Bowen, 2005, p. 218), allowing each aspect of the research questions to be answered. A synthesis from this phase is offered in the next section.

3.6.5 Synthesis

The final methodological phase of work involved synthesising the codes into a format which helped to express the direction of the findings. This was designed to help me understand my findings and also to provide a guide for presenting key data from the participants.

I synthesised the codes by firstly revisiting all of the transcripts and raw data from all of the participants so that the context was fresh in my mind. I then reviewed all of the codes and code families, looking for analytic categories that expressed and represented the data. Although some of my participants were more knowledgeable in terms of Computing background than others, there was no clear-cut distinction by which I could say that the more knowledgeable participants had different viewpoints to the less knowledgeable on some of the issues underpinning the research questions. Instead, I attempted to represent different viewpoints in a clear and unbiased way. Having separated the codes into the two research questions, I maintained this separation, and then broadly mapped the analytic categories to the research sub-questions.

Table 3.12 represents the themes I synthesised into analytic categories. These, along with their attendant findings form the basis for the concluding chapter: Chapter Six. In a similar vein, the themes and categories in Table 3.13 are expressed more fully in the latter part of Chapter Six, prior to the discussion of the wider implications of the current study.

Table 3.12: Overarching themes and analytic categories for Research Question 1

THEMES
TEACHER BELIEFS • Different beliefs about ICT and CS, • The need for a broad curriculum, real-world skills, • Concerns about marginalisation of IT, the prioritising of programming and Computer Science • Subject status, pupil abilities/vocational/academic, gender issues
TEACHER IDENTITY • Vulnerability, imposter syndrome, specialist and non-specialist identities • Impact on career, perceptions of CS, dodging bullet, pressure, loss of core status, • Continuing uncertainty re: government policy, accountability,
PROFESSIONAL ISSUES • Lack of support from senior leaders, lack of and importance of CPD, upskilling in own time, • Overt and covert costs • Importance of CAS, importance of professional networks, influential people, • Importance of resources and resource providers, the cottage industry • Transition issues (from primary to secondary school).

Table 3.13: Overarching themes and analytic categories for Research Question 2

THEMES
TRANSITIONAL PEDAGOGICAL REASONING • Pedagogical reasoning process evident but messy • Lesson planning allows for evidencing and developing PCK • Different purposes of planning and approach taken; confidence
KNOWLEDGE VALIDATION • Need to enhance knowledge and Computing pedagogy; linked to beliefs • Importance of resources and resource providers • Constraints from exam boards and changing specifications • CAS, Master teachers, hubs, support responsibilities
DEVELOPING SUBJECT AND PEDAGOGICAL CONTENT KNOWLEDGE VIA PROFESSIONAL LEARNING NETWORKS AND RESOURCES • Internet searching, found/modified/created resources • Specific role of resources: PCK by proxy; what teachers do with them • Changing teaching; developing PCK

In expressing the findings mapped to the research questions, I was also able to draw in aspects of the literature that were supported or contrasted by the participants in my study. Under each sub-question I have expressed the synthesis of the participants' perceptions and actions more fully, referencing each one in relation to their viewpoint. I have then related this back to key positions and findings from the literature. The resulting syntheses can be seen in the chapter summaries for each of the findings chapters: Chapter 4 and Chapter 5.

3.6.6 Ethical considerations

Research ethics are fundamental to working with participants, each of whom must voluntarily agree to participate. A researcher has many responsibilities towards the participant, towards their institution and towards the research community. These ethical considerations permeate every step of the research process. According to Cohen, Mannion and Morrison (2007, p. 51), "one has to consider how the research purposes, contents, methods, reporting and outcomes abide by ethical principles and practices" as each stage raises ethical issues. They cite issues pertaining to the nature of the research, context, procedures, participants, type of data and what may be done with the data as well as traditional aspects such as consent, access, human dignity, privacy, anonymity and confidentiality.

I reflected on matters of potential conflict of interest and concluded that there were none. As a self-funding doctoral candidate, I had no funders to consider. My research questions were formed entirely from professional curiosity regarding the changing curricula within my field. Having reached the position of deputy headteacher prior to beginning my research, I was no longer teaching ICT or Computing and could not have engaged in autoethnography. In effect, I could not have been a participant in my own study: I would not have met the selection criteria. I was no longer living in the same city, nor was I employed by any school, ensuring the "critical distance" necessary for the maintenance of data integrity (Bowen, 2005, p. 214). By actively including participants from a variety of backgrounds, I took steps to avoid imposing my potential beliefs and biases on the study.

In addition to reviewing the BERA ethical guidelines (BERA, 2011), and submitting a comprehensive application for ethical approval (see Appendix B: Ethical approval), I also gave careful consideration to the purpose of the research: to explore teachers' perceptual and practice-related responses to a curriculum change. I considered that the research would be unlikely to do any harm to the participants, although reflection can be emotive, drawing on personal experience. However, the opportunity to voice concerns and review personal practice was potentially beneficial. Practically and ethically, however, a study such as this highlighted the need to recruit participants with sufficient confidence in their own practice to take part and also the need to ensure an environment that was collaborative and non-judgmental (Nind et al, 2015).

The traditional ethical considerations of privacy, informed consent and of doing no harm become more significant with digital and video methods (Flewitt, 2006). Visual data must be used carefully, as privacy and anonymity can be affected. In this study, I was clear that all use of data would maintain privacy and anonymity. This was especially important as many of the documents and triangulation sources contained school names. In addition, the use of desktop sharing as a data collection method meant that the participant's computer desktop and virtual work environment was fully visible, with the potential for private, non-research related information to be visible to the researcher. This depth of access required a level of trust from the participant as to the ethical practice of the researcher. No data with identifying features were used in reporting or dissemination, and no information beyond that agreed was used in the study.

With respect to the representation of visual data without violation of privacy and anonymity, some researchers have taken the approach of editing visual data (Prosser, Clark, & Wiles, 2008), for example recreating still frames using graphic design software and using cartoon figures to represent participants. This approach was used to represent some of the context of the lesson planning process instead of still frames from the video footage. Diagrams were created rather than still frames from video, for example, Figure 3.2 on page 58, a representation of desktop sharing through internet calling. Although other researchers argue to that to anonymise is to depersonalise (Clark, 2013), for the purposes of the current study, I considered anonymity important.

Schuck and Kearney (2006) warned of possible bias in presentation of video vignettes and the need to monitor the authenticity of clips, placing the onus on the researcher to maintain transparency and ethical practice. This was an aspect I had to consider early on when considering the use of Video Stimulated Recall, Reflection and Dialogue, but became less significant when my study began to incorporate think-aloud techniques.

Transcription is another aspect of the research process where ethics must be foregrounded as "care must be taken to maintain anonymity while sharing … transcripts and observations" (Jenks, 2011, p. 6). All transcripts were created using participant initials and then allocated pseudonyms for reporting purposes. Remaining methodologically consistent, I considered that this was appropriate, in line with Jenks' assertion that,

> Pseudonyms are helpful in reminding readers that transcripts represent the utterances spoken by real people with storied lives, rather than devoid of social meaning (Jenks, 2011, p. 23).

One final aspect of ethical behaviour in relation to the participants concerned the channels of recruitment. Some of my participants were recruited through social media channels. Beyond posting the initial call for participants, I made sure to take all communications into the private domain and to refrain from posting any comments in relation to the ongoing study, so that participants could maintain their privacy and anonymity. This was especially important as several had high-profile roles as Master Teachers in the Computing at School (CAS) organisation.

3.6.7 Issues of trustworthiness

It is widely held that positivist approaches to evaluating research use terms such as validity and reliability, which do not have directly equivalent qualitative counterparts (Atkinson & Hammersley, 2011; Bloomberg & Volpe, 2012; Creswell, 2012). Accepted terms such as trustworthiness, credibility and dependability are operationalised through techniques such as prolonged engagement in the field, triangulation of data sources and methods and thick description. I was engaged in this field throughout my career and I had the expertise with which to make sense of the data encountered. I proposed methods to triangulate the data through comparison with other data (see Appendix D: Data collection matrix, on p. 234) and against the literature in the field. The most significant counter-argument to the positivist stance is that suggested by Tummons (2014), to which I subscribe: that the work focuses on the research questions to be answered and aims to provide credible answers framed through the participants' perceptions and practices.

The credibility of this study rests with the transparency with which all aspects are reported as fully as possible, especially within the methodology and findings chapters. The use of Atlas.ti qualitative data analysis software is a further example of the way that this level of credibility has been established. Underpinning the project is a digital container (known as a Hermeneutic Unit in Atlas.ti) which evidences every document, transcript, quotation, code and analytical process undertaken. I have attempted to harness the affordances of the software to provide rich contextual information through in-depth description of the participants and reflections on the study. I have been careful to outline the researcher's role, reflecting on my own background, assumptions and potential bias.

I have shared data and reflections on the findings and I have highlighted approaches to triangulation, to show the developing conclusions and to compare data gained through differing methods. I have been methodical in my approach to tabulating data and demonstrating direct connections between the data and the findings. This has included being open to discussing negative instances, discrepant findings and variation in practice, for example the different approaches to planning shared by the participants. In line with this, I have been open to participant variation, welcoming the inclusion of participants whose experiences had the potential to contradict each other.

Throughout the study I have attempted to enhance the transferability of the study and its findings. Ensuring the clear descriptions of contexts and participants meant that the findings had the potential to be transferred to a similar context, and to be understood from both a Computing perspective and a more general audience with an interest in curriculum change and pedagogic practice. Taking this approach allows readers to consider whether processes such as those I have outlined might be at work in their own settings and communities by understanding in depth how they have occurred for the participants in the current study.

Although I, as the researcher, form the lens through which the data have been interpreted, the approaches I have taken contribute to the dependability of the study. A wealth of contextual, procedural and interpretive cues has been provided which would allow a similar study to be carried out. The step-by-step data collection and analysis process and audit trail are detailed enough to allow similar immersive approaches for researchers to follow. This approach is both open in terms of researcher positioning and in being methodologically empathetic (Mills & Morton, 2013), allowing the shape of the research to grow and respond to the participants and their contexts. The methods followed, although rich in digital and visual approaches, are accessible and allow similar lines of enquiry to be followed.

3.7 Limitations

Whilst it is likely that all research studies will have limitations, it is also the case that highlighting potential and actual limitations can be seen as offering further evidence of the trustworthiness of the study. To highlight limitations is to remind potential audiences of the context of the research and to encourage them to begin their own critique about the extent to which the research might be useful for other settings.

Taking a case study approach "is frequently positioned as… atheoretical and …lack[ing] warrant" (Hamilton & Corbett-Whittier, 2013, p. x), but that is to negate the accepted wisdom of matching the design to the research questions, which is something that has been approached with great care and consideration in this study. I am confident that this was a research problem that required exploration, interpretation and triangulation through different methods. The interpretive approach allowed for methodological flexibility and the use of video methods, but in fact the video methods did not hijack the research questions. Responding to the needs and preferences of the participants meant collecting data in the ways and to the extent that the participants were able and willing to share, a position that I would argue is a strength and a feature of interpretive approaches to data.

The approach taken to the research design is a matter of a developing "scholarly habit and a moral disposition", which Mills and Morton (2013, p. 161) have suggested requires researchers to be "quietly attentive, modest, critical and above all empathetic". This study sought, in a small way, to purposefully locate a range of participants to offer their perceptions and act as key cases of professional practice for a researcher aiming to engage critically but empathetically. The study brings together literature to frame and focus the engagement. It offers insights for other researchers, for policy-makers, for school leaders and for practitioners, explored and presented in a way that is accessible and relevant. These outcomes must be considered as a counterbalance to any perceived methodological limitations.

This study is based on engagement with nine participants, therefore could be considered as a small sample in comparison perhaps to the number of respondents that could have been sampled for a survey, such as the almost one thousand who responded to the Royal Society survey (2017). However, these participants worked in eight separate schools (one participant had moved to HE). Had I taken the approach of gathering respondents in one council area or London borough, they could have been considered as the equivalent to all the secondary schools in one small borough, or all the schools in one academy chain. In fact, each of the participants is one teacher in one school in one borough. In addition, in the case of those who were currently working in schools, they represented between 20% and 100% of the total number of teachers of ICT or Computing in their respective schools. Sample size is therefore a matter of perspective and of purpose.

Participant recruitment methods may be seen as a limitation. I chose to post a call for participants via professional social media networks to access to the kinds of participants I sought. In addition, I invited participants that I met through informal channels. This could have produced only participants who were keen social media users, or who identified with certain types of social media, but the flexibility in my approach meant that I also gained participants for whom none of these conditions were true. The direct, personal approach complemented the wider participant call. As can be seen in the participant vignettes, the variation in background and experience added to the richness that the participants brought to the study. The recruitment method was convenient for me, but may not be considered convenience sampling as such, more the application of purpose, what Patton (2015, p. 53) describes as "purposeful sampling", in order to find information-rich cases.

Issues of subjectivity or bias could be considered as limitations to the study: my bias as a researcher with a background similar to the participants, and the participants' biases in potentially saying what they thought I wanted to hear. I consider these two aspects to be linked and inextricably bound to previous discussions of ethics and triangulation. In being open in my approaches to participant recruitment, the participants knew enough about my background and the purposes of the research to be candid; that they agreed to participate knowing that I would be observing their planning and documents guarded against overt bias. My researcher characteristics were such that I had no axe to grind: I was no longer an 'insider', but our shared profession and the recent curriculum changes were enough to allow the participants to relate to my research interests. The transparency of my approach to reporting the study should allay any concerns of researcher bias.

3.8 Chapter summary

In this chapter, I have outlined and discussed my full methodological approach, starting from a re-statement of the context and purpose of the research and the types of data and participants necessary to answer the research questions. I have provided a rationale for the interpretive approach, the use of a multiple case study and the triangulated research methods employed to explore the participants' words, actions and documents. I have provided step-by-step detail of the data collection and data analysis processes and methods used, including a synthesis showing how the research questions are answered by the findings. I have laid out, as fully as possible, the ethical considerations, matters of trustworthiness and limits to the research in order to be as transparent as possible. In the next chapter I will go on to outline the findings of the research and my process of interpretation.

Chapter 4 Findings and discussion of Research Question One

> *My intention is to "take what [I] have seen and heard and write it down on paper so that it makes as much sense to the reader as it did to [me]"* Bogdan and Biklen (1992) in (Hamilton & Corbett-Whittier, 2013, p. 179).

4.1 Chapter overview

In this study my overarching aim was to understand in-service teachers' perceptions of the transition from teaching ICT to teaching Computing and to explore their application of professional knowledge and skills through planning Computing lessons under the new curriculum. Subsumed within this were the following aims:

- To explore participants' perceptions of the curriculum change and its impact on their planning and teaching.
- To explore how different participants addressed the Computing subject knowledge requirement, given their differing backgrounds and entry routes into teaching ICT and their pre-2014 teaching experience within an IT or ICT curriculum framework.
- To investigate the extent to which the concept of pedagogical content knowledge (PCK) and its enactment through pedagogical reasoning (Shulman 1986, 1987) could be applied as a framework to understand the processes involved in planning lessons during the transition from ICT to Computing.

In seeking to understand this problem, this multiple case study addressed two main research questions, each with three sub-questions:

1. How do participant teachers perceive the ICT to Computing curriculum change?
    a. What are participant teachers' perceptions of the ICT and Computing curricula?
    b. What are participant teachers' perceptions of the transition from teaching ICT to teaching Computing?
    c. How do participant teachers perceive the subject-specific professional development available to them during the transition?

2. How do participant teachers approach the planning of Computing lessons?
    a. How is PCK enacted through pedagogical reasoning when participant teachers plan Computing lessons?
    b. How is the Computing subject knowledge requirement being addressed by different participant teachers to enable them to plan lessons?
    c. To what extent do participant teachers draw upon subject-specific sources and resources do to enable them to align their planning with the programmes of study?

The intention was to share the “lived experience of the individuals” (Hamilton & Corbett-Whittier, 2013, p. 61) with a view to developing a more sophisticated understanding of issues around the ICT to Computing curriculum change, which currently lacks a substantial research base (Crick, 2017).

Guided by the research questions, the analysis and discussion of data has been divided into two findings chapters. Each chapter presents the key findings obtained from semi-structured interviews, lesson planning sessions and a range of documentary evidence relating to nine participants, each of whom had been teaching ICT prior to the curriculum change in 2014, eight of whom continued to teach Computing post-2014. Chapter Four presents data in relation to the way that participant teachers perceived the ICT to Computing curriculum change, with the aim of contributing new understandings to what little is currently known. Chapter Five presents data relating to the teachers’ approach to the planning of Computing lessons, using a conceptual framework to situate it within the wider field of teacher knowledge.

This chapter is organised so that it begins by presenting a case study narrative for each of the individual participants in order to provide the context necessary to understand each case as “an idiosyncratic manifestation of the phenomenon of interest” (Patton, 2015, p. 538). The narrative is interwoven with selected quotations, selected threads that exemplify concepts and themes for later discussion. The chapter then proceeds to follow a cross-case data analysis approach. The codes developed from the research corpus are presented with the intention of remaining close to the participants’ voices. Patterns identified across the codes are offered as the key findings, organised as “patterns that cut across the diversity” (Patton, 2015, p. 528) and providing overarching responses to the research questions and sub-questions. Different forms of data are offered as evidence in support of each finding.

Rather than divorce the further analysis and discussion of the findings from the data which support them, I have taken a holistic approach to presenting them. This has the additional benefit of focusing on the insights gained from practitioners, which have the potential to be revelatory because of the lack of current research into this area. My interpretation of the data was an iterative and complex process, and to present it in a purely linear fashion would be to misrepresent it. To counterbalance this approach, I have tabulated data and used headings and sub-headings to structure the findings in order to allow the interpretation, analysis and discussion to be followed more easily.

4.2 Perceptions of the ICT to Computing curriculum change

4.2.1 Case descriptions

The following nine cases are presented to show the uniqueness of each. Pertinent background information is provided to highlight the participant's general outlook and their case's alignment to the research questions. The case study introductory narratives are built around the participants' backgrounds and teaching contexts, their perceptions of the ICT to Computing curriculum transition and their orientation to the different aspects of each subject, using direct quotations inter-woven with themes for later discussion. The treatment of this data represents the mapping to parts of the first research question from what participants said during interviews and planning sessions, followed by a cross-case analysis to focus on themes pertaining to professional development arising from the data.

4.2.1.1 Alex: a 'qualified' ICT-trained Computing specialist

Context

Participant Alex was an experienced ICT teacher and Head of Department at the time of the study. Following on from pre-university ICT qualifications, he had completed his first degree in Computing and Business and had then immediately entered teaching through the TeachFirst route. He had trained as an ICT teacher and taught ICT at Key Stages 3-5, and later at an all-through international school. He was entirely responsible for the Computing curriculum planning as well as supporting a newer member of staff in his department, who did not have a background in Computing. Alex therefore developed lesson plans in significant detail and trialled all new programming skills before planning them into the curriculum.

[Alex] Although I had a Computer Science background, I haven’t done Computer Science in 6 or 7 years, so it was like learning it all again but being used to it previously if that makes sense? But part of it you have that logic, so it makes it a lot easier.

Alex’s background can be located on a problematic continuum of ‘specialist’ to ‘non-specialist’ knowledge. However, as the Royal Society (2012) demonstrated, there is “no universally agreed definition of what it means to be a subject ‘specialist’ teacher” (2012, p. 71), citing employment-based routes into teaching in contrast to formal academic qualifications in the subject(s) taught, along with the suggestion of ‘on-the-job’ experience as providing appropriate specialist knowledge.

Alex perceived his background in undergraduate Computer Science to be a benefit. Although his training as an ICT teacher had narrow scope for developing the programming and Computer Science theory needed for the new curriculum, his prior academic learning could be drawn upon. Alex perceived that his experience with programming had provided him with the logical approach needed and that this made the transition to Computing easier.

[Alex] I'd say it has given me a bit of extra confidence, but just as a person... I always feel as though I'm not yet good enough, so I always have stuff to learn. But I'm not at the state where I feel as though I've been dropped in the deep end and I'm in panic mode. I actually think, "I've programmed before."

I can see the end goal and what I need to teach students, so I'll be able to learn this because I've got a Computer Science degree. I've obviously learned many of these concepts before. I've just not used them all or forgotten how to do them. So, I think it does give you a bit of confidence... Yeah, it probably does give you a bit of confidence.

Alex's comments highlighted several important themes. Firstly, the implication that colleagues without his background might feel as though they have been 'dropped in at the deep end' and experience panic about the transition to teaching the Computer Science and programming aspects of the new curriculum. Secondly, Alex highlighted the importance of programming as the key skill needed for the new curriculum, albeit an area he needed to revisit. Thirdly, and a key concept from the literature around pedagogical content knowledge, is the idea of reversion to novice status. Although an experienced teacher and middle leader, Alex likened the experience to 'learning it all again' in relation to the concepts he had not used or forgotten in the years since graduation.

Transition

Although Alex did not feel he had been dropped in at the deep end, he further elaborated on his perception of the experiences of non-specialist colleagues making the transition from teaching ICT to teaching Computer Science.

[Alex] There are some Computer Science teachers who are very, very good who have transferred from other subjects, and maybe that's just because they have the empathy.

Computer Science is just like any other thing. You can learn it, right? When I taught Media Studies, I never knew how to use any of those programs, but I learned it and then did it. I think that's the same as Computer Science.

Because I had to learn Final Cut and Photoshop [software] from scratch, I can empathise with how difficult it is. And even if you don't have a Computer Science background, you have massive amounts of empathy with the students because you know how difficult it is.

It is noteworthy that, although the new curriculum is called ‘Computing’, Alex specifically referred to ‘Computer Science’, an indication of the disciplinary shift towards Computer Science and away from the other strands of the new curriculum, namely Digital Literacy and Information Technology. In particular, the linkage of his experience of learning video editing and graphic design software suggested a parallel with learning programming. The new curriculum requires that pupils are taught to “use two or more programming languages, at least one of which is textual” (DfE, 2013b, p. 2). The inference here is the difficulty of learning programming ‘from scratch’ as a non-specialist teacher. One other theme represented in this excerpt, extrapolating from Alex’s comment about teacher empathy, is the importance of teacher beliefs and orientations generally, discussed later in this chapter.

Changing subjects

In terms of the differing aspects of ICT and Computing/Computer Science as subjects, one of the first aspects that Alex focused on was the way he felt that his teaching had changed. Alex reflected on the more didactic approach he had taken to teaching ICT, especially in relation to developing students’ competence with using spreadsheet software packages.

[Alex] I just remember ICT being quite choppy. Just teaching them old lessons like how to make graphs in spreadsheets, you have to stop the lesson five times, and they really don't like that. They don't like the step-by-steppiness because it's quite didactic.

In this excerpt, Alex focused on one of the main critiques of ICT as a National Curriculum subject: the prevalence of the teaching of software skills, the “rebuke for the teaching of ICT” which Woollard (Woollard, 2018, p. 15) saw as one of the key drivers for the push from industrial leaders and politicians towards reforming the curriculum.

In contrast, Alex perceived programming to be a more creative learning experience, and one directly empowering students, a theme that has had considerable significance in the area of Computing education since Papert’s ‘powerful ideas’ (Papert, 1980) and constructivist approach to learning with technology.

[Alex] Whereas I think the beauty of programming and the reason why kids get on so well with Computer Science is the massive locus of control. So, you're ultimately in control of everything.

In a spreadsheet you can only do what's in the grids, what's in the cells, and you have to do an AutoSum [function], and you have to do an Average. Whereas when you're programming, if you want to you can do a Print statement to do anything you want, or an IF statement to do anything you want.

They actually said there's less creativity in doing, say, spreadsheets than there is in, say, programming.

This seemingly dichotomous representation of ICT as ‘choppy’ and ‘didactic’ in comparison to the ‘beauty’ and ‘creativity’ of programming has direct relevance to the widespread push for computational thinking (Savage & Csizmadia, 2018; Wing, 2006), promoted by the DfE as underpinning the new Computing curriculum in England (DfE, 2013a, 2013b) and further afield (Barr & Stephenson, 2011; Giordano et al., 2015; Grgurina, Barendsen, Zwaneveld, van Veen, & Stoker, 2014).

4.2.1.2 Ben: a non-specialist primary Computing ‘specialist’

Context

Participant Ben was a PGCE-trained primary school teacher. At the time of the study, Ben had the role of school Computing lead, which meant that, in addition to his generalist primary school teaching, he planned all the Computing curriculum as well as co-teaching Computing with all the other class teachers in order to develop their Computing expertise. Ben was also involved in supporting teachers in local schools as he was a certified CAS Master Teacher. Ben’s planning was tied into whole school planning as each half-term the school had a different topic underpinning the curriculum on a two-year cycle in order to connect pupils’ learning across subjects.

Ben had studied GCSE Information Technology and A Level Computing before his degree and brought a continuing interest in Computing and Technology Enhanced Learning into his teaching career. QCA (Qualifications and Curriculum Authority, 2006) reported that this kind of pre-university grounding would have included systems architecture, the legal, moral and social implications of technology, applications of technology and structured analysis and design as well developing coursework involving specification of systems and software development with a focus on manipulation of data and the analysis of algorithms.

Ben had elected to move from a team leader role in his current primary school to that of Computing leader. Ben was also completing his BCS Certificate in Computer Science Teaching, a "certificate designed to create confident teachers of the computing curriculum" (BCS, 2017), which involved reflection on professional development, a programming project and a classroom investigation. This type of professional learning and certification was a key aspect of the Computing at School Network of Excellence strategy (Sentance & Csizmadia, 2017b).

Transition

Ben's level of competence and confidence with technology was often lacking in other primary colleagues that he encountered, a situation he empathised with and worked to improve. The following excerpt focuses on Ben's role in supporting his colleagues with the transition to the Computing curriculum and addressing their preconceptions.

[Ben] The other bit I try to include is this computational thinking as well, which I really like - erm - although I don't find these annotations within the progression pathways to be helpful, I think this picture [see Figure 4.2, below] – you're familiar with this, Liz, I presume?

[EH] Yeah

[Ben] So, I find this really easy to explain to non-specialists.

We've done a staff meeting or two on this just to be able to give all staff a base level of understanding and being able to demonstrate in the primary sector - being able to demonstrate the cross-curricular approach to it - so we split staff off into different groups and they talked about a bit of an idea about logic and you are going to have to think - right go and have a look at the NC for Music and see where logic comes in and go and have a look at the Science curriculum and see where that comes in and split people off into their areas to go off and do that one...

and they all came back even after about 10-15 minutes saying, "there's loads of them - there's loads of different links everywhere, but we kind of thought that computing was this like complicated, Computer Science kind of geeky men with beards and thick rimmed glasses sat in dark rooms and all of this kind of stuff."

The 'progression pathways' referred to were the Computing Progression Pathways documents (Dorling & Walker, 2014) mapped to the National Curriculum programmes of study with Computational Thinking and practical skills broken down in order to support teachers in delivering and measuring assessment outcomes from Key Stage 1 to Key Stage 3.

Ben found the annotated Computational Thinking concepts (AB = Abstraction; DE = Decomposition; AL = Algorithmic Thinking; EV = Evaluation; GE = Generalisation) unhelpful for non-specialists (see Figure 4.1, below) in contrast to the 'picture': the Computational Thinking ways of working (tinkering, creating, debugging, persevering and collaborating) as illustrated in Figure 4.2, below.

Pupil Progression	Algorithms	Programming & Development	Data & Data Representation
↓	• Understands what an algorithm is and is able to express simple linear (non-branching) algorithms symbolically. **(AL)** • Understands that computers need precise instructions. **(AL)** • Demonstrates care and precision to avoid errors. **(AL)**	• Knows that users can develop their own programs, and can demonstrate this by creating a simple program in an environment that does not rely on text e.g. programmable robots etc. **(AL)** • Executes, checks and changes programs. **(AL)** • Understands that programs execute by following precise instructions. **(AL)**	• Recognises that digital content can be represented in many forms. **(AB) (GE)** • Distinguishes between some of these forms and can explain the different ways that they communicate information. **(AB)**
↓	• Understands that algorithms are implemented on digital devices as programs.**(AL)** • Designs simple algorithms using loops, and selection i.e. if statements. **(AL)** • Uses logical reasoning to predict outcomes. **(AL)** • Detects and corrects errors i.e. debugging, in algorithms. **(AL)**	• Uses arithmetic operators, if statements, and loops, within programs. **(AL)** • Uses logical reasoning to predict the behaviour of programs. **(AL)** • Detects and corrects simple semantic errors i.e. debugging, in programs. **(AL)**	• Recognises different types of data: text, number. **(AB) (GE)** • Appreciates that programs can work with different types of data. **(GE)** • Recognises that data can be structured in tables to make it useful. **(AB) (DE)**
↓	• Designs solutions (algorithms) that use repetition and two-way selection i.e. if, then and else. **(AL)** • Uses diagrams to express solutions. **(AB)** • Uses logical reasoning to predict outputs, showing an awareness of inputs. **(AL)**	• Creates programs that implement algorithms to achieve given goals. **(AL)** • Declares and assigns variables. **(AB)** • Uses post-tested loop e.g. 'until', and a sequence of selection statements in programs, including an if, then and else statement. **(AL)**	• Understands the difference between data and information. **(AB)** • Knows why sorting data in a flat file can improve searching for information. **(EV)** • Uses filters or can perform single criteria searches for information.**(AL)**
↓	• Shows an awareness of tasks best completed by humans or computers. **(EV)** • Designs solutions by decomposing a problem and creates a sub-solution for each of these parts. **(DE) (AL) (AB)** • Recognises that different solutions exist for the same problem. **(AL) (AB)**	• Understands the difference between, and appropriately uses if and if, then and else statements. **(AL)** • Uses a variable and relational operators within a loop to govern termination. **(AL) (GE)** • Designs, writes and debugs modular programs using procedures. **(AL) (DE) (AB) (GE)** • Knows that a procedure can be used to hide the detail with sub-solution. **(AL) (DE) (AB) (GE)**	• Performs more complex searches for information e.g. using Boolean and relational operators. **(AL) (GE) (EV)** • Analyses and evaluates data and information, and recognises that poor quality data leads to unreliable results, and inaccurate conclusions. **(AL) (EV)**

Figure 4.1: Extract from CAS Computing Progression Pathways

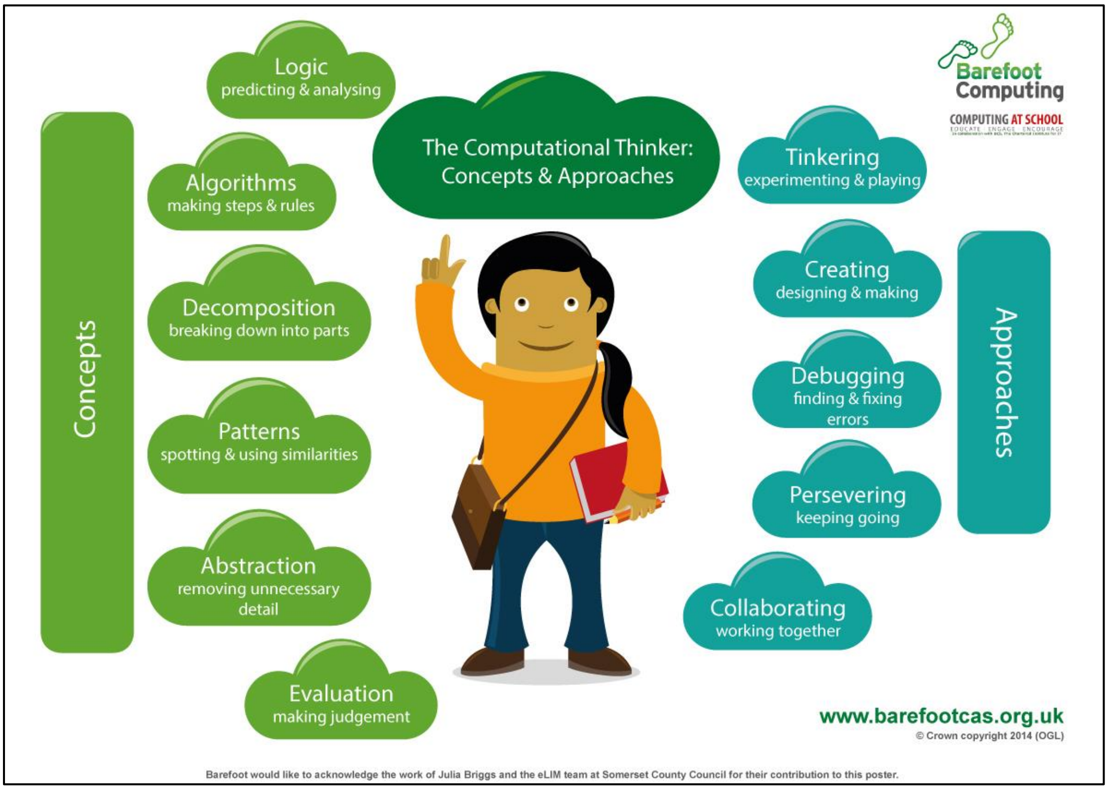

Figure 4.2: CAS Computational Thinking concepts and approaches

Ben’s commitment to the Computational Thinking concepts and approaches was evident in his planning templates, where he had one section devoted to mapping which of these were being used in the planned project. Approaches and concepts being targeted were emboldened in the overall list.

Ben’s excerpt, above, implies his colleagues’ lack of knowledge around the expectations of the new curriculum, suggesting that they were only beginning to form cross-curricular links in their primary curriculum despite his team-teaching role with each of them. Allied to that is the humorous description of the stereotypical technical expert, which evinces a wider general concern of gender stereotyping in relation to Computer Science, alluded to as the concern with “the ‘image’ of Computer Science” by The Royal Society (2012, p. 15) and repeated in the later 2017 report.

Changing subjects

From Ben’s position as a confident and competent Computing lead, it was evident that he considered the students at his school to have Computing opportunities in their primary education that were perhaps beyond the expectations of local secondary schools. This raises a wider equity and effectiveness concern relating to the transition from primary to secondary school, discussed more fully in Chapter 6. This is part of a wider debate about the importance of functional IT skills and where, when and how they should be taught.

[Ben] When I started doing this role... I got in touch with our local secondary schools - we feed about - well most of our kids go to about three secondary schools and we probably feed about six in total and so I got in touch with the heads of IT as it's still called in all of them and said could you give me an idea about what you do in Year 7?

I think all of them came back (I think one of them didn't) and it was all mind-numbingly boring stuff - like they create a PowerPoint presentation or they learn to send an email and these sorts of things.

I think they did something in Scratch in Year 7 for the more able children - like to help them create a game and I still had to write back in quite a tactful way and say, "we've done that in Year 4 and you might want to up your ideas a little bit."

In addition, the excerpt highlights Ben's perspective of the low-challenge IT-type activities and infers his preference for the Computing curriculum. Influenced by the Computational Thinking concepts and approaches, Ben appears to disavow the problematic IT skills for a new model of working with the Computing curriculum in a cross-curricular manner.

4.2.1.3 Claire: a 'qualified' post-16 Computing specialist

Context

Participant Claire was an interesting case of a teacher for whom the latest round of curriculum changes had contributed to their decision to shift to Higher Education. Ninety minutes of recorded audio interview was gathered from this participant (see Appendix F: Semi-structured interview guide 2, on p. 239). With undergraduate and postgraduate Computing qualifications, and industry experience, Claire had taught IT/ICT/Computing Level 2 qualifications to learners age 16+ full-time at a Further Education college up to the end of 2014. Claire was included in the study as the continual curriculum and qualification changes and subsequent planning requirements impacted her teaching and curriculum to the extent that she no longer wished to remain in the pre-university classroom.

A Computing background is not an indicator that a teacher will be comfortable with every aspect of the Computing curriculum. The skills of programming, so problematic for teachers making the transition from ICT to Computing, were the least preferred aspects of Claire's teaching, whereas Alex was willing to retrain himself in programming and Ben was enthusiastic about the possibilities offered by primary-level programming.

[Claire] I do what I do because I have to, not because I enjoy it. I used to avoid doing the programming if I could, but I do a bit of VB [Visual Basic], you know I do HTML [Hyper Text Markup Language], and things like that. You know, I trained as a programmer. I hated it, so... But it is something I can do when I need to.

Even with a broad academic background, Claire saw herself as a "people person", and explained that her specialist area was designing with the end user of an application in mind.

[Claire] One of my specialisms used to be User Interface Design, and working with, you know, ways, that users... if you're a programmer, and you're developing an application, you want that user to be able to use it. And, a lot of students didn't get that.

In effect, Claire's position challenges the primacy of programming since the 2014 curriculum change. As the area most likely to cause concern to transitioning teachers (Mee, 2014; Sentance et al., 2012) a broad theme emerges: Computer Science is not just about programming, despite the spotlight seeming to rest so heavily on it during the implementation of the new curriculum.

Transition

As a Computing specialist working in a Further Education college, teaching students age 16+, the impact of the curriculum change for Claire was in the courses offered. ICT GCSE was being phased out, and the vocational qualifications underwent significant changes. Claire's specialist department was approached to offer training for transitioning teachers.

[Claire] The first we became aware of it, was when we were asked if we would be prepared to deliver training to Computer, IT, or Maths teachers from the local schools?...

And I think at that time, because it was just when it was first announced, before the specifications were [published]...they didn't really know what was coming... all they'd heard was what we had on the news, you know, they hadn't actually got a hard copy of, "This is what you've got to teach..."

And a lot of staff were not sure if they were gonna be using a particular programming language or a particular programming environment, or were they gonna be given, you know, something specific.

But there was none of that information available, so all they had... the initial draft I think that I saw from one member of staff, it was only on 2 sides of A4.

Claire's experience with colleagues in local school demonstrated the uncertainty around what the new curriculum would involve, what the requirements would be and what training and support would be available for staff during the transition. Questions were also being asked about professional development "for teachers who feel they do not have the skills needed to deliver CS [Computer Science] in school"(Sentance et al., 2012, p. 83) by major players in the Computing at School organisation (Sentance et al., 2012).

Changing subjects

Claire's perspective as a Computing specialist with significant experience of teaching vocational IT was concerned primarily with the broader skills required in the workplace.

[Claire] `Computing, or IT, or whatever it's called, these days... so, despite them changing the curriculum again, I still don't think it's going to address the shortfall that employers are looking for, you know, if you see what I mean. It's still quite... it's an interesting point of view. I mean, loads of kids would really enjoy the programming, so... But I don't think it's going to give them the skills they need in the workplace.`

Two main themes arise from this excerpt. Firstly, the impact of continual changes of curriculum and the resulting confusion around what is meant by IT or ICT or Computing or Computer Science, an terminology issue of historical (Webb, 2002; Woollard, 2018) and current discussion, with Hubwieser, Giannakos, Berges, Brinda, Diethelm, Magenheim, Pal, Jackova and Jasute (2015) identifying, describing and comparing 40 different terms applied internationally to describe the fields of or around Computer Science Education, a point addressed earlier in Chapter One. Second is the debate regarding the beliefs surrounding the competencies and goals that this education can or should provide. Claire's orientation towards teaching Computing was that it should prepare students for careers, born of a Human Computer Interaction-informed approach, whereas Alex valued the creativity, independence and logical thinking of programming.

At a time of continuing reform and uncertainty in the subject, Claire elected to leave the pre-university classroom, her concerns echoing those of several other participants:

[Claire] And, at the end of the day, you know, I stayed at my job for so long because I loved the actual teaching... I liked being in the classroom with the students, and that's what I wanted to still do... And it was, everything else...

It was this whole planning... because the BTECs have changed every 2 years... You never got to run a module for more than 2 years, because it changed, it was updated, it was renamed, it was rebranded, it was taken out, it was put in...

And that was what the problem was.

The delicate ecosystem of Claire's teaching and professional knowledge bases was disrupted to the point where she left, contributing generally to teacher attrition and to the shortage of Computer Science teachers (Royal Society, 2017; Ward, 2017).

4.2.1.4 David: a 'qualified' ICT-trained Computer Science specialist

Context

Participant David had completed a degree in Computer Science and had then entered teaching through an ICT PGCE route. Having taught initially in maintained secondary schools, he then moved to teach in all-through private schools and was responsible for planning the Lower School (primary phase) Computing curriculum in his current school at the time of the study. David was also involved in teaching Key Stage 3 Computing in the Upper School (secondary phase). As the sole primary Computing teacher in a private school, and therefore not subject to the statutory requirements of the National Curriculum, David had free reign over the subject matter to be taught. David had developed an entire primary-phase curriculum and modified it to include programming modules in each year group.

David was the only participant with a single-honours Computer Science degree followed by a conventional ICT PGCE route into teaching:

[David] First year was like proper full-on programming. Second year was more to do with software engineering so the design principles and things like that. The third, obviously you build your project and specialize in different areas.

Transition

For David, the transition from teaching ICT to teaching Computing was relatively straightforward. His main concern was differentiating the content appropriately for the students, who would range from age 4 to age 11:

[David] I just found it – this is just something that needs to be incorporated in. I think the only...the trickiest part is how to cascade it down so that you're not neglecting the younger ones...you're not pitching it at such a high level that they can't cope with it.

The comment made about cascading is of particular interest as it relates to the wider research interest in pedagogical reasoning. This can be interpreted as part of the process of transformation within Webb's (2002) model of pedagogical reasoning based on Shulman (Shulman, 1987), where teachers prepare, structure and segment subject content in readiness to teach specific classes (see Chapter Two). For David, the concern was not about fears of subject knowledge or programming skills deficit, he was able to move straight to thinking about how to adapt the content to his students.

Changing subjects

Despite the confidence displayed by David in incorporating programming into the curriculum, it is noteworthy that this is balanced by scepticism regarding the aforementioned 'primacy of programming'. In this quotation, David voiced his opinion about incorporating elements of Computer Science theory into the Lower School (primary phase) curriculum:

[David] ...teaching Year 1 kids about networking and stuff like that, I think it's a bit too much for them to actually appreciate what's going on. I mean, you can do it at a really, really basic level but I feel that time would be wasted too much...

...and there doesn't seem to be anywhere in the curriculum that they need to learn how to type using a keyboard and using other peripherals like mouse, and maybe tablets and stuff like that. There's nothing explicit with regards to that.

Everything just seems to be focused on networking and programming and that's about it from what I've seen in the breakdown. So, we're still keeping with doing stuff like Word, Excel, PowerPoint and all that but we've also...each year group does a unit of programming as well so that is our Computer Science part that we've got in there.

David was enthusiastic about the benefits of retaining a core of skills from the previous ICT curriculum and keeping to the 'spirit' of the new curriculum by incorporating a unit of programming in each year group. In keeping with his evident trend of thinking pedagogically about the teaching of programming, David's scheme of work showed a spiral-curriculum approach to programming in each year group. He incorporated coding websites such as Thimble (Mozilla, 2017), Code Avengers ("Code Avengers," 2017) and Codecademy ("Codecademy," 2017) as well as Logo and Scratch software, but expressed his formal plans broadly in terms of Computational Thinking concepts such as 'giving instructions' and 'sequencing'.

4.2.1.5 Ellen: a Business-trained non-specialist teaching some Computing

Context

Participant Ellen had a Business Studies background and was involved mainly in teaching vocational subjects, including ICT and later, Key Stage 3 Computing. As a non-specialist teacher, her background had allowed her to teach ICT successfully to KS4, but with the introduction of Computing, the demands were increasing. Ellen's Head of Department, a Computing specialist and CAS Master Teacher, was responsible for the overall curriculum, allocation of teachers and supporting his staff to deliver the new Computing aspects. Ellen's planning involved taking the scheme of work and ensuring she was familiar enough to be able to teach it, with some additional support and guidance.

[Ellen] I went to Sixth Form and did Business, Geography and General Studies and then I went to uni and did Business and Management and I did my PGCE in Business which had a little bit of IT in it.

Ellen's background and context would have been common in ICT departments pre-2014. As they were unlikely to have a full department of specialist ICT-trained teachers (the Royal Society (2012) estimated 1.5 per school), many schools would have used spare timetable hours from teachers who might be expected to be competent with ICT, such as Maths, Technology or Business Studies teachers. As Business Studies would usually only be offered at Key Stages 4 and 5, the capacity for teachers of the 14-19 phase to offer a second subject to be taught at Key Stage 3 is important, and often advertised in PGCE admissions material: "Much of the knowledge, understanding and skills you will gain are transferable to teaching ICT as a second subject at Key Stage 3" (Prospects, 2017).

Transition

Although the Key Stage 3 ICT curriculum could be taught by non-specialists, leaving specialist ICT teachers to cover the more technical material with higher ability pupils and exam students, the new Computing curriculum with its emphasis on Computer Science and programming held very real concerns for Ellen:

[Ellen] Very scared that I didn't know how to teach it! [laughs] I think there are some people that still hope that it will change back but [shrugs]...

...when they realise that not all kids can do it? They've got to have some kind of comeback...

The implication is that Ellen was concerned about the level of Computer Science knowledge and programming skill that she did not have at the time of the curriculum change. Although Ellen taught a small complement of lessons at Key Stage 3, she was fearful of not being able to teach the new content. Implied in her comment is that she, also, hoped that the curriculum would change back to something more manageable with her existing knowledge base and skill set.

In addition, Ellen voiced a concern that the focus of the Computing curriculum on programming and the logic required for Computer Science theory, in her opinion, reduced the inclusivity of the curriculum. This position echoes the wider debates in the field of Computing Education around the elitist and selective nature of the new curriculum (Rudd, 2013) and the 'new digital divide' (Mee, 2014).

Changing subjects

[EH] Have you changed the way that you teach?

[Ellen] Yes, I think it's all about encouraging kids to be more independent - completely – like, rather than make a poster and then marking it and improve on it, like, working things out for themselves.

And some kids have really picked that up and some kids are just like "How do I it, how do I do it?" and I'm like "Try and figure it out for yourself" and encouraging them and they like, get it wrong and fix it for themselves as well.

Ellen inferred in this excerpt that, for her, teaching ICT had previously been a matter of teaching students to create digital outcomes, assessing them and identifying improvements, something that had changed since the introduction of the new curriculum. Continuing the theme of “not all kids can do it”, Ellen suggested that some of the key skills needed to engage with the new curriculum involve resilience and perseverance, echoing Alex’s earlier comment about the move away from the “step-by-steppiness” of the ICT curriculum. Ellen’s concern with students trying to work things out for themselves is connected to the debate around the need to teach Computational Thinking as a distinct approach to underpinning the new curriculum (Selby, 2014, 2015).

4.2.1.6 Faith: a ‘qualified’ Maths-trained secondary Computing specialist

Context

Participant Faith was a PGCE-trained Maths teacher with Business Studies as a second subject. She had a particular interest in Computer Science stemming from pre-university Computer Studies and Computer Science qualifications, as well as Computing modules in her first degree. In her current school, she had been employed to teach Business Studies and ICT, had taught some Maths and taken on other whole-school responsibilities. Having preferred Computing to ICT, she was pleased with the curriculum changes and was now responsible for Key Stage 4 Computing. Faith had planned a comprehensive GCSE Computing curriculum.

[Faith] I did Computer Studies O Level and I did Computer Science at A Level. My first year at university, we had to do three first year subjects: I did Marketing, Maths and Computing.

Faith’s qualifications situate her background in the pre-GCSE, pre-National Curriculum era. Computer Studies O Level,

> “typically involved learning the BASIC programming language and using it to create a programming project for 30% of the total mark. BASIC was the standard language built into all of the school microcomputers available at that time. The remaining 70% came from a written examination on computing knowledge such as the ways in which the digital computer stores and processes data, associated hardware, the history of computers, their applications, and their social and economic impact.” (Avis, 2014, online).

The introduction of GCSEs from 1988 saw the emphasis change to problem-solving with computer applications, the same situation as at the time of the 2014 curriculum change. This was deemed part of the “harmful” ICT curriculum (DfE, 2012) discourse espoused at that time. The main theme to be developed from Faith’s context and background is that it links into the wider debate around curriculum (Young, 2013) and its reversion to earlier structures. The concerns in the 1980s around the development of the subject area (Lamb, 1985), which have been replayed thirty years later, demonstrate historical policy amnesia with regards to lessons learnt at times of curriculum change.

Transition

Faith’s early Computing education meant that she was particularly well equipped for the ICT to Computing curriculum change, and moreover, that she had actively pushed for it in her school, independent of the Computing at School campaign to re-introduce Computer Science in schools.

[Faith] ...when did I start getting interested again?

I had been pushing to get Computer Science put on as an option for a few years...I can't remember what started to make me talk about it... because I wasn't aware of the bigger debate in CAS or anything at that time.

In conversation, it emerged that Faith had disliked the ICT curriculum and found it uninteresting. She did not like the uncertainty of the constantly changing software and technology landscape and the constant push to keep up. She wanted to get back to the certainty of programming and theory.

[Faith] A computer doesn’t change...a computer is a computer. I’m trying to get back to what I want to teach. I want a Computing teaching job. I want to ... just stand in front of the class and use a computer.

Faith's comments suggest that she saw Computing as a very strongly classified discipline (Bernstein, 1971), to be kept separate from the less stable ICT subject area and "waves of technological innovation [which] are constantly redefining the skills and knowledge which a competent user of the technology needs to possess." (Pearson, 2001, p. 204). Faith's comments revealed that she had very clear ideas around Computing as a distinct, science-like discipline:

[Faith] That's very much to me a science. It's very much that there's a body of knowledge and skills that they develop and it's not about getting them to construct something in Scratch or getting into something in Python. It's about using the programming language to demonstrate that they understand the concept of something.

This was very much in line the Computing at School Working Group, who lobbied for Computer Science to be recognised as "the fourth Science" (Computing at School Working Group, 2012, p. 3). For Faith, the curriculum change was about developing a specific body of knowledge and skills that could be evidenced through programming. For Faith, as with Claire, the programming language used was not the issue, rather it was a case of the logic needed, echoing back to Alex's "I've programmed before", distinct from the widespread post-2014 uptake of two specific programming languages: Scratch and Python.

Changing subjects

Faith's clearly defined view of ICT was evident when she reflected on how she felt about ICT:

[Faith] But I think the thing with ICT is it was probably necessary at a point in time where ... it's a bit like my Dad never passed his driving test. At one point it wasn't necessary and then they realised they had all these people driving without licenses. They just gave them out because they sort of just have to deal with it

... and we had this technology coming and nobody knew anything about it. So, we had to do something... but I think it may well have served its purpose ...

Faith's argument about the nature of ICT as a subject ties in with the larger set of debates (Hubwieser et al., 2015; Pearson, 2001; Webb, 2002). It provides an interesting insight to be considered: that taking a historical perspective, and potentially a programming perspective, the branching of the Computing Education program into an ICT subroutine before re-joining the Computing pathway may have been a necessity while the technology was developing.

4.2.1.7 Glenn: a 'qualified' ICT-trained secondary Computing specialist

Context

Participant Glenn had taken a vocational route into teaching, moving from industry experience and part-time degree studies into an IT PGCE. Coming from a background in industry, he was pleased with the curriculum change and was Head of Department at the time of the study, in addition to work as a CAS Master Teacher and local CAS hub leader. Glenn had planned comprehensive GCSE and Key Stage 3 Computing curricula.

[Glenn] I [worked] as a web developer, and then [as] a technician in a school... So they trained me up in how to install and manage networks and I did my Cisco CCNA Certified Network Associate certification with them. And I also got into developing their website and also doing some work for [a council] doing training for staff. I was developing SCORM compliant e-learning stuff for them, e-learning packages that you could import into VLEs.

And then I was spending so much time developing e-learning software for teachers that I thought I'm missing a trick here, and I went and did my PGCE. But all the time I was working as an e-learning content developer, I was getting my degree as well.

So that's my background, it's mostly hands-on technical, and then I went into teaching ICT in 2008. And I first started teaching Computer Science GCSE five years ago now.

Evident from Glenn's comments on his background was the level of technical confidence and competence that it gave him. Interviewed in 2016, Glenn had therefore been teaching Computer Science GCSE since 2011, when it would have been in the pilot stages, there having been no GCSE in Computing since the late 1980s until it was reintroduced by the OCR exam board in 2010 and by AQA and Edexcel for first teaching from September 2012 (Computing at School Working Group, 2012).

Transition

Unsurprisingly, Glenn was not "worried" or "perturbed" by the change from ICT to Computer Science. He felt able to pick up the by-now-ubiquitous Python language:

[Glenn] So, in terms of how happy I was when the ICT curriculum was scrapped and the Computer Science curriculum was pushed forward – I wasn't worried, I think I was one of the few people that wasn't particularly perturbed by it.

But, I'm frustrated by the lack of clarity in terms of what we're expected to do. And also, the difficulty for our senior leaders of actually understanding what it is we do because of the nature of the subject.

My background's in PHP originally as a web developer, so I've always been confident using HTML, CSS, PHP and MySQL and SQL Server, so I've sort of come from a web development background, so really learning to use Python as a scripting language wasn't as complex as it probably would have been for somebody else.

Glenn expressed his concern around the lack of clarity in the new curriculum, which was shared by other participants. His comment about senior leaders is especially important as it highlights a key theme around the perceptions held about the nature of the subject, discussed later in this chapter. Senior leaders in schools were slow to realise the implications of the push for curriculum change and many adopted a 'wait and see' approach reinforced by the sudden disapplication of the ICT programmes of study from September 2012. The loud message from politicians and the media was that ICT as a subject would cease to be statutory from September 2014.

Glenn highlighted another key issue resulting from the curriculum change: the 'gaming' of qualifications (Richardson, 2009), where large vocational ICT qualifications were worth the equivalent of several GCSEs and were used to shore up the A* to C 'good pass' equivalents used as a yardstick for measuring school outcomes. The issue remains unresolved in 2018, with the DfE's late publication of the list of ICT qualifications counted in the 2019 school performance tables, leaving some schools scrabbling at the start of term for an ICT qualification to suit their non-Computer Science pupils that would still have some currency in the performance tables.

[Glenn] At one point we were core [a core National Curriculum subject], and then as the curriculum changed and also the [qualifications]... I think a lot of reasons why schools liked ICT at one point, especially the OCR Nationals sort of time, late 2000s was you could get 4 GCSE equivalents through an ICT course, and you could do that on 4 hours a week, 3 hours a week for some people.

So, you would get a lot of bang for your buck, a lot of results for your money, and we've never quite recovered from that because as soon as the qualifications agency stopped those qualifications counting towards GCSE results, schools weren't interested in the subject...

In addition, the loss of 'core' National Curriculum status and conversion to an optional subject at Key Stage 4 when many schools would have made ICT a mandatory Key Stage 4 subject created a very different climate for the subject area, a topic which recurs in the comments from Ian, below.

Changing subjects

When queried about his pupils' reactions to programming and the Computer Science theory, Glenn inferred that he did not see Computing as a subject for all students, despite his background and positive reception of the changing curriculum, a prevalent theme across the participants in this study.

[Glenn] It depends on the children: some students really enjoy the programming and they really get into it and they don't want to do theory, but then other students really do not engage with the programming at all, and I feel sorry for those students because they've been kind of mis-sold this qualification as something that they're going to suddenly learn how to program and be amazing at programming when actually we do have a bit of a prerequisite that you do need to be able to do it beforehand.

Certain students prefer the programming and certain students don't, and it generally depends on how self-motivated they are.

Experience had told Glenn that bright, self-motivated pupils who enjoyed programming would do well. The question of what to do with the other students remains a key theme.

4.2.1.8 Helen: a non-specialist ICT-trained transitioning ICT teacher

Context

Participant Helen had a non-specialist background but had moved from adult IT training to complete an IT PGCE. Having made significant efforts to upskill with the curriculum change, she was Head of KS3 Computing and faculty director at the time of the study, as well as a CAS Master Teacher and local CAS hub leader. Helen had embraced a range of opportunities including exam board coursework moderator, CEOP ambassador, student extra-curricular activities and was also involved in outreach with local schools. Having planned a comprehensive Key Stage 3 Computing curriculum, Helen was using external opportunities to develop expertise in Key Stage 4.

[Helen] I went into teaching late. I'm an IT teacher without an IT degree. But my background is really IT rather than computing, so everything I know now I had to learn in the last couple of years to keep up with curriculum changes.

Fundamental to this study is the theme highlighted by Helen in this excerpt: that of teachers needing to develop their subject and pedagogical skills in order to be able to teach the new curriculum, especially at Key Stage 4 and beyond. In effect, serving teachers need to develop undergraduate-equivalent subject knowledge and programming skills to be able to teach the subject in any depth: a tall order when working full-time. CPD is discussed later from a cross-case perspective, but Helen is an example of a teacher willing to remain in the field and do what was necessary to manage the transition.

Transition

Developing this line, Helen explained the steps she had taken for her own personal and professional development:

[EH] How have you coped with the changes?

[Helen] As best we can really [laughs]. There's not really much you can do. I joined CAS. I'm a CAS hub leader now. I'm a CAS master teacher now. So, anything I can do to help myself...

I've done the CAS certificate for Computer Science teaching. So, anything I can do in my own time to try and increase my understanding – that, I've done.

However, the most illuminating aspect of her journey was that, despite all the efforts made in her own time to upskill, and the achievement of supporting other schools, she still saw herself as a non-specialist, recognising her limitations as a non-IT, non-computing graduate:

[Helen] I have a member of staff going and they're trying to replace him with a non-IT teacher to save money. And I want a Computer Science specialist. We aren't Computer Science specialists.

Helen had explained that the member of staff leaving was not willing or able to take the same kinds of steps that she had. He had been comfortable teaching some ICT and another curriculum subject, but the demands of the new curriculum were too much:

[Helen] As it's become more Computing he says, "it's not for me, I can't do it".

Helen's member of staff leaving, and the school's preference to replace like with like provided additional material to consider with regards to the Computer Science teacher shortage. As she (and other participants) had mentioned, the general lack of understanding of the differences between the ICT and Computing curricula impacted on several fronts. Extrapolating from this, it is now clear that the teacher shortage may be worse than that reported in the media. Until the point is reached where there is a physical limitation on timetabling, such as insufficient staff to cover the teaching, a school may well have a full complement of teaching staff, and therefore no 'shortage', despite the non-specialist teachers. Helen shared her experience of another school facing this situation, whose response was to drop Computer Science at GCSE and teach a vocational course on the approved performance tables, further compounding the issue.

Changing subjects

Helen was clear that Computer Science is different to ICT, and more difficult to transition towards. Although she was in the process of upskilling, her frustration with the situation was evident in the simile used.

[Helen] The biggest issue we've got is that schools don't really appreciate that Computer Science is different to IT. A lot of schools still believe that anyone can teach Computer Science. And they're not really getting the difference between IT and Computer Science.

I just say to them it's a bit like you asking me to teach German. Or a French teacher being asked can you teach German from next week and they have never spoken German before – it's the same thing.

The dramatic example of being asked to teach a foreign language is a clear but stark reminder of what the curriculum change has felt like for teachers without a Computing background.

4.2.1.9 Ian: a non-specialist Science-trained transitioning ICT teacher

Context

Participant Ian had a non-specialist industry background but had moved into teaching Science and then ICT. His experience with ICT had been very vocationally-oriented and he had used this experience to design a comprehensive curriculum map across the key stages, while the department adapted sections in line with curriculum changes. Ian made use of external resources to guide the planning of Computing topics. As a non-specialist with a Computer Science graduate in the department, Ian also found himself teaching Science again as ICT was no longer a compulsory subject, therefore leading to a reduction in his timetabled teaching hours for Computing.

[Ian] I did a civil engineering degree. I did a conversion course to teach KS3 and KS4 science which I taught for two years, then I started teaching the old GNVQ [IT] course.

Then I moved to a school where I managed IT and then I moved to this school ten years ago and we have been running vocational qualifications ever since.

Ian's decade of vocational teaching, whilst successful for the students and the school in terms of performance outcomes, is further testimony to various splits in the ICT and Computing field. Firstly, this involved the subject versus skills debate and the longstanding lack of a robust model of ICT as a distinct subject area (Pearson, 2001). Secondly, it was about the trend towards technical competence taking precedence over specific Computing knowledge, leading to the widespread focus on the vocational elements. This led to criticism about students demonstrating proficiency in order to meet assessment criteria "rather than being introduced to new and more challenging skills" (Royal Society, 2012, p. 33).

Transition

Perhaps recognising that additional challenge in the subject area was needed, Ian had initially welcomed the push for an increase in programming and Computing theory. However, his comments about the resulting lack of balanced provision, as suggested by the Royal Society, highlight another major theme within this study: the marginalisation of IT and the impact of this on future cohorts of pupils.

[EH] How did you feel when the curriculum focus started to change?

[Ian] The ideas behind it were very good: I'm very happy with getting the kids do more programming, getting them doing more Computing and actually understanding what Computing is.

I'm not happy that schools seem to have only implemented a third of what was suggested. So, the Shutdown and Restart [Royal Society Report] suggested a Digital Literacy and IT...

and because the Government have said Computing is an EBACC subject, schools delivering Computing at Key Stage 4 really don't have a clue what they want to deliver at Key Stage 3 and aren't all delivering the new programmes of study and now there is no provision for the Digital Literacy or IT at Key Stage 4, basically.

Changing subjects

Ian's reflection on the different aspects of his current teaching highlighted a high level of self-reflection and an understanding of his own preferences and the gaps in his knowledge and skills:

[Ian] I really enjoy what I'm doing at Key Stage 3, I quite like the open flexibility of what we are doing. Key Stage 4...I enjoy all of the vocational stuff that we teach, not sure I enjoy teaching the pupils the difference between the two!

Erm... the Computing side of it I like teaching the programming ...I'm not sure I'm good enough at it to teach it well but we've had some good success at that. I quite like the other practical stuff, I quite like doing that and from the old specs -I'm quite happy with the hardware, the binary stuff and the database stuff, I did an Oracle database course in the past... those sorts of things I'm quite happy with.

But the other areas of the curriculum I'm finding much harder to deal with and there's more stuff in the new specs now that I'm unfamiliar with that would cause me more problems if I was delivering it to the current Year 10. So that detailed binary and there's more about the binary logic and there's bits and pieces of I've never come across and never taught before and don't know either. And would have to go away and learn before I can teach them now.

Ian's comments reveal the non-specialist debate coming full circle. Non-specialist ICT teachers such as Ellen were happy to teach Key Stage 3 ICT but less confident at moving into teaching exam classes. It would seem that formerly competent and confident teachers of ICT, now relegated to the position of non-specialist teachers of Computer Science also feel the distinction, realising that the lack of specialist Computing knowledge now holds them back. Ian's case in particular shows that this translates into significant career changes. Ian had already had a loss in timetabled Computing hours and had moved back into teaching Science in order to safeguard his job. In addition, his career advancement possibilities had been severely curtailed:

[Ian] ...as it is now there's no way I can go and teach Computer Science at a school that teaches Key Stage 5: it's just beyond me now.

The single most important thread throughout the case study narratives has been the importance of the teachers in the curriculum change. Whether the participant teachers experienced the change positively or cautiously, with specialist backgrounds or not, their positions as mediators of the curriculum have been important. In the next section, the teachers' perceptions of subject-specific professional development are considered.

4.3 Chapter discussion

In this section, themes relating to the first research question will be explored. These were developed from the individual participants' comments about their background and context, experience of the transition from ICT to Computing and their orientation towards ICT and Computing as subjects. The section begins by developing a cross-case analysis of the third sub-question before synthesising the findings from the other sub-questions and then drawing together the overall discussion of Research Question 1 in light of recent relevant development in the literature.

4.4 Perceptions of professional development available

Significant concerns had been reported by The Royal Society in relation to Computing in schools, with co-ordinated "CPD provision for Computer Science and Information Technology that deepens subject knowledge and subject-specific pedagogy" (Royal Society, 2012, p. 9) emerging as the third recommendation. In addition, Computing at School began to discuss the 'grand challenge' of upskilling teachers in readiness for the introduction of Computer Science (Sentance et al., 2012). The Network of Teaching Excellence in Computer Science was run by The British Computer Society and CAS. CAS Master Teachers formed the core of the Computing CPD offer, but this was not funded by the DfE until April 1st, 2013. By September 2013 there were thirty-one Qualified Secondary Master Teachers in England ready to get started (BCS, 2013).

Given that all the teacher participants in this study were teaching ICT well before the curriculum change, they would have been part of the cohort of serving teachers needing CPD to support their transition from ICT to Computing. Table 4.1, below, summarises different types of CPD opportunities the participants were involved in around the time of the curriculum change. In three of the nine cases, participants accessed more knowledgeable peers in their own school, local authority support, such as IT coordinator meetings or a regional support centre at their local university. Seven of the nine participants attended training courses specific to the changing curriculum. Two of the nine participants enrolled in courses leading to certification, specifically the British Computer Science (BCS) Certificate in Computer Science Teaching, which was piloted in early 2014 and launched officially in October 2014 (Sentance, 2016).

Table 4.1: Matrix of participant CPD opportunities

Participant	Access to local or peer support	Went on training course(s)	Worked towards certification
1. Alex	No	Yes	No
2. Ben	Yes	Yes	Yes
3. Claire	No	No	No
4. David	No	Yes	No
5. Ellen	Yes	Yes	No
6. Faith	No	No	No
7. Glenn	No	Yes	No
8. Helen	Yes	Yes	Yes
9. Ian	No	Yes	No

Regardless of each participant's qualifications and level of subject-related knowledge, the majority accessed short training courses or training opportunities relevant to the new curriculum. Short, intense courses are a common way for teachers to access subject-related information needed, such as exam board changes and assessment information. These tend to focus more heavily on expectations in relation to teacher practice and student knowledge and skills than pedagogy.

Analysis of the coded material resulted in 36 quotations relating to the theme of CPD. Several additional sub-themes emerged from within the CPD thematic group: relating to support, cost, provision and resources. Each of these is discussed below.

4.4.1 Support for continuing professional development

Support, or the lack thereof, was a common theme arising in relation to participants' access to CPD in the early stages of the curriculum change, irrespective of the background qualifications and experience of the participants. The variety of different opportunities were perceived to be largely uncoordinated, emanating from multiple different sources: local authorities, other schools, colleges and universities, commercial offerings and exam boards. Information about opportunities available to transitioning teachers seems to have been poorly communicated, and dependent to a certain extent on luck:

[Helen] I was just lucky to get on a session.

Another participant explained, that in relation to providing support through local CAS meetings as a Master Teacher and hub leader, just getting to a meeting was a big hurdle:

[Glenn] The difficulty is, in terms of CAS, if you're going to a CAS event, you've kind of got over the biggest stumbling point, which is trying to find some help.

It's probably the teachers who don't know about CAS or don't get involved in any of the local events - they're the people who actually really need the help and they might not be getting it.

By early 2016, Schoolsweek reported that,

> The DfE said it was down to schools to ensure teachers were sufficiently trained. They [the schools] had been given more than £4.5 million over the past three years, which had resulted in more than 15,000 hours of training for teachers (Dickens, 2016 [online]).

The Royal Society had previously estimated "some 18,400 ICT teachers" in secondary schools, based on the 2010 DfE Schools Workforce Census (Royal Society, 2012, p. 71). The number did not include primary school teachers, each of whom was required to teach ICT and therefore to make the transition to teaching Computing post-2014. Even focusing solely on 18,400 secondary teachers, it is clear that 15,000 hours of training could not have met the needs of the secondary workforce. This was reflected in the words of participant Faith: "we've had nothing here… literally nothing" [Faith].

From the earliest official indication that things were about to change, Michael Gove's disapplication of ICT speech at the BETT Show in January 2012, it was evident that the transition to a new curriculum would not involve a staged strategy:

> The traditional approach would have been to keep the Programme of Study in place for the next four years while we assembled a panel of experts, wrote a new ICT curriculum, spent a fortune on new teacher training, and engaged with exam boards for new ICT GCSEs … We will not be doing that (DfE, 2012).

The uncertainty of what was needed and the suddenness of the announcement left schools and teachers struggling to move forward.

[Claire] ... they [the schools and ICT teachers] didn't really know what was coming... all they'd heard was what we had on the news, you know? They hadn't actually got a hard copy of, "This is what you've got to teach...

Without new programmes of study and curricula, and without a clear government strategy for training and retraining teachers, professional development opportunities seemed to have been given low priority.

The publication of the Royal Society *Reboot* report in November 2017 made reference to the continuing professional development issue. Their analysis of self-selecting online survey responses from 341 primary respondents and 604 secondary respondents pointed to:

> …wide variations in the amount of computing-related CPD undertaken in 2015/2016. In primary schools, 29% indicated having undertaken zero hours of CPD during this period, and over 60% had less than nine hours. In secondary schools 26% of the respondents indicated that they have undertaken zero hours of CPD, and over 40% had less than nine hours (2017c, p. 99).

The perceptions of the participants in the current study support these findings. Despite the survey's potential limitations and the risk of bias, the amount of professional development reported is worryingly low. Whilst a zero-hours response could be interpreted as an indicator of a teacher fully competent and confident with the new curriculum, and not needing any professional development whatsoever, it is more realistic to suggest that, as with the participants in the current study, other factors were at play. The later list of the top ten support needs (p. 12) ranked the need for more training as the top priority and time for training as number two, with specialist expertise to help with Computing education in schools as number three. These are not the requests of a confident profession.

4.4.2 Costs: overt and covert

Cost was a recurring theme for the participant teachers. Given that the aforementioned £4.5 million government funding over the three years to 2016, when divided by 18,400 would equate to less than £250 per secondary-school teacher, the implication therein is that schools would need to finance the retraining of ICT teachers, at a time of cuts in education budgets (Coughlan, 2016). Participant teachers identified several areas of concern in relation to the costs of CPD. In real terms, the costs of training also included the costs of teacher release and covering teacher time, usually not funded by CPD providers. As one participant explained, although a local university offered a free subject knowledge booster course:

[Helen] It's obviously a great opportunity for us but obviously schools don't get paid for that – you've got to get the schools to release [teachers].

The lack of strategically planned professional development could also be seen as a way of cutting corners. Approving funding for a teacher to attend a course to cover one aspect of the curriculum change, such as a day of Python programming skills training, was viewed with some scepticism as a money-saving strategy by one of the participants:

[Ian] ...to save money on offering proper training to those that are not CS specialists.

The Royal Society *Reboot* report also concluded that:

> A fully resourced national professional development programme building on the Network of Excellence requires a tenfold increase in funding from government and industry. This would provide computing teachers with a comparable level of support to mathematics and the sciences (2017, p. 6).

Although it is not clear what funding data were used to arrive at the conclusion for a 'tenfold increase', it is telling that the minimal investment in CPD has been recognised, along with praise for the success of the Computing At School Network of Excellence despite minimal resources "through a model built on enthusiastic volunteers developing a mutually supportive community of practice" (2017, p. 6).

In addition to explicit costs outlined above, the lack of strategic planning of professional development belied a hidden cost: the time outside of teachers' normal working hours. It seemed common across all the participants that an expectation was placed upon teachers that the majority of such activity would be undertaken in their own time. One participant explained that an industry internship was available in holiday time:

> **[Ellen]** I got offered [the chance] to work for Computing companies in the holidays ... so I have done that.

While another was clear that the opportunities, although valuable, were undertaken above and beyond the normal workload, a point echoed in the Royal Society *Reboot* report.

> **[Helen]** But for our school, we were quite lucky, but we've not had any extra time. I've been reliant on the fact that I was willing to go to [X University] to do stuff on algorithms... There's a lot of investment of our own time. A lot of investment in us going after school.

An additional implied cost was also attached to not taking the opportunities to upskill if you were a non-specialist ICT teacher trying to convert, with several participants fearful for their career and already experiencing changes because they were limited by their lack of specialist background, as discussed previously.

4.4.3 Provision: the rise of the Computing superstar

With the lack of strategic and coordinated professional development, non-specialist participant teachers proactively transitioning became reliant on those with more knowledge, as evidenced by the number of recurring mentions of contemporary training providers. Most of these providers seemed to be former teachers and technologists working as freelance trainers, who were able to help transitioning teachers to upskill.

This training focused particularly on learning programming skills, at least enough for transitioning teachers to gain enough confidence to begin teaching programming and then to approach teaching the new GCSE courses in Computing and Computer Science. A notable feature of these individuals was their presence on social media and online forums, where the positive feedback from satisfied course participants further enhanced their reputation.

In addition, other training opportunities referred to by participants included online programming courses, MOOCs, training from technology providers, exam board training, CAS support and paid training offered by schools that might be considered as leading the field with their Computing provision.

Whilst all participants named influential people and organisations in relation to their professional development, those with a background in Computing were dubious about the longer-term quality of such provision. One such participant explained his concern about the impact of rote-learning programming solutions as opposed to developing programming fluency:

> **[Glenn]** So, from my experience of people I meet, generally secondary people are OK: they're at a point where they've used enough resources to teach themselves [programming], but it is quite a one-dimensional approach to programming.
>
> It seems to be quite linear and doesn't really think about functional programming or creating objects, or any other methods of actually solving the problems.
>
> ... hopefully, as more teachers become fluent in different programming languages, they're able to then develop other ways of teaching solutions to similar problems, instead of just by rote ... which is probably what most people are doing.

As a final summary for this sub-section, the individual participants' perceptions are condensed in Table 4.4: Summary of teacher perceptions on page 130.

4.4.4 The importance of CAS and professional networks

Interesting among the participants was the extent to which they developed professional learning networks either online through social media and online forums, or offline through provision of CPD for other teachers or involvement with the CAS community, as summarised in Table 4.2, below.

Table 4.2: Participant professional learning networks

Participant	Uses social media for professional learning	Provided CPD for others in school or beyond	Active in online/offline CAS community
1. Alex	Yes	Yes	Yes
2. Ben	Yes	Yes	Yes
3. Claire	No	Yes	No
4. David	No	No	No
5. Ellen	No	No	No
6. Faith	No	Yes	No*
7. Glenn	Yes	Yes	Yes
8. Helen	Yes	Yes	Yes
9. Ian	Yes	No	Yes

* Downloads resources

Participant David, the Computer Science specialist in the private school setting, did not report any engagement at all. Ellen, the non-specialist teaching some Key Stage 3 Computing in addition to her other subjects and whose head of department was a supportive CAS Master Teacher also did not report any engagement. At opposite ends of the spectrum, this could be interpreted as David not needing to, as he had sufficient confidence in his background, and Ellen relying solely on her head of department for Computing support. In contrast, participant Alex had developed an online personal learning network through engagement with a number of groups on Facebook, Twitter and Reddit:

[Alex] Facebook, there's a computing teachers' group. We share a lot there. Where else? Twitter, sometimes people share good lessons on Twitter. There's a couple of hashtags like #CASchat and #comp@UK. They're both quite good.

There are a few good ebooks. There's Reddit as well. On Reddit there's a subreddit called Learn Programming and people often post stuff on that.

Six of the nine participants reported that they had provided CPD opportunities for other teachers: for colleagues in school, as a college supporting local schools, and in CAS Master Teacher and hub leader roles, thereby contributing to local or regional professional learning networks.

The membership growth of CAS, the Computing at School organisation and now the main subject association for Computing teachers, is illustrated in Figure 4.3, below. In January 2012, when the disapplication of ICT was announced, and CAS was linked with the publication of curricula, the membership numbered in the hundreds, but grew to somewhere in the region of 15,000 by September 2014.

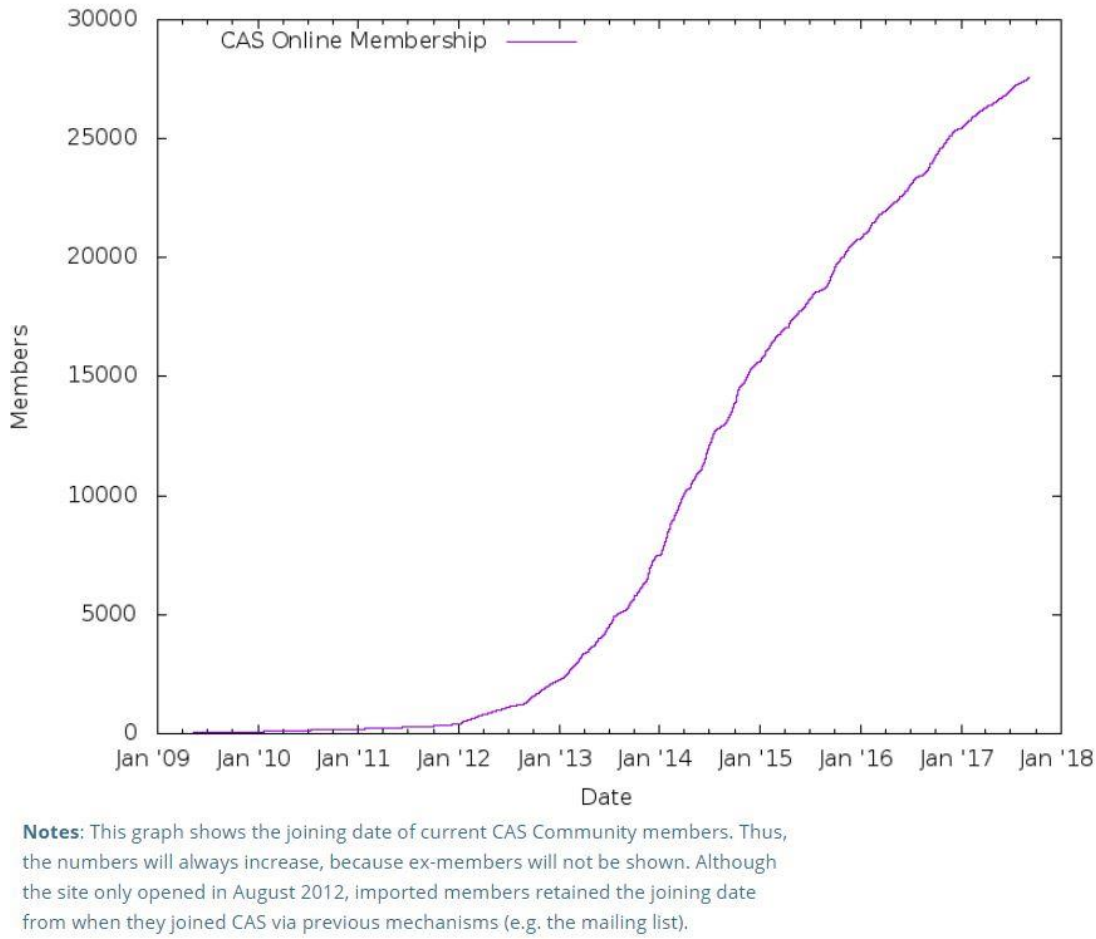

Figure 4.3: CAS registered membership from 2009-2017 (CAS, 2017)

4.4.5 Resources – a new cottage industry

In part, the CAS community formed a focal point for teachers as the impact of the curriculum change started to be felt. It also hosted resource contributions from the members, itself a key consideration as most of the participants reported their concerns about finding resources to support their teaching. This point was reinforced by participant Glenn, a Master Teacher and hub leader with experience of supporting transitioning colleagues:

> **[Glenn]** To be honest, as you'll know, most teachers will beg, borrow or steal anything, really!

Also noteworthy and linked to the provision of training and professional development by more knowledgeable others: the 'rise of the Computing Superstar' alluded to previously, is the rise of the Computing resources cottage industry.

The phenomenon of the birth of small technology-related businesses can be seen in the similar cottage industry that arose at the time of e-Learning Credit funding for the Curriculum Online initiative (BBC, 2002), where small providers (including teachers) registered to supply digital learning materials.

Although the Royal Society *Reboot* survey report did not make the same connection to the rise of the cottage industry in the wake of E-Learning Credit funding, it reported on "anecdotal evidence of an exponential growth in the amount of teaching resources following the introduction of the new curriculum" (Pye Tait Consulting, 2017c, p. 65), with many reported resource providers and organisations echoing some of those described by the participants in the current study.

Participant Helen explained that she bought in some resources in order to avoid preparing everything herself from scratch:

[Helen] There are some people who kindly share theirs at not-a-massive profit, but people like [Provider A] you have to pay ten pounds a year per subscription to get access to his resources. And [Provider B] are really good for key stage 3 and 4 and 5. So if I'm looking for resources, they have some really good resources and then we do buy stuff in.

And if we feel that it's a benefit... we have bought student workbooks off [Provider C]... the Python ones and they have like a guide and at least they can provide them homework without massive [effort on our part]... they've got answer books with them for a few so at least we don't have to overthink everything. 'Cause there is a lot of stuff that you're having to prepare or you would be if you couldn't get access to other things.

Although the extent to which participant teachers draw upon subject-specific sources and resources to enable them to align their planning with the programmes of study is a question discussed in Chapter Five, the issue of resources also emerged in relation to professional development, with participant teachers scaffolding their own subject knowledge by reviewing the way that others prepared and represented subject content for teaching. This is theorised more fully in Chapter Five.

4.5 Findings: perceptions of the transition from ICT to Computing

The participant teachers in this study were drawn from a variety of backgrounds and subject experiences, with the common denominator being that they had all taught ICT under the previous curriculum, with eight continuing to teach Computing in schools after the introduction of the new curriculum. Whilst five of the participants could be considered as 'qualified', or with sufficient Computer Science-related content in their undergraduate studies, their perceptions of the transition did not fall neatly into categories represented by their backgrounds.

The Royal Society *Reboot* report cross-tabulated their survey respondents' self-reports of understanding of computational thinking and favourability towards the new curriculum into four distinct teacher profiles: advocates, supporters, critics and less-engaged, as represented in Table 4.3, below.

Table 4.3: Teacher profiles (based on Royal Society Survey Report, 2017)

Group	Computational thinking understanding	Favourability towards new curriculum	Comments
Advocates 54%	Strong understanding >=7/10	High favourability >=7/10	• computing education must keep up with the pace of industry and technological change • computational thinking is a vital cross-curricula skill • reformed computing qualifications more interesting, creative and challenging than traditional ICT • ICT vague and monotonous
Supporters 8%	Less understanding <7/10	High favourability >=7/10	
Critics 24%	Strong understanding >=7/10	Low favourability <7/10	• balance of content is weighted too heavily towards computer science • vital fundamental ICT skills are at risk of being side-lined • new curriculum implemented without sufficient regard to who would teach it • no regard for potential amount of additional knowledge/ upskilling that may be required by teacher
Less engaged 14%	Less understanding <7/10	Low favourability <7/10	

This representation of teachers' perceptions was further simplified in the final report, with just two groups being mentioned: a confident, favourable group and a supportive but feeling "inadequately trained" group (2017, p. 53). The comments ascribed in the table above to the two groups represent this dichotomously, whereas the findings of the current study demonstrate that teachers' perceptions are far more reflective and nuanced. Taking the broad descriptions of the current study's participants as either 'qualified' or 'non-specialist' is also too simplistic, therefore, each has a contextual description within the current study to help situate their identity. Delving deeper, pre-2014 the majority of the participants could have been considered as an ICT specialist by dint of their specialist ICT teacher training. Post-2014, the situation was much more complex. The Summary of Teacher Perceptions table (Table 4.4, below) is presented in order to reject the use of this framework, which attempts to corroborate a preconceived and simplistic proposition.

The summary of teacher perceptions (Table 4.4, below) demonstrates that this kind of theoretical replication is far too simplistic because each participant brings a unique perspective, shaped by prior experience, context, ideas, beliefs and values.

Table 4.4: Summary of teacher perceptions

Participant	Participant description	Curricula	Transition	CPD access	CPD themes	Influences
Alex	a 'qualified' ICT-trained Computing specialist	Programming is difficult ICT didactic; CS creative; learners have more control	Strong personal beliefs; empathy for others; had made multiple transitions himself	Support others Extensive CPD	Self-directed	CAS External practitioners / providers
Ben	a non-specialist, generalist primary Computing specialist	Address CS stereotype IT potentially boring	Supportive; embraced new opportunities. Proactive	Support others Self-directed; extensive CPD Certification	Proactive through CAS	External practitioners / providers CAS
Claire	a 'qualified' post-16 Computing specialist	Not enjoy programming; value other aspects of Computing IT needed for workplace	Uncertainty; frequency of change; left classroom	Willing to support; uncoordinated efforts No external CPD	Uncertainty witnessed as to what teachers needed	n/a
David	a 'qualified' ICT-trained Computer Science specialist	NC not statutory but had incorporated programming Concern over disregard for IT skills and over emphasis on CS	Had made multiple transitions himself Straightforward; issue of differentiation	Some external CPD	Not useful	External practitioners / providers

Participant	Participant description	Curricula	Transition	CPD access	CPD themes	Influences
Faith	a ‘qualified’ Maths-trained secondary Computing specialist	ICT curriculum uninteresting but skills necessary CS as a science; programming as demonstration of concepts	Pushed for CS	Support others No external CPD	In-house support for others, provided by Faith	CAS External practitioners / providers
Glenn	a vocational-route ‘qualified’ ICT-trained secondary Computing specialist	Computer Science not inclusive CS requires student self-motivation	Not worried; welcoming Frustrated by lack of clarity Lack of SLT understanding	Support others Some external CPD Self-directed;	Highlight CAS as a baseline Focused on programming, but one-dimensional	CAS External practitioners / providers
Helen	a non-specialist ICT-trained transitioning ICT teacher	CS needs specialist teachers IT different to CS, like a different language	Accepting; trying to meet the challenge by embracing opportunities	Support others Self-directed; extensive CPD Minimal access	Costs to school and teacher time Luck	CAS External practitioners / providers
Ian	a non-specialist Science-trained transitioning ICT teacher	Concern over disregard for IT skills and over emphasis on CS Enjoys flexibility of KS3	Supportive. Frustration at emphasis on CS	Some external CPD	Insufficient quality of CPD	CAS External practitioners / providers
Ellen	a Business-trained non-specialist teaching some Computing	Computer Science not inclusive IT focused on digital outputs	Fearful Hopes of changing back	In-school support No external CPD	School holiday internship offered	External practitioners / providers

The table headings relate to participants’ comments in relation to the ICT and Computing curricula, how they perceived the transition from ICT to Computing, and how they perceived the CPD available to them. Building on the CPD comments, two further columns have been added to capture broader themes and influences upon them, including in relation to resource providers. The table serves as a reference point for the findings in relation to the sub-questions for Research Question One and for interpretations made from the data in the conclusions chapter.

Summarising from the direct quotations from participants and the table above, what follows is a precis of the current study’s participants’ perceptions of the transition from ICT to Computing. Perceptions ranged from stoicism (David, Helen) to concern over the ongoing uncertainty (Faith, Claire, Ian) to frustration around the lack of clarity (Glenn, David, Ian), fear over lack of subject knowledge (Ellen, Ian, Helen), impact on career progression (Ian, Ellen) and perceptions of vulnerability (Alex) and stereotypes (Ben) evident in colleagues. Participants were disturbed by the realisation of the shortage of specialist teachers (Faith), concerned by teachers leaving the profession (Claire, Faith, Helen) and empathetic (Alex, Faith) while bearing the load of supporting others (Helen, Glenn, Ben, Faith) or grateful for any support (Helen, Ellen, Ian). Support from senior leaders, governors and the government seemed lacking, generally because of a lack of understanding about the enormity of the impact of the curriculum change (Helen, Glenn, Ian). Those with a stronger relevant background seemed willing to persevere (Alex, Glenn, David) despite a prevailing sense of ‘imposter syndrome’ (Alex, Helen, Ian, Ellen).

As a final summary for this sub-section, the individual participants’ perceptions are condensed in Table 4.4: Summary of teacher perceptions on page 130.

4.6 Findings: perceptions of ICT and Computing curricula

Influenced by their differing backgrounds, beliefs, values and experiences, the participants' perceptions of the ICT and Computing subjects and curricula can also be summarised thematically but do not fit neatly into mutually exclusive categories. With regards to ICT, participants' perceptions ranged from describing the subject as choppy, didactic and task-based (Alex, Ellen), boring when restricted to office-type software (Ben) and less creative than Computing (Alex). They valued its flexibility (Ian), inclusivity (Claire, Ellen) and vital, valuable, vocational skills (David, Claire, Ian), all the while recognising that it may well have served its purpose during its time (Faith) and having been irretrievably damaged by the qualification gaming entered into by many schools in an effort to manipulate league table results (Glenn).

Computing, usually understood as programming specifically, was felt to be harder, more difficult and more challenging than ICT (Alex, Ian, Glenn, Ben), in fact more like a science subject (Faith) or like a completely different language (Helen). It allowed much greater independence (Ellen) and control by the students (Alex) and more creativity (Alex) but at a cost to skills valued by employers (Claire) since few would need programming in their work (Claire). Some felt that it was too complex, especially for younger pupils (David) or less able pupils (Ellen) and needing high levels of self-motivation (Glenn). The focus was too heavily on Computer Science aspects (David) at the cost of the other two strands (Ian, Glenn).

As can be seen by the participant names referenced beside each theme, which can be cross-referenced to each participant in the current study, many of the views that the Royal Society report ascribed stereotypically to one or other of their identified groups run counter to those expectations. The ideas, beliefs, experiences and values of the participants in the current study have influenced their perceptions but not prevented them from articulating the aspects of the curriculum change that they have been dissatisfied with. In addition, regardless of the many difficulties in making the transition, the majority of the participants were continuing to work to do so. Where this had not been possible, or where circumstances had dictated, pragmatism came to the fore and they have moved into other positions.

As a final summary for this sub-section, the individual participants' perceptions are condensed in Table 4.4: Summary of teacher perceptions on page 130.

4.7 Findings: perceptions of available CPD

Most participants reported a lack of access to CPD (Alex, Claire, David, Faith, Glenn, Ian), but some made significant efforts outside of school time to upskill (Alex, Ben, Glenn, Helen). The costs of this approach were significant in terms of teacher time (Helen, Ian) but those for whom CPD was not accessible recognised the opportunity cost of not being able to upskill as much as needed in the role (Ellen, Ian), and as assessment continued to place subject knowledge challenges on them (Ian, Claire).

Most of the teachers referred to CAS as a significant source of support (Alex, Ben, Faith, Glenn, Helen, Ian), either for themselves or for those supporting them (Ellen). In addition to CAS, most of the participants had an immediate working knowledge of influential practitioners and sources of support and teaching resources (Alex, Ben, David, Faith, Glenn, Helen, Ian). Notwithstanding this, one participant, Glenn, also a Master Teacher, was concerned that the influence of CAS was not reaching far enough and posited a theory that there were still teachers struggling on their own, who had not engaged with CAS. More research is needed to better understand the types of teachers who need additional support and to ascertain their CPD needs. There is a risk that continued investment in one form of support will not identify or address the needs of all teachers of Computing.

4.8 Chapter summary

This chapter has presented the findings in relation to the first research question: How do participant teachers perceive the ICT to Computing curriculum change? It has been structured to allow each of the sub-questions to be considered separately. The early part of the chapter focused on presenting findings in relation to teachers' perceptions of the transition from ICT to Computing and their orientations towards the two different subjects by presenting these as part of individual case narratives set in the context of the individual participants' background and experience. The chapter then moved to a cross-case discussion of participant teachers' perceptions of the subject-specific professional development available to them during the transition. Finally, emergent themes were discussed in light of the literature reviewed. A summary table (Table 4.4, starting on page 130) summarises each participant's perceptions in relation to each of the sub-questions.

A thematic synthesis provides the framework for the findings from this research question. They are grouped into three overarching themes: teacher beliefs, teacher identity and professional issues. This framework forms the basis for the structure of the concluding comments in Chapter Six.

TEACHER BELIEFS

- Different beliefs about ICT and CS.
- The need for a broad curriculum, real-world skills.
- Concerns about marginalisation of IT, the prioritising of programming and Computer Science.
- Subject status, pupil abilities/vocational/academic, gender issues.

TEACHER IDENTITY

- Vulnerability, imposter syndrome, specialist and non-specialist identities.
- Impact on career, perceptions of CS, dodging bullet, pressure, loss of core status.
- Continuing uncertainty re: government policy, accountability.

PROFESSIONAL ISSUES

- Lack of support from senior leaders, lack of and importance of CPD, upskilling in own time.
- Overt and covert costs.
- Importance of CAS, importance of professional networks, influential people.
- Importance of resources and resource providers, the cottage industry.
- Transition issues (from primary to secondary school).

The next chapter, Chapter Five, presents the findings in relation to the second research question: how do participant teachers approach the planning of Computing lessons? In Chapter Six, I shall summarise all the findings, explain their implications and suggest areas for further research.

Chapter 5 Findings and discussion of Research Question Two

5.1 Chapter overview

As outlined in the previous chapter, the overarching aim of this study is to understand in-service teachers' perceptions of the transition from teaching ICT to teaching Computing under the new statutory 2014 National Curriculum in England programmes of study for Computing at Key Stages 1 to 4 and to explore their application of professional knowledge and skills through planning Computing lessons under the new curriculum.

In seeking to understand this problem, this multiple case study addressed two main research questions, each with three sub-questions. The previous chapter outlined the findings in relation to participant teachers' perceptions of the ICT to Computing curriculum change. This chapter focuses on the second research question: how participant teachers approach the planning of Computing lessons. Subsumed within this question are three sub-questions:

a) How is Pedagogical Content Knowledge (hereafter, PCK) enacted through pedagogical reasoning when participant teachers plan Computing lessons?
b) How is the Computing subject knowledge requirement being addressed by different participant teachers to enable them to plan lessons?
c) To what extent do participant teachers draw upon subject-specific sources and resources to enable them to align their planning with the programmes of study?

This chapter is organised so that it begins by summarising the main approaches to planning undertaken by participant teachers for the purposes of this study. Because of the inter-relatedness of the main concepts involved in planning: PCK, pedagogical reasoning, subject knowledge and resources, examples of data from each participant are presented as evidence to demonstrate how the sub-questions can be answered for each case. In the second part of the chapter, prevalent cross-case findings are discussed.

5.2 Participants' approaches to planning

This chapter presents the key findings obtained from semi-structured interviews, lesson planning sessions and a range of documentary evidence relating to nine participants, each of whom had been teaching ICT prior to the curriculum change in 2014, eight of whom continued to teach Computing in schools post-2014.

As described in Chapter Three, data collection included a specific focus on lesson planning. The geographical spread of the participants and their willingness to make themselves available to share their planning procedures with me meant that I had to be flexible with the procedures for data collection. With the exception of Claire, the teacher who had moved sectors to teach in Higher Education and was no longer teaching Computing, the other eight participants all provided a window onto their Computing planning processes, whether through face-to-face or remote sessions. As Claire did not contribute any planning data to the study, all references to participants from this point forward relate to the other eight participants.

In the Participant Information Sheet (see Appendix C: Participant information and informed consent on p. 232), which participants signed to indicate their agreement to participate in the study, the participants were asked to allow the researcher access to the process of planning a lesson, as well as to the materials and resources used and produced. In conversation, I had explained that I was open to them deciding what form of planning they wanted to share with me, as I did not wish to impose any assumptions about what participants' planning might entail. I anticipated that the planning would result in some form of output, whether that might be notes in a planning book, adaptations to an already planned scheme of work or resources to be used in the planned lesson. As I was working with experienced teachers, there was no expectation that they would provide full written lesson plans of the type they might have been expected to produce during their initial teacher training or for a formal lesson observation undertaken by a line manager or Ofsted inspector.

Table 5.1, below, shows the focal topic area for each participant for the purposes of this study.

Table 5.1: Summary of participants' planning examples

Participant	Participant description	Planning examples
Ben	a non-specialist, generalist primary Computing specialist	- Year 3 & 4 planning –animation - Year 3 & 4 planning – programming
Alex	a ‘qualified’ ICT-trained Computing specialist	- Year 10 planning - programming - Year 7 planning – devices
Glenn	a vocational-route ‘qualified’ ICT-trained secondary Computing specialist	- Planning for binary, logic, truth tables GCSE - Y9 mobile app planning
David	a ‘qualified’ ICT-trained Computer Science specialist	Full primary curriculum for KS1 and KS2, focus on programming
Faith	a ‘qualified’ Maths-trained secondary Computing specialist	Planning KS3 Programming in Python
Helen	a non-specialist ICT-trained transitioning ICT teacher	Planning for fetch-decode-execute & Little Man Computer for GCSE
Ian	a non-specialist Science-trained transitioning ICT teacher	Logic gates lesson planning GCSE
Ellen	a Business-trained non-specialist teaching some Computing	Curriculum planning done by Head of Department; adapted by Ellen for her classes

In considering the participants’ approaches to planning, I have employed a ‘pedagogic metaphor’ (Woollard, 2005) from Computing to structure the next section, partly because the intention in this chapter is to move towards exploring how participants’ planning reflects their pedagogical content knowledge (PCK) during the transition from the ICT curriculum to the post-2014 Computing curriculum.

In Computing, students are routinely taught about computer systems in terms of an input, process and output model, usually with a built-in feedback loop. For example, for the answer to a computational problem, numeric data is input, processed by the application of formulae and results in numeric output. In helping students to understand this, pedagogic metaphor is useful to encourage thinking about how other systems involving inputs, processes and outputs may also be understood. However, in employing the metaphor to describe the process of lesson planning, I will reverse it and start with the outputs, which I define as the tangible products from the lesson planning process, feeding them back into the process model in order to follow it through. I will then move on to the process: the planning of the lesson using the inputs (the knowledge bases and sources that are used in the process of pedagogical reasoning), see Figure 5.1, below.

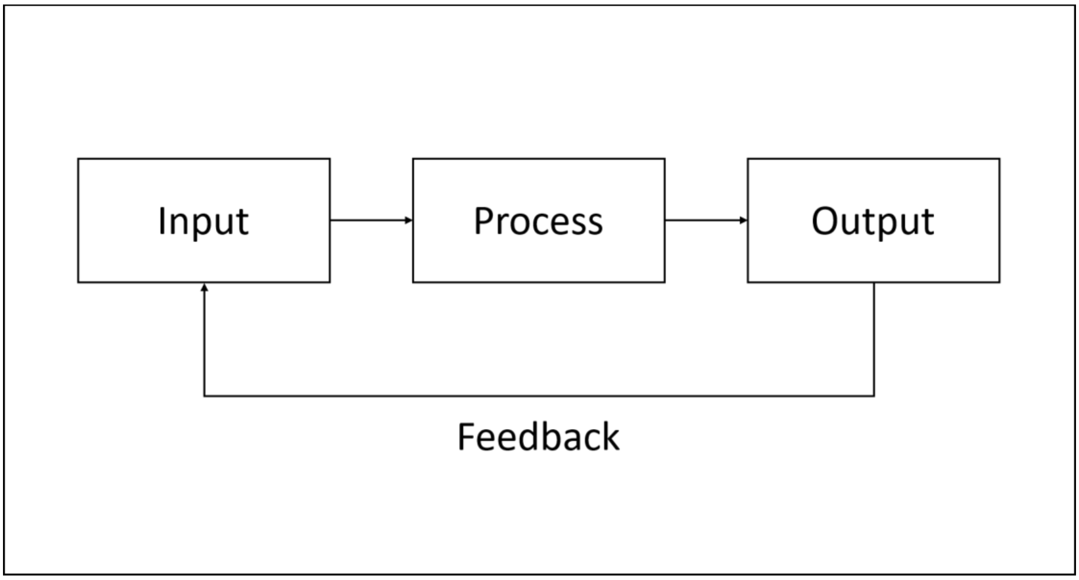

Figure 5.1: Input-process-output model adapted as pedagogic metaphor

5.3 Planning outputs

Each participant provided a document outlining their planned coverage of the curriculum (see Table 5.2, below), although the naming of the document differed, itself a factor of the school context. This ranged from either the subject area name or just ‘curriculum’ ‘map’, ‘cycle’ or ‘overview’ to’ long-term plan’, ‘order of units’ or ‘strands of learning’. This type of planning may best be described as ‘yearly planning’, prevalent in the planning typologies in the literature along with ‘term’, ‘unit’, ‘weekly’ and ‘daily’ (Clark & Yinger, 1987).

Table 5.2: Planning overview and outputs

Participant	Curriculum overview	Planning	Lesson resources
Ben	Curriculum cycle	Unit plan	Worksheet Prompt sheet
Alex	Curriculum map	Lesson PowerPoint	PowerPoint files
Glenn	KS3 long term plan	Lesson plans	PowerPoint
David	ICT Overview	Lesson by lesson schemes of work	Link to website
Faith	Computing 7-9 16-17 and Computer Science 9-1	Lesson by lesson schemes of work	Workbook

Participant	Curriculum overview	Planning	Lesson resources
Helen	Order of units and strands of learning 16-17	Lesson PowerPoint	PowerPoint Handouts
Ian	Curriculum map and 16-17 Year Plan	Visual lesson plan	PowerPoint Handouts
Ellen	Long term plan 16-17	Medium term plan	Workbook

Yearly planning, in this study, is best described as the breaking down of units of study chronologically across the academic year. In addition, some participants' planning documents took this a step further and presented a Key Stage plan, grouping the planning into stage-related categories in line with the National Curriculum Key Stages, as in Figure 5.2, below. Each cell in the grid could then be broken down into a unit plan, and then into individual lesson plans.

Key Stage 3 ICT and Computing Order of Units					
Year 7		**Year 8**		**Year 9**	
7.1	Health & Safety/Networking	8.1	Health and Safety (Personal risks)	9.1	Health and Safety (Data Risks)
7.2	What is a computer	8.2	Using a Computer	9.2	What is a computer
7.3	Sequencing (Scratch Game)	8.3	Programming (Python)	9.3	Programming (Python)
7.4	Data Handling	8.4	Datahandling (Edit and Format)	9.4	Graphics/Web Design
7.5	Graphics (Planner Cover)	8.5	Modelling	9.5	Data Handling (Create)
7.6	Modelling	8.6	Web Design and Graphics	9.6	Animation
				9.7	Control
				9.8	Extended Project (STEM)

Figure 5.2: Helen's Key Stage 3 overview

Where the lesson being discussed in the planning session had been part of a formal observation, either for internal appraisal or for a teaching job interview lesson observation, a formal written lesson plan was provided (participants Glenn and Ian). All participants provided materials they had located, created or adapted for the lesson.

Participants' planning outputs included resources for use in their lessons. As can be seen in Table 5.2 above, half of the lesson resources took the form of PowerPoint files for display during the teaching session. The use of PowerPoint or other presentation software serves multiple purposes for teaching and learning (Levasseur & Kanan Sawyer, 2006). It is both a presentation tool and a structuring tool, and the software affordances, if used well, can serve a pedagogical function, depending on "the teacher's didactical knowledge and pedagogical approach, which affects their orchestration of the setting" (Kennewell, 2001, p. 112). Five of the eight participants also provided or developed materials for direct use by their students: handouts, worksheets and workbooks, whether these were designed to be printed or used interactively while working on computers. In some cases, participants provided marking breakdown documents, which incorporated subject-specific criteria and assessment information for pupils, with success criteria.

5.4 Planning processes

Moving now from the functional and procedural aspects of lesson planning to the process of pedagogical reasoning necessitates drawing on Shulman's original 1986 concept of what this process involves. Shulman argued that that the process was dependent on the exchange of ideas. The idea to be explored in the lesson must first be

> …grasped, probed and comprehended by a teacher, who then must turn it about in his or her mind, seeing many sides of it. Then the idea is shaped or tailored until it can in turn be grasped by students (Shulman, 1986, p. 13).

For some of the participants in this study, comprehension of the idea is a critical point in the lesson planning process. Teachers making the transition from a background in ICT may not possess a broad enough Computer Science subject knowledge base to be able to engage confidently in the process of pedagogical reasoning. However, key to the findings of this study is Shulman's assertion that grasping the ideas needed for comprehension 'is not a passive act'. This assertion opens up the problematic space for the participants of this study. Regardless of background, participants needed to interact with the ideas in the Computing curriculum in order to be able to plan lessons based on them.

From the planning session data, I have developed a model with which to categorise the pre-pedagogical reasoning approaches to planning taken by the participant teachers: see Figure 5.3: Planning model.

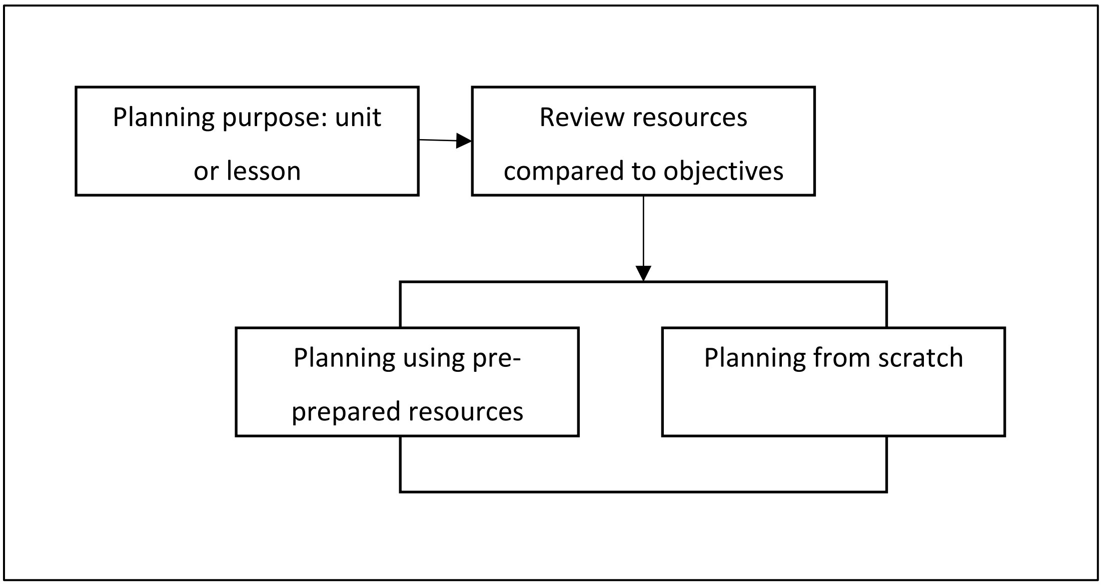

Figure 5.3: Planning model: purpose of planning and review of available resources

This model starts from the position of the purpose of the planning to be undertaken. One I have labelled as **curriculum intent at the unit level**. This applies where the planning process is a result of the need to plan at the unit level. The other I have labelled **need-based planning at the lesson level**. This is where the participant is working within the bounds of a single lesson to be taught. It is logical to expect different kinds of planning being undertaken at different times.

From the planning purpose, teachers must review the resources already available to them and whether planning needed to be **started from scratch** or whether **pre-prepared materials** were available to be used in the process. These were not mutually exclusive categories because, having started from scratch, it is feasible that teachers could then source elements of the lesson using pre-prepared materials, or modify something similar. Equally, having started planning with pre-prepared materials, it is possible that a lesson element may need to be developed from scratch.

In the next section, I will use these categories to present case data to demonstrate the enactment of PCK in pedagogical reasoning.

5.4.1 Planning from scratch

5.4.1.1 Pre-resource planning: internal approach

Approaching the planning of Computing lessons without existing materials or resources meant that participants displayed elements of practice that I interpreted as corresponding to the 'comprehension' stage of Shulman's process of pedagogical reasoning. Although Shulman described the processes, Webb (2002) had further developed this into a visual model of pedagogical reasoning (2002, p. 242), which was presented in Figure 2.2 on page 30.

Following on from a discussion of Webb's adapted model in Chapter Two, it is important to re-emphasise that the arrows on Figure 2.2 on page 30 represent the influence of ideas, beliefs and values on the processes of pedagogical reasoning without detracting from its main purpose. The current study explores teachers' ideas, beliefs and values surrounding the transition from ICT to Computing, and the ways in which these are reflected in the teachers' professional practices.

Three participants started their planning from scratch: one with the intention of creating a unit of work and two with the intentions of developing a single lesson within a sequence. I have used the categories of **curriculum intent at the unit level** and **need-based planning at the lesson level** to separate their approaches. Their data are presented and discussed in the next section.

5.4.1.2 Curriculum intent at the unit level

5.4.1.2.1 BEN: A NON-SPECIALIST PRIMARY COMPUTING TEACHER

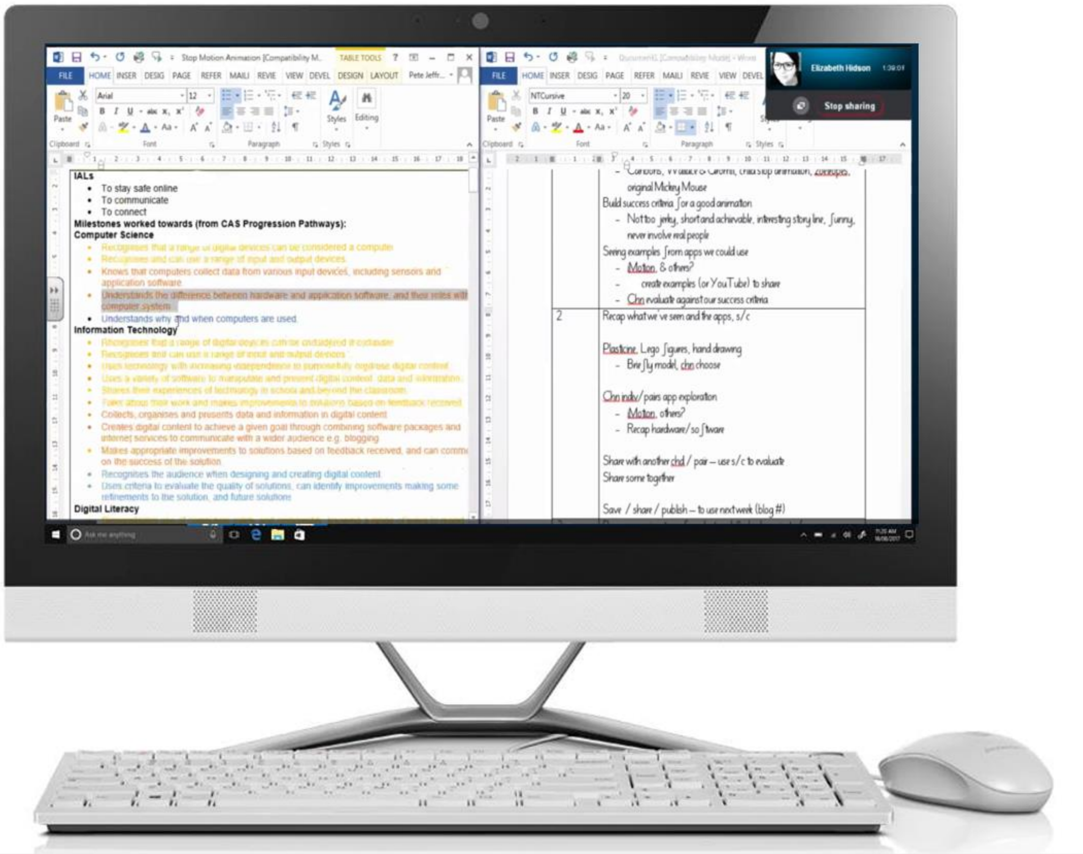

Figure 5.4: Ben's screen during lesson planning

Ben's planning approach was tied into whole-school planning as each half-term the school had a different topic underpinning the curriculum on a two-year cycle in order to connect pupils' learning across subjects. Ben followed a very clear process during the planning of the unit of work, as demonstrated in Figure 5.5, below. Figure 5.4 (above) shows a representation based on the split-screen approach taken by Ben during the process, whereby he was able to refer to additional documentation and source material in order to develop the unit plan. The image is not presented here for reading purposes: it serves to demonstrate the researcher's view of Ben's desktop in desktop-sharing mode. Were it possible to present the full complexity of the lesson planning session observed through Skype desktop sharing, what would have been experienced here is the audio and video stream of every action that Ben took during the planning session. Multiple desktop windows were opened, multiple documents referred to, and multiple web searches for illustrative material were carried out, resulting in a richness of data that can only be hinted at in this chapter.

The unit being planned was a stop-frame animation project, which was linked into a whole-school theme based around Hollywood. Key Stage 1 had worked on animating drawings on iPads, Year 3 and 4 would develop this concept into stop-frame animation and Years 5 and 6 would go on to work on video-editing projects on laptops.

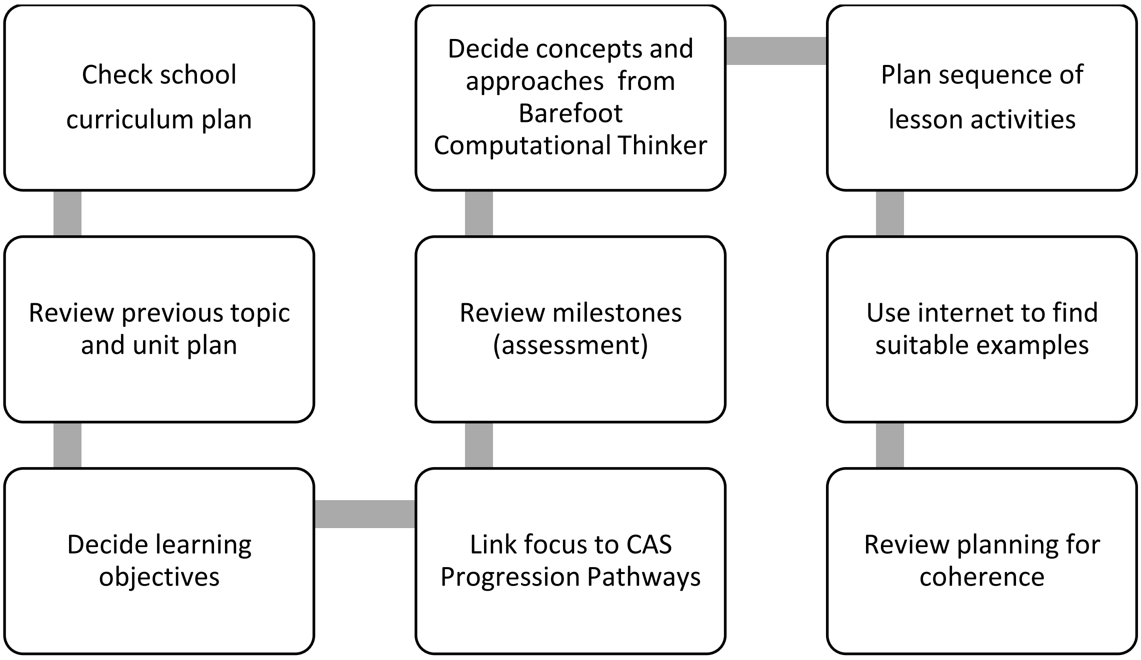

Figure 5.5: Ben's planning process

Relative confidence with the relevant subject content was evident in Ben's planning process. The topic did not present a challenge to Ben's subject knowledge or comprehension of the set of ideas to be taught, so he was able to move smoothly into the transformation stage and begin to make decisions on the structure of the lesson. It was at the preparation stage that Ben's knowledge of curriculum links was tested.

The following extract from the planning session transcript relates to Ben making the link back to the CAS Progression Pathways and working out which elements apply to the age group for which he was planning. The purpose of making these elements explicit in the written plan was primarily internal justification and to be able to explain what the pupils would be doing and how it covered 'lots of things' in the curriculum. Throughout this extract, Ben struggled with making the link back to the relevant Computing progression pathway descriptors. His think-aloud train of thought showed that this was a process of elimination and best fit rather than a thorough conceptual understanding of the underlying subject area. From this extract it is possible to follow Ben's thinking that stop-frame animation was loosely to do with understanding algorithms and creating programs, but also his uncertainty as to whether he was correct in his interpretation. The 'mildly interesting' 'little codes' referred to in the third paragraph below are computational thinking concepts promoted by CAS (as illustrated in Figure 4.2 on p. 94):

- **AB** = Abstraction;
- **DE** = Decomposition;
- **AL** = Algorithmic Thinking;
- **EV** = Evaluation;
- **GE** = Generalisation.

[Ben] Right, so ... milestone, Computer Science, which one are we doing ...understand algorithms...erm yeah, I think loosely, that's going to be in there, especially those two, understand how programs specify the function general purpose...not sure it's that third one. I'm just going to copy those two out and drop that in there - let's take it - just the text there we go erm (create programs....)

I still get into a little debate in my own head now... well, the stuff we're going to do - creating stop-motion animations - comes into the first part of that but not into the second so we're not using sensors in there. I tend to err on the side of being a bit more generous. I don't know whether that's the right thing to do so I think I'm probably a bit more generous ... and drop that in, whether that's the right thing to do or not, I don't know.

These little codes afterwards are mildly interesting, but I've never found them at all useful, so while it's useful to think about which the abstractions are, and which are the algorithms and things like that I've never ever used them in a planning sense.

A significant point to note is that Ben demonstrated the level to which his Computing subject knowledge in relation to Computational Thinking concepts could take him. Although a four-stage framework for planning lessons to develop Computational Thinking in the classroom was published by CAS (Curzon, Dorling, Ng, Selby, & Woollard, 2014), Ben did not see this approach as part of his planning repertoire.

Another finding of interest from Ben's planning process is the extent to which his planning aligned with Shulman's view of teacher knowledge and the pedagogical reasoning process. Coding of the planning transcript had produced 10 segments coded using the PCK_ code stem (see Figure 5.6, below) and a further 16 segments coded under the PED_REASON code stem (see Figure 5.7, below).

60:36	PCK Assessment knowledge
60:48	PCK_Curricular knowledge
60:49	PCK_Curricular knowledge
60:52	PCK Pedagogical knowledge
60:57	PCK_Knowledge of students
60:68	PCK_Curricular knowledge
60:88	PCK Pedagogical knowledge
60:100	PCK Pedagogical knowledge
60:219	PCK Pedagogical knowledge
60:228	PCK_nobody teaches the same way tw.., RESOURCES

Figure 5.6: Teacher knowledge codes in chronological order for participant Ben

Figure 5.6 shows the ten PCK_ code stem segments grouped together as codes relating to teacher knowledge. Using Atlas.ti 7's query function to locate these codes returned the segments in chronological order, which reflected their application during the planning process and provided the data for this finding.

Repurposing the figure into narrative form: early in the planning process, Ben used assessment knowledge when reviewing the Progression Pathways document, then moved on to thinking about how this fit with the curriculum, considered how this project might work in practical terms, thought about the prior learning experiences of the specific students who would be working on the project, aligned the plan to the Computational Thinking framework, thought again at considerable length about the teaching and then, at the end, reflected on his approach to the use of resources.

Figure 5.7 shows the sixteen PED_REASON code stem segments grouped together. It shows the way that Ben's actions while planning were coded as displaying elements that indicated he was working within the 'transformation' phase of the pedagogical reasoning process proposed by Shulman.

60:7	PED_REASON_Sequencing
60:12	PED_REASON_Instructional selection
60:51	PED_REASON_Differentiation
60:65	PED_REASON_Sequencing
60:77	PED_REASON_Preparation
60:78	PED_REASON_Representation
60:81	PED_REASON_Representation
60:82	PED_REASON_Representation
60:85	PED_REASON_Preparation
60:89	PED_REASON_Representation
60:98	PED_REASON_Adaptation
60:101	PED_REASON_Preparation
60:109	PED_REASON_Preparation,
60:215	PED_REASON_decision, PED_REASON_Sequencing
60:216	PED_REASON_Sequencing
60:227	PED_REASON_Evaluation,

Figure 5.7: Pedagogical reasoning codes in chronological order (Ben)

Notable from the sequence of pedagogical reasoning codes in the figure is the dynamic nature of the process of transformation within Webb's modified version of Shulman's pedagogical reasoning model. Although Webb's model represents this as a staged cycle of processes, what is clear from Ben's approach to planning is that this is a dynamic model, perhaps better represented in a cluster diagram, such as that portrayed in Figure 5.8 on page 149. It therefore follows that Ben's process of pedagogical reasoning is a good conceptual fit with Webb's adapted model of transformation in pedagogical reasoning.

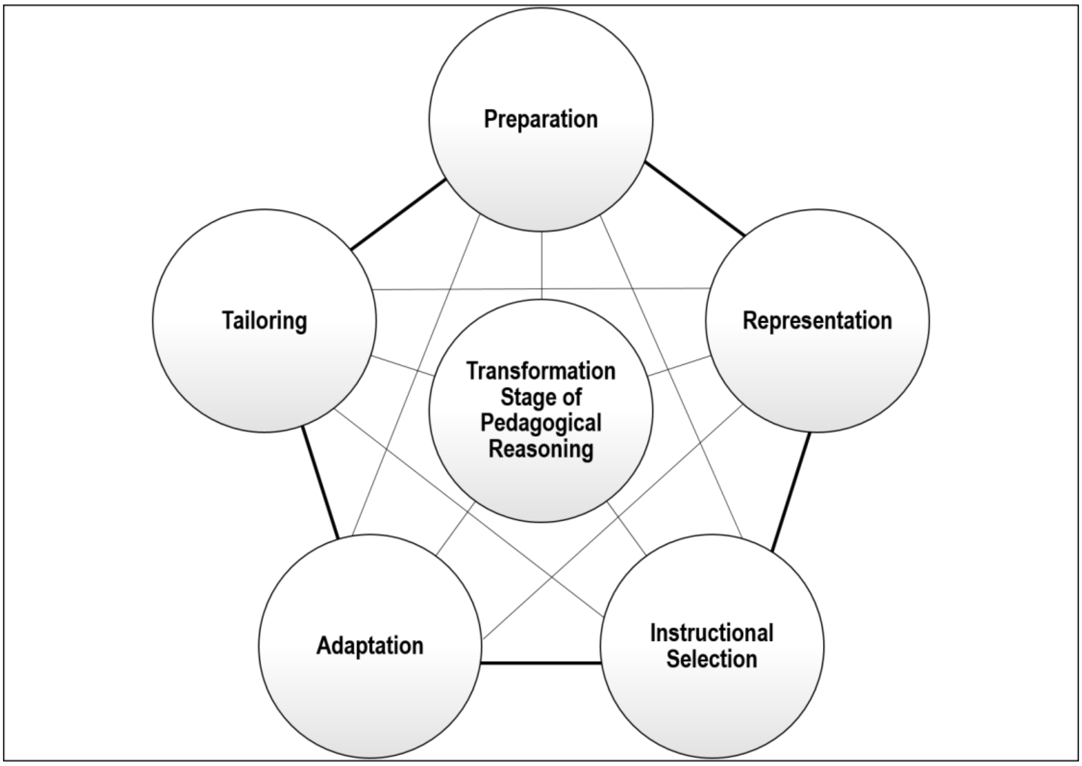

Figure 5.8: Transformation represented as a cluster diagram

Ben's planning focused on developing the lesson-by-lesson unit plan. Within the lesson planning session, he did not create resources for the pupils to use, and explained his rationale:

[EH] And then the actual lesson materials that you'll present to the children, do you then create those? Are you responsible for putting that together?

[Ben] Yes ... back in the day, I used to have really detailed SMART™ Notebooks with everything on there and what you found was that you spent far too long creating these things and for something that was on the screen for 10 seconds before you moved on, so what I tend to do is have a couple of bits on there with some reminders; once we've got things like the success criteria bottomed out then that will be on there.

So, it kind of becomes one or two things, useful as a reference point during the lesson... so, for these examples that we've got there, I will go find them on YouTube videos for each of those, and then post a blog post on each of the class blogs with all those videos on there. So, we kind of use the blog as a teaching resource as well, which is quite nice for them...

... I don't create loads and loads of stuff partly because I don't find it particularly useful: and also, things change. One class becomes very different to other classes.

Ben explained that he had moved from providing very detailed, instructional-type resources under the ICT programmes of study to using fewer resources and integrating them within the class blogs. As the class blogs were public, it was possible to triangulate this by reviewing several iterations of the class blogs. Those created based on the unit of work Ben had planned for this study showed draft and final stop-frame animations developed using modelling clay, craft and everyday materials, interspersed with questions and prompts for the pupils encouraging links and comments to be made, photos of success criteria written on the whiteboard in class during the project and links to example YouTube videos. This approach was also taken with a programming unit Ben had developed, with additional highlights included, such as outdoor work with mini robots, and cooking by following recipes (algorithms). The class blogs were an accurate reflection of the planning undertaken.

Interesting in the extract is the comment made by Ben that 'one class becomes very different to other classes'. This theme was present in the project hermeneutic unit, coded as **PCK_nobody teaches the same way twice** and was applied to five quotations: from Ben, Alex, Ian, Ellen and Helen, all of whom I would categorise as making diligent efforts with the transition from ICT to Computing. Each coded instance suggested conscious variance in the participants' approaches to teaching different students, even for the same topics. For Ben, despite planning a unit to be used with two classes, which he could have seen as identical, his comments are indicative of his pedagogical content knowledge. Ben's knowledge of pupils: a) of pupils in general and b) of specific pupils, was brought to bear on his approach to developing resources. He developed a general set of references and resources, leaving the use and interaction with the resources open to the developing interests of the pupils in the course of the lesson sequence.

5.4.1.3 Need-based planning at the lesson level

5.4.1.3.1 ALEX: A 'QUALIFIED' ICT-TRAINED COMPUTING SPECIALIST

Alex's planning session started from reviewing his curriculum map and deciding that the next thing he needed to teach his Year 10 Computer Science class was a review of FOR loops in searching and sorting algorithms. He decided, based on instructional approaches he had learned about on external training courses, that he would select a programming challenge for the main lesson activity. He then decided that his starter activity would revolve around a series of errors of increasing challenge that he wanted to students to spot and then correct. The intention was to address student misconceptions (a key element of PCK for programming (Ohrndorf & Schubert, 2013; Park & Oliver, 2008; Qian & Lehman, 2017)) and allow them to identify different possible errors that he had included, as seen in Figure 5.9: Alex planning a loop error debugging task, below, as he began to develop the task.

4) Asks them to input money until their balance is 0

```
price=int(100)
cashIn=int(0)
balance=price-cashIn
while balance >0:
    cashIn=int(input("Please pay £"+balance+" to access"))
    balance=balance-cashIn


print("Thank's for paying")
```

Figure 5.9: Alex planning a loop error debugging task

Figure 5.10, below, summarises the overall approach to lesson planning taken by participant Alex. As with participant Ben, there was far more movement between different phases of the transformation stage of the pedagogical reasoning process than the process model suggests. In particular with participant Alex, the think-aloud process revealed that he moved fluidly backwards and forward between the different phases focusing in some depth on adaptation and tailoring as he was able to access pupils' prior work on the school's network drive and see for himself how different students had coped with previous programming tasks. He was evidently using pedagogical knowledge based on experience but with new or less familiar content.

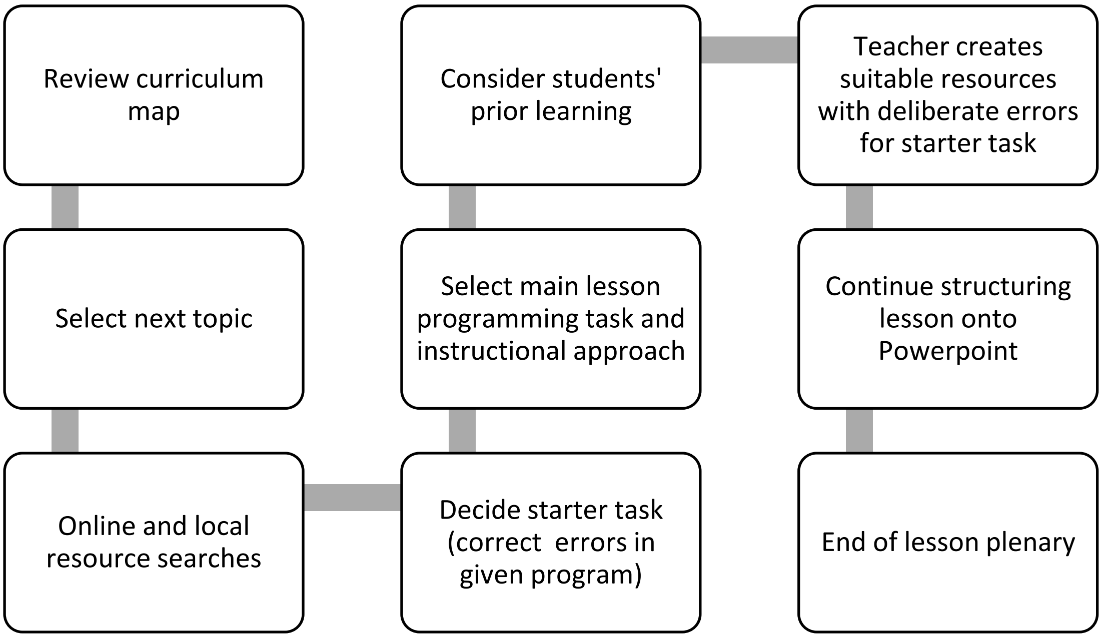

Figure 5.10: Planning process for participant Alex

The following extract is a clear instance of the representation phase of transformation within the pedagogical reasoning process. Keen to identify potential learning from deliberate errors in the code, Alex thought through alternative ways that the errors could be represented [float, string and round function]. In so doing, he drew on his knowledge of his pupils' prior learning, adapting the task based on their characteristics [they'll like that, they've done it before].

[Alex] The only other thing I'm going to add in here is some people might get the wrong misconception. So, they might tell me that this is actually meant to be a float, which is correct. It could be a float, because someone could enter 20p, but actually what the real misconception is that string there, so I'm going to re-correct that. Ok, so… if we enter that as £55, get £45 point zero, this becomes like the round function as well, formatting to two decimal places. They're gonna have to research that. They'll like that, they've done it before.

Taken together, these elements of Alex's lesson planning process demonstrate the combination of subject knowledge and pedagogy: the 'teachability' factor that is PCK.

Later in the planning, Alex's subject knowledge was challenged by an unexpected problem in the code he had been developing for the students' use.

[Alex] Yeah, this is really, really interesting now...You know what? They might not be able to concatenate this [long pause] we might have to do a print here, we might have to take out the concatenate there. This has really got me, it's a bit of a copout really...I don't think that will work...you see? What can we do here? Force a zero onto the end?

[long pause] Yeah, that's really got me. That's completely stumped me...I mean the only thing I can think of is this. if...balance...divide modulus...modulus 10 is equal to zero, i.e. if it divides by ten perfectly...this won't work either. No.

[pause] it has to check if the flow is...a tenth? That's not even correct is it? But I only need to see if it's a whole number...

<<searches programming reference website>>

[pause, reading from screen] How to check if a... whole number in Python...so we'd need to use 'is integer' dot is_integer, I didn't even ... so these are like functions which you've never heard of and never knew of...

The thing is, my students won't even know what this is. I mean, I've struggled to program this, so how are they going to do it?

Frustrated and unable to work out what the error was, Alex tried several different approaches of increasing difficulty and eventually turned to an online resource to find the answer. However, his concluding statement in the extract was telling: if he had struggled to program this, he had concerns that his students would also struggle. The emotional tone of Alex's session had changed as he wrestled with the program code and became disheartened.

Continuing to work on the code, Alex found a workaround solution and was relieved on a personal basis to have found a solution, but realised that it was beyond his students.

[Alex] 55...45 ...it worked! Or did it? [laughs] Uh, that's an integer, it worked fine. How about we do £22.22? Oh, my goodness, it worked. Crikey!

Right – so, this is, I suppose, the life of an ICT teacher with a Computing and Business degree converting to teach Computer Science.

So, the logic behind this is, you know that 'it worked' moment – I'm sure that's what students feel all the time. Now this is not really something which I want to students to look at, because where are they gonna find the error? They won't necessarily understand the code *per se*.

Despite the relatively specialist background in Computing, Alex identified himself in this extract as 'an ICT teacher with a Computing and Business degree converting to teach Computer Science'. His developing subject knowledge confidence had been knocked but his PCK had developed new nuances as he needed to rethink his lesson planning. Shulman asserted that the teacher's grasping of an idea to be taught was not a passive act: "the teacher's comprehension requires a vigorous interaction with the ideas" (Shulman, 1986, p. 13). Shulman pre-empted that teachers, especially novice teachers, would not always proceed from a secure comprehension: "some sort of comprehension (or self-conscious confusion, wonder, or ignorance) will always initiate teaching" (Shulman, 1986, p. 14). In the scenario explored by this study, formerly expert teachers had, to some extent, reverted to novice status, needing to relearn their subject knowledge as they continued to make the transition from ICT teachers to Computing teachers.

Alex had decided to plan from scratch inasmuch as he had no pre-existing lesson resource that could be used. Part of the issue arose from Alex attempting to push the boundaries of his own PCK by creating a set of tasks to address student misconceptions and spot errors in programming code rather than perhaps follow a tutorial with a predetermined pathway. As seen in the previous section, Alex had reached a stumbling point, and his immediate response had been to check online materials to develop his own understanding enough to be able to teach his students.

Alex started his planning for this section by reviewing a page from an online reference resource for learning the Python coding language (Figure 5.11, below).

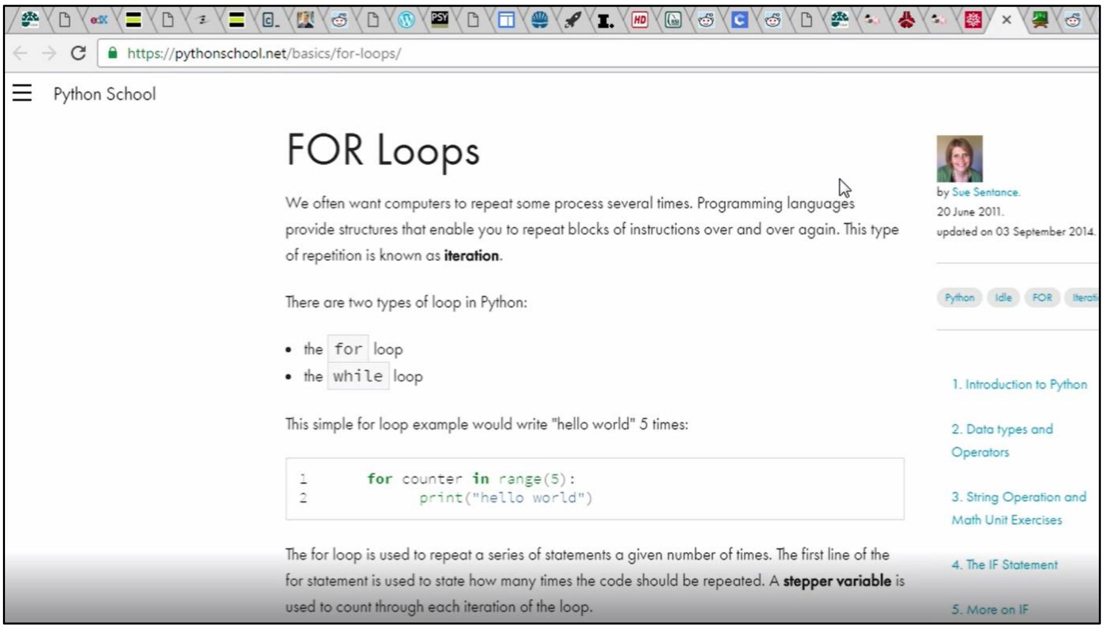

Figure 5.11: Screenshot of Python School resource page used in Alex's planning

The site, Python School, states that it "provides a way for existing ICT teachers to gain the knowledge and skills necessary to teach Computing and Computer Science in schools. The materials are designed to enable you to gain the experience necessary to teach Computing at Key Stage 3, GCSE and A-Level" (Sentance & McNicol, 2017). However, to be able to move beyond this minimum level, Alex had to locate resources to develop his programming knowledge.

In the extract below, Alex had forgotten the correct syntax for the code he was working on and moved to a reference resource to check it. He referred to locating a range of internet sources of support, such as Stack Overflow, an online community for developers to learn and share programming knowledge, and YouTube, where video solutions could be found.

[Alex] I've done this so many times that I never actually remember the syntax, so my go-to is the internet, Stack Overflow even...

Let's get this side by side… and I don't know, is this how real programmers program? I think they often do, because people do use Stack Overflow quite a lot. Unfortunately for GCSE Computer Science, the internet's banned – and I mean, I understand that, because most of the controlled assessments are on YouTube and Stack Overflow and loads of other forum websites, but at the same time, you know, when a student doesn't know how to format to two decimal places, should they really learn the syntax off by heart? Some of you might say, "Yes, they should learn it off by heart, like FOR loops, WHILE loops, IF statements, strings, dictionaries, lists."

But in reality, remembering the syntax, unless it's something you use every day, which it's not, I don't think it's that big a deal...

One thing that is evident from Alex's approach to planning is the wealth of sources of support that he had familiarised himself with. Beyond those explicitly mentioned, it was noticeable from sharing his desktop screen that having these sources immediately at hand was a key part of giving him confidence that he could articulate his approach to developing code in an authentic manner. Referring back to Figure 5.11, above, it is possible to see at the top of the screenshot that he had more than thirty browser window tabs open while he was working. He was not alone in this: participants Ben and Helen also discussed their multitasking, multi-tab style of working.

Another notable aspect of this excerpt is Alex's reflection on the pedagogy of programming [is this how real programmers program?]. Alex was actively working on his comprehension of the programming subject knowledge and moving into transforming that knowledge through the application of PCK, albeit tentatively. Alex started with a problem at the comprehension stage, sought resources to solve the problem and then transformed that learning for himself in the process of transforming it for his students. By engaging with a professional community of practice, he was able to follow their thinking and apply it to his planning. Having done the process for himself, he therefore gained a foothold on PCK, gaining experience which has the potential to make the process easier the next time.

5.4.1.3.2 GLENN: A 'QUALIFIED' ICT-TRAINED SECONDARY COMPUTING SPECIALIST

Initially, Glenn's planning had centred around updating a GCSE theory lesson, aimed towards the exam at the end of the course, about Boolean logic in terms of just simple gates, but during the course of the planning session, he mentioned another lesson he was planning, which went beyond the theory into practical application of Computing knowledge.

Glenn's approach to planning is an example of need-based planning at the lesson level, whereby he had already planned the curriculum in terms of the learning intentions in advance, and then needed to plan the lesson in detail to be able to deliver it to his class. In this, he took a similar approach to Ben, except that Glenn's planning in this session was targeted at the lesson level.

[Glenn] I personally tend to write quite detailed schemes, so because I've got a long-term plan that covers the whole year, the schemes are more detailed. So, on a lesson-by-lesson basis I've already kind of pre-decided what the learning intentions are going to be and then I generally will just tweak the content to fit the level of the students.

Being able to move swiftly from comprehension to transformation, Glenn's pre-planned learning intentions at the unit level facilitated him to begin operating at the adaptation stage of pedagogical reasoning, having already covered preparation, representation and instructional selection at the unit level of planning.

[Glenn] So, for my higher ability students it might be more extension activities and for the low ability students there might be more differentiation and support. I spend a lot of time creating tutorial videos for students, especially... that seems to be at both ends: I have a lot of videos for students who are struggling, and I also have quite a few extension videos, but I still rely on the main parts of the lessons with me demonstrating, because I think that way you can get instant feedback from students in terms of what they do or don't understand.

Moving a step further, Glenn then emphasised his grasp of tailoring content to his specific class and specific students:

[EH] What's your Year 9 class like?

[Glenn] The top set, more girls than boys – 17 girls, 15 boys. Big, I would say: 32. 32 in a class, 22 desktop computers, 10 laptops, which is challenging! They're very enthusiastic.

Personally, I think they've suffered from quite mediocre teaching probably in the last few years from non-specialists and not really been introduced to the Computing curriculum at all apart from they did one six-week project on Python last year, and they said straight away they hated it.

So, I'm surreptitiously trying to develop their programming skills without them knowing that they're doing programming and things like that. That's the plan anyway.

Glenn's point about surreptitiously developing the students' programming skills illustrated his PCK. His understanding of how to teach programming in this way, and his rationale for the subterfuge are key to the way he has transformed the curriculum intention into a teachable unit, harnessing subject-specific pedagogy.

Part of the reason for the apparently smooth and seamless progression through the process of pedagogical reasoning and transformation of knowledge was the extent of Glenn's subject knowledge. In this unit of work, Glenn has not had to work especially hard to access the subject knowledge in the way that Alex had to. Although the lessons are not directly comparable in that Alex was teaching text-based programming and Glenn was approaching it from the direction of the graphical user interface, they dealt with the same underlying principles of computation.

[EH] You were saying something about planning something for next week?

[Glenn] I'm being observed next week as part of my performance management, a lesson for Year 9 ICT, so they're set, so it's a top set group. They've been developing mobile apps using a website called AppShed. The aim of the mobile app is to support students in schools, so they have developed their own choice of features, things like most importantly, obviously, a lunch menu so they know what's for lunch every day!

They've also developed a school sports fixtures list and some of them have done team lists and things like that, so it's quite nice, and the actual observation's going to be on them developing a test strategy for their app.

[EH] Have they got something working yet or is it just in the planning stage?

[Glenn] They've used some open source wireframing software called Pencil to create a wireframe outline of their app and what they want it to look like, then they've used the AppShed app builder tool. It's a drag and drop interface to build a web app basically, a phone app for an Android platform.

So, they've built their drag and drop feature pages and they've built the navigation, and then we're going to develop a test strategy to test that next lesson.

Glenn's experience of web design and systems prior to training as a teacher had provided him with a strong base of real-world applications of Computing, demonstrated by the confidence with which he was able to explain the lesson sequence and the underpinning concepts. Also noteworthy was the significance of the next lesson in the sequence, which was due to be a lesson observation for performance management purposes.

Having already planned the sequence of learning at the curriculum level, Glenn chose to continue with the sequence rather than modify it for the purposes of the lesson observation. Glenn's confidence in the suitability of the lesson and his subject knowledge and skill in planning to teach that lesson rather than switching in a different lesson for the purpose of enhancing his lesson observation demonstrated the confidence he had in his own subject knowledge and PCK. The lesson teaching resources, a One Note™ document with links to a starter quiz, stimulating images for a starter, an open-ended question on why software needed to be tested, demonstration test plan table, evaluation and plenary tasks took up no more than two sides of A4. This meant that the bulk of the instruction phase was down to Glenn during the lesson. His knowledge of the class and how they would respond to the challenge mean that he was secure in his ability to teach an effective lesson, and confident that a non-specialist observer would also be able to follow the learning intentions.

In addition to the generic technological pedagogical resources for teaching (Microsoft One Note™, a multi-user program for collating information, and Socrative, an 'online formative assessment tool' ("Socrative.com," 2017)), in the test-plan lesson planned by Glenn, he also made use of AppShed, 'a free online app-creation tool where anyone can design and publish mobile apps' (AppShed Ltd., 2017) and Pencil, 'a free and open-source GUI prototyping tool' ("Evolution Solutions Co. Ltd," 2017). The physicality of the approach to teaching Computing with technological tools suggests a sense of competence and confidence born of the physicality of this approach. Mediating teaching and learning through technology requires sufficient PCK to promote the learning intentions through the use of technology.

As well as technology, Glenn made use of two kinds of resources in his lesson planning for this lesson: **bespoke lesson resources** and **gathered, unmodified resources**.

Bespoke lesson resources

The Microsoft One Note™ document (see example in Figure 5.12), designed to be accessed from the school network drive by the students during the lesson, was developed in part as a lesson-structuring tool as well as an instructional and presentational resource. Glenn created this from scratch to match the learning intentions of the lesson.

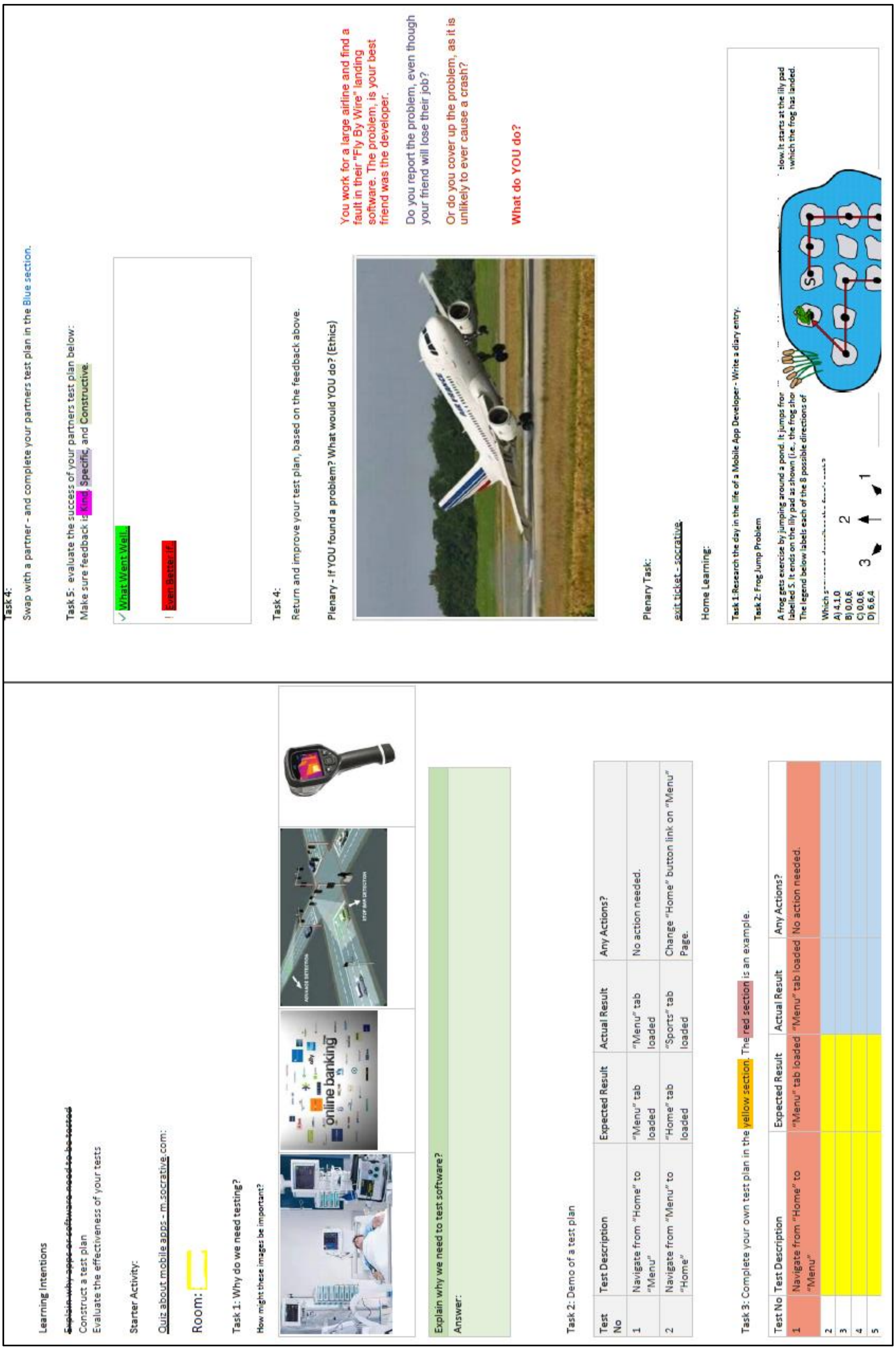

Figure 5.12: Bespoke lesson resource created by Glenn

Gathered, unmodified resources

Within the One Note™ document, Glenn gathered several images to use as stimulus material. By doing so, this demonstrated moving from the preparation phase of the pedagogical reasoning process into the representation phase, where his choice of images represents different ways that the wider implications of the concept of software testing could be envisaged. Although the images were publicly available, generic images, Glenn's subject knowledge and PCK determined that they would be suitable for the purpose. In addition, Glenn located a specific Computing teaching resource for homework, the frog jump activity, to encourage computational algorithmic thinking.

Glenn's approach to planning this lesson is a strong example of the confidence and competence stemming from good subject knowledge and good pedagogical knowledge. Unlike the examples from Ben and Alex, whose approaches had moments of uncertainty, being limited to some extent by Computing-specific subject knowledge and pedagogy, Glenn's approach showed a positive potential future for teachers in transition, when subject knowledge and PCK are stronger and allow them to operate at the expert rather than novice stage.

5.4.2 Planning using pre-prepared materials

5.4.2.1 External approach

The next five participants used pre-prepared materials and therefore worked from the middle of the process of transformation within the pedagogical reasoning process. They accepted that the process of preparation, representation and instructional selection had been partially completed, either by themselves or others. In this sense, in addition to using gathered, unmodified resources, they made use of another category of resources: **repurposed lesson resources**.

5.4.2.2 Curriculum intent at the unit level

5.4.2.2.1 DAVID: A 'QUALIFIED' ICT-TRAINED COMPUTER SCIENCE SPECIALIST

ICT Overview 2015-2016

Year Group	T1-1	T1-2	T2-1	T2-2	T3-1	T3-2
Reception	**Mouse Skills**		**Keyboard Skills**		**Art Work** - Introduction to Paint	**Introduction to Programming**
J1	**Creating Pictures** (Using Paint, Editing photo's, Rotating and Enlarging)	**Word Processing** (Finding keys on the keyboard, using the Shift key, typing stories)		**Giving Instruction** (Navigation using simple commands)	**Handling Data** (Tally Charts, Pictograms)	**Modelling** (Sorting and Grouping items, Labelling objects)
J2	**Creating Pictures** (Wood rubbing, Jackson Pollock, Mondrian, Fireworks, Famous buildings)	**Giving Instructions** (Coding using blocks, Sequencing, Looping using Repeat)	**Internet Research** (Navigating websites, Using a website to answer questions, Presenting information from the Internet, Collecting information from different websites)	**Handling Data** (Getting information from graphs, Creating a questionnaire, Gather information, Present collected information)	**Word Processing** (Using a Word Processor, Typing and editing, Using the Shift key, Writing and presenting a story)	**Animation** (Creating a stick man animation - including multiple characters)
J3	**Creating Pictures** (Mosaics, Stamps, Repeating patterns and rotation)	**Giving Instructions** (Coding using blocks, using angles to navigate mazes and make shapes), **Internet Safety**	**Word Processing** (Formatting text, Inserting images and formatting the wrapping, Spellcheck and Grammar check, Typing skills)	**Word Processing** (Combining text and images, Evaluation, Medieval Report)	**Databases** (Paper based database, Comparing paper and computer, Using information from a database, Updating information in a database, Searching and presenting information)	**Animation** (Creating a stick man animation - including multiple characters and a maze)
J4	**Creating Pictures** (Pointilism, Symmetrical images, Layering images)	**Giving Instructions** (Introductions to Control, Creating letters and shapes through block coding using Scratch)	**DTP** (Designing a newspaper article, using DTP software to create the article, Evaluation)	**3D Project** (Introduction to SketchUp, designing a keychain) Scratch (Creating a cartoon)	**Databases and Spreadsheets** (Introduction to Database basics, Searching a database, Creating a questionnaire, Collecting information, Presenting findings)	**Media** (Filming a short stop go animation film and editing, Evaluation)
J5	**Creating Pictures** (Using Paint tools, Creating images and then layering them (Patrick Caulfield), Comparing using two different graphics packages), **Modelling** (Introduction)	**Modelling** (Basic Formulae, Functions, Collecting information, Changing a model to suit needs, Creating Graphs), **Control** (Introduction)	**Control** (What sensors are, Robot Constructor activity, Introduction to Flowcharts)	**Databases** (Key Database Concepts, Data Dictionaries, Creating a table structure, Data Entry, Searching)	**Multimedia Group Project**(Create a story, Storyboarding, Creating interactive story using PowerPoint, Evaluation)	**Multimedia Group Project** (completion) **3D Project** (Introduction to SketchUp, designing a keychain)
J6	**Standard Ways of Working, Internet Research, Presenting Information** (Introduction, SOAP, Storyboarding, Creating the presentation)	**Presenting Information** (Finishing off presentation, Presenting the work, Evaluation), **Modelling** (Introduction)	**Modelling** (Recapping the basics of spreadsheets, Formulae, Functions, Graphs, Sorting and Searching, Formatting Cells, Test)	**Modelling** (Collecting data, Analysis of information, Presenting findings), **DTP** (Designing a comic)	**DTP** (Implementation of Design, Evaluation), **3D Project** (Introduction to SketchUp, designing an automata kit)	**Website Design** (Webpage basics, Programming in HTML5)

Figure 5.13: David's curriculum overview showing programming in each year group

Having trained as an ICT teacher at secondary level, David had moved into the primary and all-through sector. He brought a broad understanding of how the curriculum might develop across the full mandatory schooling range. His responsibility for the primary phase, and teaching in Key Stage 3 at the same school allowed him to develop his scheme of work from previously found or developed material and then adapt it to suit the current school and department that he was in.

David's curriculum overview, summarised on one page of A4 in Figure 5.13 above, traced a very clear path from the first half-term of Reception right through to the final half-term of Year 6. His key development following the 2014 change was to incorporate programming into each year of the curriculum, which could be tracked through his scheme of work and marking breakdown documents. Each line of the grid was underpinned by a series of assessment criteria assessing the pupils' work against a scale from beginning, approaching, meeting, exceeding and mastering expectations. David was able to outline the planning of programming right up to Year 9 in the senior school phase of his school, which was the extent of his teaching load. With this range of ability to consider, it was interesting to note that David did not create resources from scratch to address each year group's learning intentions. Instead, he had located a series of interactive websites and software applications to use with pupils. This is broadly similar to the way that Ben approached planning at the unit level. In the excerpt below, David explained that he tested out each one to make sure they were suitable to use.

[EH] Is there anywhere that you would go to look for stuff for planning a lesson?

[David] Not really. I'll just basically Google it and then I'll go test each and every one out.

This represented a significant investment of time and effort into trying the application, informally evaluating the PCK and pedagogical reasoning underpinning the teaching activities and building a module of work around it. In terms of PCK, David's Computing subject knowledge gave him the confidence to undertake this approach to planning, secure that he would be able to make a judgment in each case. The incorporation of the interactive resource can be considered as repurposed lesson resources because David selected activities he thought were useful and developed contextual lessons around them. His subject knowledge gave him the confidence to be able to repurpose the activities, rather than simply follow a tutorial. For someone with less established Computing PCK, it may have been tempting to delegate the PCK to the creator of the resources, absolving themselves of the need to fully understand the material they were working with.

For David, subject knowledge and programming skill was not an issue and he was able to highlight the development of programming knowledge and skills over time, demonstrating his assessment knowledge and how that might impact on his pedagogical reasoning process when planning curricula. Although both primary practitioners, this is somewhat different for Ben, whose background and role led him to take a more generalist approach. Ben incorporated programming into the plans, but suited to the curriculum topic, whereas David focused on the development of programming over time.

[David] But basically, I can see the progression of how it will go through because I've seen the old GCSE: they had to create an app using App Inventor and with them having already experienced how to do Java Script, they've done block programming which is that. They've learned how to do loops in Code Combat in Year 7 and again in Year 8 as well. I can see how that's going to benefit them.

With the Codecademy stuff and doing Java Script, you learn about variables, procedures, the FOR loops, the WHILE loops, conditional statements, etcetera, etcetera so it just builds them up nicely when they go.

As part of the document collection for this participant, David provided a list of thirteen coding and programming websites sorted into year groups, with explanatory notes for how they were used in his overall curriculum. It was clear that this curated list represented a significant attempt to draw upon subject-specific sources and resources to enable David to align his planning with the programmes of study by introducing a programming strand. It could be argued that his belief in the importance of IT and digital literacy was central to his reluctance to jettison parts of the curriculum in favour of extended time spent on programming and Computer Science. This controversial approach, taken by a participant with a strong background in Computer Science suggests that subject knowledge and PCK confidence and competence has allowed David to aim for a more balanced curriculum, where the IT and Computer Science strands of the Computing curriculum co-exist more easily. Part of the confidence in this case, however, is that David has followed the spirit of the curriculum change voluntarily. As a teacher in the private sector, he was not answerable to the same processes of accountability as the participants who worked in the maintained sector.

5.4.2.2.2 FAITH: A 'QUALIFIED' MATHS-TRAINED SECONDARY COMPUTING SPECIALIST

Faith's planning process occurred at the curriculum level. She developed her scheme of work and then gathered materials to support her vision for the development of Computing at her school. Faith's case was an example of a participant with significant background experience in Computing, whose pedagogical vision was firmly rooted in her beliefs about the subject area.

[Faith] It's very much to me a science. It's very much that there's a body of knowledge and skills that they develop and it's not about getting them to construct something in Scratch or getting them to construct something in Python.

It's about using the programming language to demonstrate that they understand the concept of something... teaching the concepts rather than them just thinking 'oh I can do it because I can program' and you know I think they could spend a whole year on Scratch and think they're amazing -

- and yet still not actually have come up with any real actual concepts or knowledge.

Although Faith's curriculum was structured around a central core of programming, for her it was a case of programming in its own right rather than using a particular programming environment or language to develop specific programs. Part of the explicit statement about her approach to programming exposed her opinion of an attitude often found with non-specialist teachers who are more focused on the outputs of programming than the inputs. That is to say that the product is emphasised at the expense of the inputs and processes of learning to develop a program, potentially because of a lack of knowledge, skill or sufficient experience with programming. For Faith, this approach could be seen in her scheme of work for Year 7 (Figure 5.14), where even introductory work with the Scratch programming environment was grouped around its use for developing selection, conditions, operators and variables, with no mention of the software's visual interface or multimedia affordances, which pupils usually find very engaging.

Year 7 all sets 2016 - 2017

Week	Topic	Lesson Objectives	Resources
22	Programming with Scratch	Students understand about the concept of Selection Students are able to use the IF - THEN block Students are able to use the IF - THEN - ELSE block Students are able to use sensing blocks that have built-in conditions	Projector Internet Workstations
23	Programming with Scratch	Students are able to use the operator blocks to create their own conditions Students are able to use compound operators (AND, OR, NOT) Students are able to use the control blocks to perform repetition Students understand the difference between a loop and the loop body Students understand the difference between a forever loop, counting loop (FOR loop) and conditional loop (WHILE loop)	Projector Internet Workstations
24	Programming with Scratch	Students are able to use a forever loop, counting loop (FOR loop) and conditional loop (WHILE loop) Students understand the difference between persitent memory and volatile memory Students understand what variables are and what they are used for Students are able to use predefined variables	
25	Programming with Scratch	Students understand the characteristics of a variable (name, value, contents change, related to sprite (local variable) or all sprites (global variable), shown or hidden) Students are able to create their own variables Students are able to use variable blocks for manipulating variables Students know how to get input from the user using the ask block	
26	Programming with Scratch	Students are able to add comments to their programs Students are able to use centralised code Students are able to carry out testing on their programs	

Figure 5.14: Faith's partial Year 7 programming scheme of work

Contrary to David's approach to teaching programming, which involved ensuring that the material allowed the pupil to access the concepts, Faith's approach was that the material needed to be worked through at a pace that ensured that pupils could all access sufficient knowledge and skill to continue their programming development. In discussion, this meant that pupils would evidence their progress using a workbook and exercise book. Year 8 pupils were expected to get further in the booklet than Year 7:

> **[Faith]** Hopefully, we're just starting further along in this booklet, [aiming] to get further and maybe actually give them some more independent programming... put them in a little project at the end... to get their teeth into...

Some of Faith's rationale behind this approach stemmed from the speed of the curriculum change and the perceived need to 'even up Key Stage 3' by providing all pupils with this core knowledge. Faith's very specific approach to Computer Science and programming as a set of knowledge and skills underpinned her PCK and pedagogical reasoning process. In terms of planning, she outlined the way that she began with the programmes of study and used those to shape the curriculum.

[Faith] I start with Key Stage 3 National Curriculum statement, which said that we needed to do this, this and this. And that's all...

...It's much more of a subject than ICT ever was.

Faith's confidence and competence with the subject knowledge allowed her to develop a curriculum that matched her beliefs in the nature of the subject. During the course of the planning session, Faith made the point that, for her, Computing was 'much more of a subject than ICT ever was', likening it to her experience of teaching Maths and shaping her approach to teaching. Faith's reflection harks back to Chapter Two, where the literature review around curriculum permitted the argument that the previously weakly classified subject of ICT had not merely been updated, but shifted to a different, and more strongly classified, discipline (Bernstein, 1971).

It in an interesting point to note that the PCK Faith developed from the teaching of Maths seems to have allowed a much easier crossover to teaching Computing than PCK developed from the teaching of ICT. Faith recognised that in her department, she was unusual in her subject knowledge, and while she would have liked to give pupils exposure to deeper programming experiences, her colleagues were far less confident:

[Faith] and so, while we would quite happily have them on two or three different languages, some [of the teachers] were quaking in their boots about doing Python. Some of them were quite wobbly about Scratch!

In this streamlined approach to planning a Computing curriculum, Faith had selected complementary resources, most often sourced from the CAS website. Significant use was made of a substantial pupil workbook for learning the Python programming language and a booklet covering some of the basic theory (see Figure 5.15, below). In addition, PowerPoint presentations about specific content, such as data types, were displayed on the interactive whiteboard so that pupils could access additional material to make notes in their exercise books.

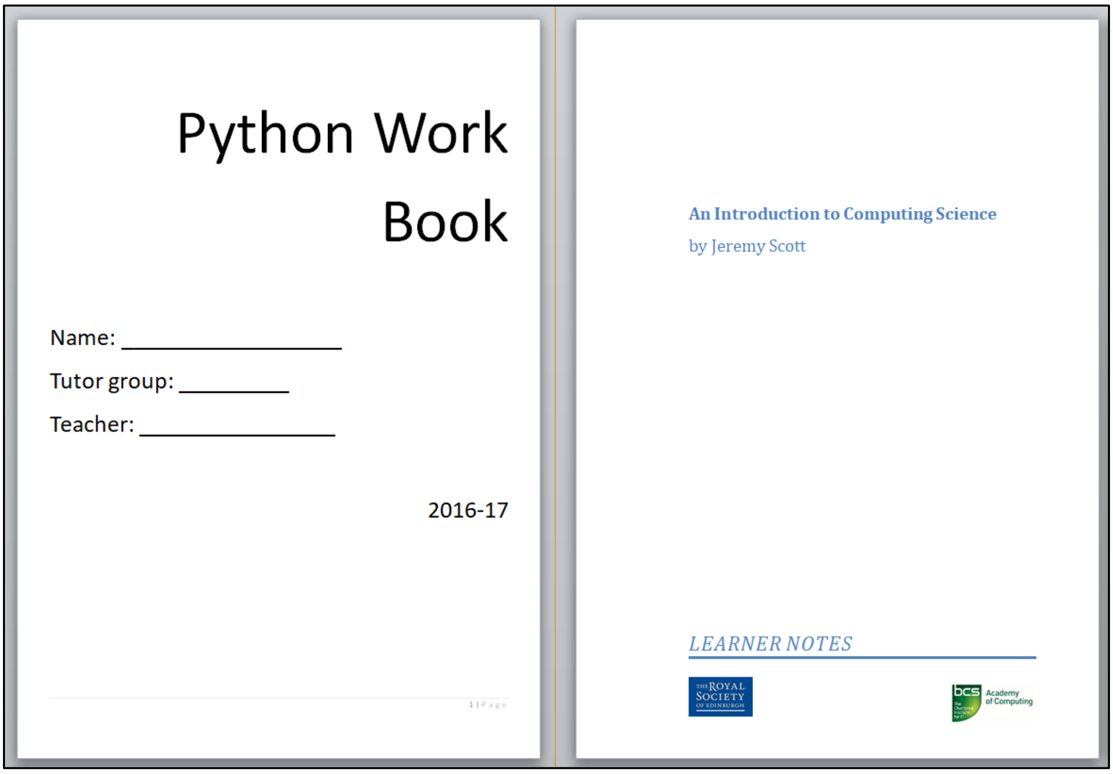

Figure 5.15: Faith's Python workbook and Computing Science learner notes booklet

Faith related her approach to resources back to her Maths teaching, where one textbook would cover the material for a year or a course, and could be supplemented with material from other textbooks, perhaps where more or better material was available, such as for extra practice on fractions.

In the following excerpt, Faith's personal pedagogical philosophy detailed her approach to the use of resources for teaching:

[Faith] You've got a body and it's up to you to dress it, but the body is all there for you - everything you need is in place and theoretically, to be honest, it will all work if you just use that body, but if you want to you can make the body look better by putting a coat on it or a hat or a whole outfit, depending.

But to me that's... that's what you do, which doesn't often mean I'm never happy with that - with the scheme of work...

In being the key person for planning the Computing curriculum in her department, Faith also reflected that, for reasons of limited time, or subject knowledge, other members of the department tended to not query the choices she made for the curriculum. She reflected that her subject knowledge had put her in the position of being the main authority in the department:

[Faith] The textbook knows best - I've almost become the textbook.

5.4.2.3 Need-based planning at the lesson level

The final group of teachers worked with pre-prepared materials during their planning sessions. These were either located through their attendance at CPD events or downloaded from websites the participants used when seeking resources. They also included websites that acted as teaching resources in their own right, such as those used by David. In Ellen's case, she worked with materials provided by her subject leader.

5.4.2.3.1 HELEN: A NON-SPECIALIST ICT-TRAINED TRANSITIONING ICT TEACHER

Helen had attended a CAS conference and seen a lesson on the topic of the Little Man Computer (LMC) being demonstrated and shared by another teacher (see Figure 5.16, below). She had slotted it into her curriculum to fill a perceived gap.

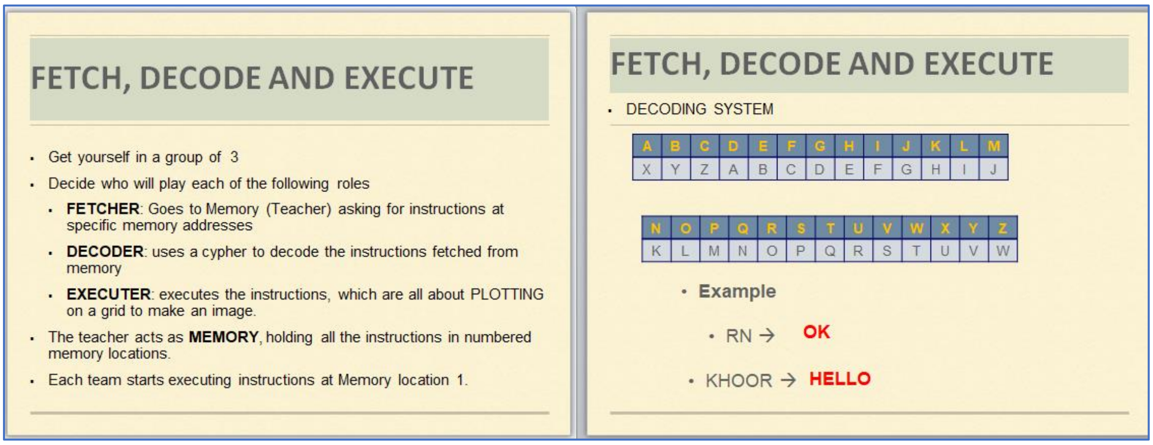

Figure 5.16: Helen's LMC Fetch-decode-execute unplugged lesson activity resource

Helen particularly liked the 'unplugged' style activity (Sentance & Csizmadia, 2017a) where pupils would role-play acting like the control unit of a computer's CPU (Central Processing Unit), fetching, decoding and executing instructions, competing against each other in teams.

[Helen] `So, we then took sections of the lesson out, we didn't necessarily teach it all. We taught the fetch decode execute cycle to all of the Year eights, nines, tens and elevens.`

`After that we got it. It was quite straightforward, so we thought we might as well teach all of it.`

Most noteworthy in Helen's transcript excerpt above is the comment that 'we got it'. The inference here is that this was an area of subject knowledge that Helen and her team had previously been lacking. Having seen the lesson demonstrated gave her the confidence to incorporate it into her curriculum, but it would seem that this had felt risky. Having tried out the lesson, she then understood the subject material and was confident to try other parts of the resource she had acquired. Like Faith, Helen felt that there was a specific body of Computing knowledge that pupils needed as a baseline. Moving on from the standard coverage of hardware, input and output devices, memory and storage, which Helen would have encountered when teaching GCSE ICT previously, this LMC lesson went into the mechanics of Computing and added curriculum depth.

Issues of confidence and competence have recurred throughout the participants' comments. Helen was frank when she outlined the challenges (and opportunities) faced when things did not go as expected in the lesson:

[Helen] So, you use different bits that can go wrong to a certain extent to explain different things, so we just make it up as we go along.

We put the kids to work and the kids accept that that was meant to happen and that was meant to happen. So yeah, it works really well, and I think they will remember it because they had to physically get out of their chair.

I mean particularly with the slow students, or who's not really involved, we talk about their [decimal place] may only be on one point, and children can come out from the back. We talk about how they must sit closer to the box and obviously we talk about this.

But we make it up, and they believe it by the time we finish.

[EH] As long as you sound confident, they're fine?

[Helen] Yeah, as long as we sound confident they are like yeah, yeah, right, okay. So, we only talk about things like they've got more RAM and they've got this and they've got that. We even talk about clock speed and them having a 2.2 gigahertz processor compared to when they have a 1 gigahertz processor, it can do two billion instructions compared to 1 billion instructions depending on how small they are. And the fact that they take 8 seconds compared to two billion that can be done in 7 seconds.

Evident from this excerpt is the extent to which this new lesson content challenged Helen's subject knowledge. She did not have all the answers to why the process might not work as intended, but was able to take basic Computing knowledge and use it to maintain the unplugged pedagogical strategy she was trialling. Pupils accepted the variations and the responses given because the teacher was confident with the lower-level subject knowledge. Throughout this activity, Helen was reliant on the PCK and pedagogical reasoning process of the teacher who had shared the lesson and resources with her. By engaging with the teachability of the material, she was also enhancing her own PCK and her own confidence.

Having trialled the lesson, Helen's emerging PCK allowed for reflection on the experience and for the new knowledge to be 'banked' for planning future lessons using the same resources.

[Helen] We didn't teach the whole thing. We just taught sections of it. So, the actual activity we set up in slightly different ways to try out how it would work in class...

But it's probably something I would go back to, rather than do it all in one go. And I wouldn't have taught this as a lesson, I would have taught this as a series of lessons.

So, I would then go back and give it to the set and someone else looking at Little Man can then go rematch that program and maybe use computer outlets and it wouldn't just be the flow charts and have separate instructions. As a separate lesson.

I will bring it back out ...I won't do it all in one go. I think especially with the fetch-decode-execute cycle is enough for one lesson. Took probably a fair amount of time in the lesson.

Evaluation and reflection are the final stages of Webb's adapted model of pedagogical reasoning, allowing a loop back to the start for the next planning instance. By engaging with the pre-prepared lesson, Helen had effectively worked through each phase of the process of pedagogical reasoning, condensed the preparation and representation stages of the transformation sub-process and considered the instructional selection, adaptation and tailoring for future lessons. Shulman saw reflection as “the processes through which a professional learns from experience” (Shulman, 1987), leading to new comprehension, “both of the purposes and of the subjects to be taught, and also of the students and of the processes of pedagogy themselves” (Shulman, 1987).

Helen had adopted an expansive approach to gathering resources to complement her planning. She saw her approach as very much guided by a paid-for skeleton syllabus and resources at Key Stage 3, mapped onto the expectations of the exam syllabus followed in Key Stage 4 and then filled in with other resources. Helen explained that she got a lot of resources from CAS:

[Helen] I get a lot of resources from [CAS]. I don’t necessarily upload a lot of resources - I’m more of a receiver than a donator.

Some stuff I can use without too much effort: other things are just good as an idea, as a starting point and I think that obviously, the main place I get a lot of my things from are other teachers.

We’ve bought stuff in before and I’m not saying that I necessarily would have bought some of the resources in that they have bought in before. We do have some bought-in resources, but they tend to be very expensive and not necessarily what you want. They’re not like an off the shelf, ready to use system.

[Helen] There are some people who kindly share theirs at not a massive profit... So, if I'm looking for resources, they have some really good resources and then we do buy stuff in. And if we feel that it's a benefit.

Because there is a lot of stuff that you're having to prepare, or you would be if you couldn't get access to other things.

One more, hitherto hidden, impact of the curriculum change has been the resource void that needed to be filled in order for teachers to be able to teach the Programme of Study without creating every resource from scratch. Even with the existence of commercial systems (often expensive) Helen made the point that they were not the answer, a comment borne of wider experience and expertise. Key to her choices for sourcing new resources were the criteria of ease of use, new ideas for developing existing plans and materials, and the opportunity to use resources that other teachers had developed, for which she was willing to allocate departmental funding.

CAS provides a categorised and searchable repository, with a stated 4346 resources (as of 10/12/2017), all freely downloadable. There is an expectation that this is a two-way process, with people sharing as well as downloading, and commenting or reviewing after using a downloaded resource in order to share their knowledge. However, a brief review of a selected number of resources suggests that comments tend to veer more towards expressions of gratitude than the sharing of pedagogical insights. Nonetheless, as Helen highlighted, her experience in teaching enabled her to try things out and make those kinds of judgments. Unlike Faith, whose confidence with the underlying curriculum meant that she was prepared to teach from the skeleton curriculum and either fill in her resources from standard materials or do without, Helen's continuing learning curve meant that she continued to seek out new materials to fill in gaps in her curriculum, and her subject knowledge.

Without a degree background in Computing, or appropriate industry experience, Helen's comment (made in 2016) that "there is a lot of stuff to prepare" is ironic, given the point made in Michael Gove's 2012 speech: "and beyond the new, slimmed down National Curriculum, we need to consider how we can take a wiki, collaborative approach to developing new curriculum materials" (DfE, 2012). Firstly, the speech offered a slimmed down curriculum that brought in an extensive and ever-changing discipline, which was unfamiliar to the majority of teachers expected to teach it. Secondly, by down-playing the need for curriculum materials to be developed it also down-played the demands on teacher time and professional learning that this 'collaborative' enterprise would take – to understand the curriculum and then to resource it. The Royal Society *Reboot* report highlighted and praised that so much had been achieved on this front by enthusiastic volunteers, but called for a tenfold increase in funding for the overall effort (Royal Society, 2017).

5.4.2.3.2 IAN: A NON-SPECIALIST SCIENCE-TRAINED TRANSITIONING ICT TEACHER

Ian's approach to planning under the new curriculum had been to map the old and new curricula and maintain topics that appeared in both. Correctly anticipating the direction of the change, he had already implemented some programming in Key Stage 3 before it became compulsory, so the initial change at Key Stage 3 has seemed manageable. What Ian had not anticipated was the amount of change that would ensue in the Key Stage 4 qualification specifications, as exam boards attempted to keep up with curriculum changes as well as with government-driven changes to qualifications and assessment.

[Ian] It has been a constant process for the last four or five years. We have never taught the same thing to two year groups in a row, so we're constantly adapting and changing and adding new units and removing units and stuff like that.

We don't get any consistency in what we're doing because we never get to reuse it, and then we never reuse it in the same way because we're reusing it in a slightly different context each time.

We don't really get the chance to develop things as much as we would like to, maybe, so there's bits and pieces like that are frustrating, I would say.

In addition to the scrappage of GCSE and A-Level qualifications in ICT and changes to remaining qualifications, an annual frustration amongst teachers of Computing has been whether and which qualifications in their subject area have been included in the school performance tables, often finding out that qualifications had not been approved until the new school year was about to start (DFE, 2017).

Ian had shared his frustration with the constant changing of qualification specifications in the wake of the change from ICT to Computing. These were a challenge to his subject knowledge and a perceived limiting factor. Responding to the pressure to keep up with the changes meant that Ian felt that neither the curriculum, nor his subject knowledge had the opportunity to progress.

[Ian] So, we're spending all of our development time working on things like that and not actually on the curriculum itself.

With the GCE Computing becoming as hard as it is now there's no way I can go and teach Computer Science at a school that teaches Key Stage 5: it's just beyond me now.

From the excerpt above, Ian's stark comment that, as a non-specialist, the Key Stage 5 curriculum was 'beyond him now' highlights the subject knowledge gap: one of the biggest problems stemming from non-specialist attempting to learn Computer Science on the job, from the bottom up. Teachers usually consider that their degree-level knowledge and skills are utilised most effectively in Sixth Form teaching – they have students who have opted to specialise in the subject, they are able to bring their degree learning into the classroom and share wider insights and a passion for the subject. For Ian, and non-specialist teachers in transition, this is not, and may never be the case without significant time to develop the advanced subject knowledge needed to teach a subject at A Level.

Ian had shared his planning of a lesson on logic gates developed using a bricolage approach, bringing together resources from several sources.

[Ian] So, I found probably about 4 or 5 different things on [Provider C website] that I was looking at - there was a Star Wars lesson plan, a Star Trek one, the one that I based most of my work off: the boyfriend/girlfriend choosing one and there was something else.

And I took that, and I looked at the puzzle they used towards the end, where some of those were taken from a revision resource and then the really complicated one was taken from an end of topic test for logic gates about the outcome of this more complicated system.

Ian was clear about the objective of the lesson and what he wanted to achieve from a curriculum perspective, but more interesting is that, like Helen, he was able to use his pedagogical knowledge gained from his previous teaching experience to think about the lesson and the pupils as much as the subject content. In the following excerpt, Ian was thinking through how to piece the materials together in a coherent way – he had entered the transformation stage of the process of pedagogical reasoning and was thinking about the teachability of the concept, the preparation of the material, alternative ways to represent the core learning points and his options for different teaching strategies. He was able to do this by bringing prior pedagogical knowledge to bear:

[Ian] The next lesson is going to be logic tables and move away from the gates and the symbols and stuff like that. We need to get to that end point within one lesson and I just can't work out how to make it engaging to the pupils. Having lots of short simple ones to start with and opportunities to get pupils to try them on paper, quiz them about their progress and find out about where they got to and get everybody contributing, is the aim of the first, simpler puzzles.

And then giving them the challenge question at the end to see where they'd got to... but the start of it: how do I get the kids to engage with the key words AND, OR and NOT? What can I do to make them think about it? You know - asking people to do things in the past and if you've got brown eyes stand up and if you've not got brown eyes stand up, things like that... yeah, the kids do them, but do they actually have to think about them? They can just stand up, sit down – whatever - they'll just do it.

Ian was wrestling with the very crux of the pedagogical content knowledge issue: ensuring a link from a lesson activity to deeper understanding and learning. This perhaps, is another point for the transitioning teacher: where in the ICT curriculum, the teacher might have been able to engage in pedagogic metaphor (Woollard, 2005) and tell a wider story to bring the learning point alive, in this instance Ian was limited in his repertoire, struggling with how to teach effectively, once again an example of a teacher reduced to novice status, but in the strangely insightful position of knowing what was is they didn't know.

In the process of making the transition from ICT to Computing, Ian's PCK had been developing in key areas. Having developed his own skills with the Python programming language, his understanding of programming pedagogy and PCK was evident from a discussion about the next lesson he was planning to teach in which FOR loops would be covered:

[Ian] I'm teaching some Python tomorrow and we're trying to do FOR loops... we did IF statements before the holidays and the class I had today proved that they didn't remember anything about IF statements, so I've got a debugging activity - it's got an example of an IF statement in it which hopefully will then stay on the desk and prompt them back to the syntax of the IF statement.

Today we tried to build the IF statement first and then put it in to make something happen, which just didn't happen, so tomorrow we're going to try a FOR loop that does counters, something like that. And once we've done that, we'll look at putting the IF statement inside and hopefully the pupils do the IF statements themselves afterwards instead.

We're just changing around the order [to] see if that suits the pupils better. I've done it both ways in the past and it's worked both ways in the past but it's just which one works for which classes, so that's what we will find out tomorrow.

In an effort to ensure that pupils had the maximum opportunity to develop their understanding, Ian, like Helen earlier, was prepared to take risks to push the boundaries of his PCK by trialling different approaches in order to maximise his transformative knowledge. In this situation, Ian was not coming fresh to the teaching of programming: he had previous knowledge to build on, some confidence based on prior attempts and a willingness to develop that knowledge further.

When queried on his approach to using resources for the lesson to which he had referred, it was clear that his programming PCK had begun to consolidate to the point at which he was confident that his approach to teaching programming worked well. He was able, like Alex before him, to dig into the deeper learning needs of the pupils with which he was working, and make pedagogical decisions based on their characteristics:

[Ian] I'm literally going to demonstrate the Python at the front and try to show them the steps.

I kind of like doing the Python coding live, because it's good to show them making mistakes and having the code not working and it gets them more engaged then just working from a worksheet and just copying something, so it's something to work from.

So, seeing how people make mistakes and seeing how people deal with mistakes - that could be part of learning to debug their own work and learning not to get frustrated about it.

This was further evidence of Ian's development as a teacher of Computing. His identification of ideas, values and beliefs about teaching programming point towards transitioning teachers being able, with effort and determination, to become successful in some aspects of the new curriculum, providing a foundation for further improvements. Whether or not this is enough to be able to offset the degree-level knowledge deficit without significant additional opportunities for CPD is a theme to be discussed in the concluding chapter.

5.4.2.3.3 ELLEN: A BUSINESS-TRAINED NON-SPECIALIST TEACHING SOME COMPUTING

The case of Ellen presents one of the most difficult scenarios. As in many schools, Ellen was a non-specialist teacher of ICT, timetabled to teach a few periods of Computing, thereby filling a gap in the Computing department timetable. Her background was in Business Studies and the bulk of her teaching load was in Business Studies and Health and Social Care in addition to her role as the school's vocational coordinator. Teaching Computing post-2014, she had seven timetabled Key Stage 3 lessons per week, a mixture of middle and bottom sets: three classes of Year 7 pupils, one of Year 8 and three of Year 9. In practical terms, this amounted to three different additional schemes of work that Ellen needed to be familiar with, alongside her work in the other departments.

Ellen was not responsible for planning the schemes of work and was not a specialist in the area, meaning that for her, every unit and every lesson had to be approached from the perspective of using materials developed by someone else, making her wholly reliant on the curriculum leader for direction and support. A similar example of this curriculum leader role was explored in the cases of Faith and Ellen, earlier. For Ellen, she had to operate in a continual state of uncertainty, trusting in her curriculum leader and being willing to spend additional time beyond her timetabled allocation in order to develop her knowledge and skills sufficiently to be able to teach Computing.

The complexity of this situation became evident when Ellen mentioned a unit of work using physical computing devices in her department. Lacking the subject knowledge needed for linking the physical computing devices into the curriculum meant she realised that in order to teach the next lesson, she was going to have to get support from her head of department.

[Ellen] We do quite a lot with Raspberry Pis – I haven't done them with my class yet, but I know that [Joe] has got that planned for the next unit: he's got a whole class set that he had before everyone else...

[EH] And that’s how it works for you: [Joe] brings them in and figures it out and puts it together? And then what happens? Does he train the department how to do those things?

[Ellen] Yes. Last year it was more like he had time to show everybody else how to do it, but this year it’s more like you get as much support as you ask for, so I’ve been really busy, so after Christmas I do plan sitting down with him every week and going through all the new stuff.

I’ve been lucky because [so far] it’s stuff I’ve already done, but then after Christmas he’s got all sorts - the logic gate stuff - I know it’s about the Raspberry Pis, just stuff that he does with his tutor group or his GCSE classes and we're going to have to cascade that down, so I need to sit with him and go through it.

[EH] Will he be able to come in and help out with one or two sessions?

[Ellen] Yes, sometimes I'll watch him teach it first if I'm really not sure with it - if I’m free and it does work out that I’m free when he teaches the class for the first time, I’ll go and support and then if he’s free when I teach and he'll come in and help us out.

A far from ideal situation, but a relatively familiar one, it seemed that this was likely to become even more demanding in the next academic year. Then, the plan was for Year 9 pupils to begin accessing the GCSE Computing curriculum because the scrapping of the ICT GCSE meant that pupils could no longer be organised into those who might access ICT and those who would access Computing at Key Stage 4. In effect, this would take Ellen to the beginning of the phase experienced by Ian as his various courses changed and GCSE Computing became the default qualification driving the curriculum.

Ellen's capacity to develop strong Computing PCK was hindered in such a difficult situation. She thought that her flexibility from picking up new things in teaching ICT because of the constant changes gave her the flexibility to approach teaching Computing. She felt that she had, however, changed the way that she taught:

[Ellen] I think it's all about encouraging kids to be more independent... rather than make a poster and then marking it and improve on it - working things out for themselves.

And some kids have really picked that up and some kids are just like "how do I it, how do I do it" and I'm like "try and figure it out for yourself" and encouraging them [to] get it wrong and fix it for themselves.

Ellen's perspective on encouraging pupil independence highlights one of the criticisms levelled at the old ICT curriculum. The difficulty post-2014 for non-specialists has been that this perspective also typifies the results of the lack of strategy for teachers' upskilling: teachers needing to independently figure out the Computing curriculum for themselves. Ultimately, like Ellen's pupils, some teachers have really picked that up and some teachers have not.

In terms of Ellen's planning, the school structures have meant that her planning was always needs-based at the lesson level, using pre-prepared materials:

[Ellen] [Joe] does a long-term plan for the whole year, and then he breaks it down into units and every unit has a medium-term plan and he breaks it down into lessons in the folder and there's resources in there, so we are so lucky because we get given activities and homework, reviews and help sheets, PowerPoints, videos: it's all there.

Ellen's pedagogical skill in this scenario was in the mediation of structure and materials she had been presented with. She had the responsibility for adapting and tailoring the lesson and the materials for the pupils, and thereby developing her PCK as she worked through each lesson and each unit, but with minimal freedom and autonomy to deviate from the plan. It is arguable that Ellen had the furthest distance to travel in terms of subject and pedagogical knowledge, but it is clear that she also had a very heavy burden, despite the enthusiasm and willingness evident in her description of her practice. A final point to end this presentation of findings is that, for some teachers, the struggle of making the transition from teaching ICT to teaching Computing was simply too much. It is notable that of the nine participants in this study, one (Claire) had already left the classroom, leaving just eight participants.

5.5 Chapter discussion

This section begins with a presentation of Table 5.3, below: a summary of the thematic findings from the planning phase of the study. The table serves as a reference point for the findings in relation to the sub-questions for Research Question Two and for interpretations made from the data in the conclusions chapter. The headings of the table relate to each of the sub-questions: PCK in the process of pedagogical reasoning, how subject knowledge is addressed, and the use of resources. The themes interpreted from the actions, comments and outputs of each participant during the planning undertaken for the current study are presented so that each individual case can be contextualised before moving to cross-case analysis.

The chapter discussion then moves to the cross-case synthesis of each of the three sub-questions before drawing together the overall discussion of Research Question Two in light of developments in the recent literature.

Table 5.3: Summary of thematic findings from planning

Participant	Research sub-question	Findings
Alex: a 'qualified' ICT-trained Computing specialist	**PCK in pedagogical reasoning**	• Teaching style had changed • Informed by own transitions between subjects and key stages • Intention to address pupil misconceptions • Worked dynamically with stages of pedagogical reasoning • Clear process (fig 28) • Focus on adaptation and tailoring • Existing pedagogy applied to new content • Active engagement with comprehension stage • Promoted rote learning of syntax despite contrary beliefs
	Subject Knowledge	• Degree level knowledge; needed refresh and further development • Confident • Used knowledge from training session to develop programming challenges • Taught himself the programming approach first before trying with pupils • Subject knowledge stretched with complexity of programming challenge • Expert becomes novice
	Use of resources	• Online resources for developing subject knowledge • Programming tutorials and forum • 30+ windows open • Multiple sources
Ben: a non-specialist, generalist primary Computing specialist	**PCK in pedagogical reasoning**	• Used to teaching multiple subjects as a primary practitioner • Clear process of planning taking a multi-strand approach (Figure 5.5 on p. 145) • Chronological process (Figure 5.6 on p. 147) showed accessing of different knowledge bases (assessment, curriculum, pedagogy, knowledge of students) • Moved smoothly from comprehension stage to transformation • Struggled within preparation stage: best-fit approach • Worked dynamically with stages of Pedagogical Reasoning • PCK belief that nobody teaches the same way twice
	Subject Knowledge	• Good pre-University knowledge base • Personal enthusiasm and confidence • Supportive of Critical Thinking • Doubt about interpretation of Critical Thinking concepts: CAS Critical Thinking planning framework not used

Participant	Research sub-question	Findings
	Use of resources	• Created materials for use in lessons • Sourced general resources from internet, YouTube etc. • PCK used to interpret suitability of gathered resources • Development of class blog, which then became a teaching resource • Had reduced the amount of resources prepared for efficiency and to decrease pupil passivity and reliance on visuals • PCK used to interpret suitability of online resources and those accessed during CPD
Claire: a 'qualified' post-16 Computing specialist	**PCK in pedagogical reasoning**	n/a
	Subject Knowledge	• Undergraduate and postgraduate qualifications; specialist area • No longer teaching in schools
	Use of resources	n/a
David: a 'qualified' ICT-trained Computer Science specialist	**PCK in pedagogical reasoning**	• Had made multiple transitions himself e.g. secondary to primary, maintained to private • Assessment knowledge accessed for planning – plans for progression • Belief in the importance of IT and digital literacy meant that these strands given suitable weighting
	Subject Knowledge	• Degree level knowledge • Allowed development of spiral curriculum for programming • Confidence in SK allowed planning and resource evaluation
	Use of resources	• Repurposed lesson resources • Interactive websites - PCK used to interpret suitability – repurposed to suit pupils • Multiple sources
Ellen: a Business-trained non-specialist teaching some Computing	**PCK in pedagogical reasoning**	• Teacher of multiple subjects • Now teaching resilience • PCK belief that nobody teaches the same way twice • Dependency on PCK of subject leader as expressed in planning documents • Slow development of PCK • Pedagogical skill in the mediation of structure and materials • Focus on adaptation for students
	Subject Knowledge	• IT strand in PGCE • Already non-specialist pre-2014. • Dependency on subject knowledge of subject leader

Participant	Research sub-question	Findings
		• Struggle to work with next topic
	Use of resources	• Every lesson prepared and resourced by others • Repurposed lesson resources as mediated through subject leader's perspective
Faith: a 'qualified' Maths-trained secondary Computing specialist	**PCK in pedagogical reasoning**	• Teacher of multiple subjects • Planned at curriculum level • Beliefs from content knowledge drove planning: body of knowledge and skills to be learnt • PCK of underlying concepts
	Subject Knowledge	• Good pre-University base and modules in undergraduate degree. • Strong subject knowledge and beliefs informed planning and resourcing • PCK used to interpret resource suitability
	Use of resources	• Repurposed lesson resources to match planned curriculum and core vision • High expectations that resource needed to match vision • PCK used to interpret suitability • Multiple sources
Glenn: a vocational-route 'qualified' ICT-trained secondary Computing specialist	**PCK in pedagogical reasoning**	• Moved swiftly from comprehension to transformation • Operated at the adaptation stage of pedagogical reasoning, having already covered preparation, representation and instructional selection at the unit level of planning. • Knowledge of students informed planning process • Strong subject knowledge leading to confident PCK
	Subject Knowledge	• Undergraduate subject knowledge and industry experience • Competent with programming languages • Strong subject knowledge allowed for broader intentions around developing pupils' programming skills: confidence in own ability to do so • Positive potential when subject knowledge and PCK are more equally aligned – expert stage • Strong subject knowledge allowed for agile development of lesson – juggling of concepts
	Use of resources	• Resourcing to flesh out pre-planned yearly plan • Updating prior lessons • Developing new lessons based on industry experience • Differentiated resources: videos for weaker students • Modelling as a resource • Bespoke lesson resources and gathered, unmodified resources used • PCK used to interpret suitability of gathered resources

Participant	Research sub-question	Findings
		• Multiple sources
Helen: a non-specialist ICT-trained transitioning ICT teacher	**PCK in pedagogical reasoning**	• PCK belief that nobody teaches the same way twice • PCK used to, and developed by interpreting resource suitability • Unplugged style developing PCK • Prior experience gave confidence to take pedagogical risks • Engaging with the PCK of the material enhanced own PCK and confidence. • Evaluation and reflection key to PCK development • Engaging with pre-prepared lesson allowed for working through each phase of process pedagogical reasoning process
	Subject Knowledge	• IT background only. IT PGCE. Upskilling as much as possible • New lesson content challenged subject knowledge • Trying new approaches from resources gave confidence
	Use of resources	• Repurposed lesson resources sourced through CPD • Resources to fill gap • Reliant on the PCK and pedagogical reasoning process of the teacher who had shared the lesson and resources • PCK used to interpret suitability of gathered resources • Expansive gathering of resources informed by knowledge of assessment • Time issue • Multiple sources
Ian: a non-specialist Science-trained transitioning ICT teacher	**PCK in pedagogical reasoning**	• Teacher of multiple subjects • PCK belief that nobody teaches the same way twice • PCK used to, and developed by interpreting resource suitability • Curriculum knowledge used to map and retain matching topics • Bricolage approach • Engaging with the PCK of the material enhanced own PCK and confidence. • Prior experience informed PCK • Focus on transformation and PCK • Willing to take risks by trying out different techniques and reflecting on what worked, and with whom.
	Subject Knowledge	• IT background, gained while teaching vocational IT • Enthusiastic about programming; lacked broader and deeper knowledge • Constant change in assessment a challenge to subject knowledge: limiting factor

Participant	Research sub-question	Findings
		• Expert becomes novice • Developing programming knowledge leading to developing programming pedagogy
	Use of resources	• Repurposed lesson resources • Multiple sources brought together – compared, discarded, developed to suit objectives • PCK used to interpret suitability of gathered resources • Modelling as a resource

5.6 Findings: PCK enactment through pedagogical reasoning

Summarising from the direct quotations from participants and the table above, what follows is a precis of the current study's participants' practices. For each of the participants, planning lessons followed a clear and logical process, whether they were responsible for planning of the whole Computing curriculum for their phase (Alex, Ben, David, Faith, Glenn, Helen), jointly with others (Ian) or not at all (Ellen). The processes were observable and could be represented visually (as with the examples for Ben and Alex) as research suggests that the functions and components of PCK and pedagogical reasoning are widely operationalized (Alonzo et al., 2012; Ohrndorf & Schubert, 2013; Webb & Cox, 2004). That is not to say that the process was linear or straightforward, as it was often messy, but dynamic (Ben, Alex), in line with Webb (2012), recognising that nobody teaches the same way twice (Alex, Ben, Ian), accommodating ongoing and idiosyncratic development of PCK (Loughran et al., 2004; Mulhall et al., 2003). The literature provided a strong indication that lesson planning activities were fertile ground for evidencing and developing PCK (Aydin et al., 2015), especially when ensuring that the full process of pedagogical reasoning is carried through from initial planning to reflection (De Jong & Van Driel, 2004).

Depending on whether planning during the current study occurred at the unit level (Ben, David, Faith) or the lesson level (Alex, Glenn, Helen, Ian, Ellen), there was a clear sense of planning involving developmental processes within processes, in line with research findings that this develops teacher confidence (Nilsson & Loughran, 2012), teacher efficacy and professionalism (Park & Oliver, 2008). Strong beliefs about the nature of Computing as a body of knowledge (Faith), about the need to develop programming skills (David, Ian) and to incorporate real-world understanding (Glenn) influenced the way that participants approached their planning, as recognised by Hubwieser, Mühling, Magenheim and Ruf

(2013) in relation to developing PCK in Computer Science teachers. Participants made use of multiple sources of knowledge and material to inform their professional knowledge bases, such as curriculum knowledge (Ben), assessment knowledge (Ben, Ian) and knowledge gained from professional development activities (Alex, Helen), all aspects germane to enhancing PCK (Loughran et al., 2001; Shulman, 1987).

The stages and processes of pedagogical reasoning were evidenced across the full complement of participants, covering examples of comprehension (Alex), reflection and evaluation about instruction and assessment (Helen, Ian, Alex) in line with Webb's (2002) model, often leading to participants questioning themselves and their approaches during and after the planning process (Alex, Ian, Helen, Ellen) thereby demonstrating reflection-in-action and reflection-on-action as discussed by Park and Oliver (2008) and Griffin (2003) as essential attributes for developing PCK. Within the process of transformation (Shulman, 1987), where participants' PCK works to develop the teachability of the lesson content, participants' planning processes demonstrated preparation (Ben, Alex), representation (Ben, Alex, Glenn, Ian), instructional selection (Ben, Alex, David, Glenn, Helen, Ian), adaptation and tailoring to the needs of the students (Alex, Glenn, Helen) based on knowledge of students generally (Ian, Helen) and their own students, specifically (Alex, Glenn, Ben, Ellen). Efforts were consciously made to address misconceptions (Alex) and develop programming pedagogy (Alex, Faith, Ian), both key themes in the contemporary literature relating to developing pedagogy post-2014 (Qian & Lehman, 2017; Sentance & Waite, 2017).

In each participant case, their prior knowledge, general pedagogy and teaching experience was useful as evidenced in previous studies relating to experienced teachers' PCK (Lee & Luft, 2008; Loughran et al., 2001), in terms of taking experience from other subjects (Faith), and industry experience (Glenn) and exhibiting coping strategies (Ellen, Helen, Alex) through the struggle for new professional knowledge and skills in a similar way to novice teachers described by Appleton (2008). It is clear that mixing and matching resources in planning contributes to developing new and better PCK (Alex, Ian, Ben, Ellen) even when a teacher is reliant on the subject knowledge and PCK of the person who created the resources (Helen, Ellen), a theme which is evidenced very strongly in the case study schools reviewed for the Royal Society *Reboot* report (Pye Tait Consulting, 2017a).

As a final summary for this sub-section, the individual participants' approaches to planning are condensed in Table 5.3: Summary of thematic findings from planning on page 188.

5.7 Findings: Computing subject knowledge when planning lessons

Participants came to the study with subject knowledge ranging from undergraduate studies (Alex, Faith, David) and industry experience (Glenn) to knowledge initially more suited to the primary phase (Ben) or ICT curriculum (Ellen, Helen, Ian). Whilst some required minimal knowledge enhancement (Glenn, Faith, David, Alex), some actively sought it out (Alex, Helen, Ben), despite the difficulties of doing so, or wished that they had time (Ian) or the scope to upskill further (Ellen). The variety of teacher backgrounds, qualifications, confidence and access to continuing professional development was a key theme discussed in the Royal Society *Reboot* report, based on almost one thousand teachers' responses (Pye Tait Consulting, 2017a).

Some participants felt comfortable with their level of subject knowledge (Ben, Glenn, David, Faith, Alex) but some recognised that this was an ever-changing situation (Ian, Helen, Ellen) that may well result in them having reached their capacity at the current time (Ian, Ellen). These struggles were observed in the practice of participants Glenn, Faith and David, and to some extent initially with Alex and Ben. Their behaviours and comments indicated that they were able to think about aspects of the process, such as the teachability of the subject content they were working with in terms that could be mapped to PCK. The process seemed to stutter somewhat with Alex and Ben, when they reached points in their subject knowledge that were just beyond their comprehension, slowing down the process at the preparation stage as they attempted to either address the issue directly (Alex) or ignore it (Ben). Alex could not move forward until he had solved the programming challenge for himself, and therefore seemed to work slowly through the preparation and representation stages but with comments that suggested that in theoretical terms, he was developing his PCK at the same time. Ben opted to ignore his discomfort with applying the Computational Thinking concepts to his planning, but rather than slow the process, he simply moved on from the area of difficulty, judging the planning to be good enough as it was. In contrast, Helen attempted to address an area of difficulty by working with the pre-prepared materials from another teacher, repeating the lesson until she felt competent with it, and able to take ownership of it by suggesting future strategies which I have interpreted as adaptation and tailoring. These three participants displayed different kinds of coping strategies to address deficits in their subject knowledge and PCK.

For some, the subject knowledge struggles were evidence of the desire for ever-deeper knowledge (Alex, Helen, Ben) and indicative of personal values and deep emotions in relation to professional identity (Alex, Helen, Ian, Faith, Ellen), a point recognised by the Computing at School working group as the new curriculum was being introduced (Brown, Sentance, Crick, & Humphreys, 2014). For most of those who were comfortable with their knowledge, the perceived responsibility of passing it on by supporting colleagues was strong (Alex, Ben, Faith, Glenn, Helen) and indicative of the wider enthusiasm for the national network of Master Teachers (Boylan & Willis, 2015), although the responsibility placed on individual teachers in schools to support their colleagues has so far gained limited recognition. Five of the eight planning participants had significant support for others built into their roles at school (Alex, Ben, Faith, Glenn, Helen) and one was reliant on that type of support in their school (Ellen). No literature has been located that reviews the potential issues inherent in this cohort of teachers making the transition to teaching Computing as they become responsible for training and managing new entrants to the profession, some of whom will be significantly more qualified in Computing, but who will lack the PCK for the subject, which at best can be considered as a developing field.

Subject knowledge confidence was connected to beliefs about the subject itself (Faith, Helen), the pedagogies needed to deliver the knowledge and skills of the new curriculum (Alex), such as unplugged pedagogy (Helen), the capacity for its development (Ian), constraints imposed by the awarding bodies (Ian, Glenn) and the ways in which the subject was primarily expressed through Computational Thinking constructs (Ben). Several teachers were optimistic about their subject knowledge developing over time (Helen, Ian, Ellen), particularly through ongoing practice (Helen) and support (Ellen). As a broad and vital aspect that will contribute to Computing education, it is appropriate that the Royal Society has both reviewed the literature relating to Computing pedagogy (Waite, 2017) and called for further research and professional development to be key items on the Computing agenda (Pye Tait Consulting, 2017b).

These tentative conclusions around the value of ways to develop the PCK of Computing teachers align with research into ‘what makes great teaching’, where Coe, Aloisi, Higgins and Major (2014) proposed that PCK was the highest ranked of six components of great teaching, based on the quality of evidence of impact on student outcomes:

> The most effective teachers have deep knowledge of the subjects they teach, and when teachers' knowledge falls below a certain level it is a significant impediment to students' learning. As well as a strong understanding of the material being taught, teachers must also understand the ways students think about the content, be able to evaluate the thinking behind students' own methods, and identify students' common misconceptions (2014, p. 2).

When such robust educational research concludes with a finding of this magnitude, it is further validation and encouragement for research, as with the current study, into the challenges to teachers' PCK and ability to plan lessons brought about by government policy which appeared to lack an appreciation of the deeper impact of dramatic curriculum change.

As a final summary for this sub-section, the individual participants' approaches to planning are condensed in Table 5.3: Summary of thematic findings from planning on page 188.

5.8 Findings: use of subject-specific resources for planning

Prior to the current study, minimal attention had been paid to the specific role of subject-specific teaching resources as part of a teacher's professional knowledge base. The concept was subsumed into curriculum knowledge for Shulman (1987), transposed into the research on PCK in ICT by Webb (2002) and then burgeoned into considerations of online sharing practices (Brown & Kölling, 2013; Weatherby, 2017) and the development of personal learning networks (Preston et al., 2018; Trust et al., 2016) following the curriculum change. The debate had somewhat bypassed consideration of what teachers do with the resources. The current study has devoted some consideration to this and findings indicate that there may be further work needed to understand it better.

Three distinct categories of lesson resources for use in teaching were distinguished through the course of the current study. These were **bespoke lesson resources**, created by participant teachers for a specific purpose; **gathered, unmodified resources** located and used by the participants with little or no change and **repurposed lesson resources**, which were gathered and modified by the participant teacher to fit their lesson objectives more effectively.

All participants made use of gathered resources to plan lessons in line with the new programmes of study. These were often gathered to save preparation time (Glenn, Helen, Alex, Ben, Ian) but also to fill gaps in subject knowledge (Helen), in schemes of work (Helen, Faith, David, Alex) or in specific lessons (Glenn). However, it was also noted that locating resources and quality-assuring them was a time-intensive activity (David, Ian, Helen).

Repurposing was common, especially to fit the current teaching context (David, Helen, Glenn, Ian) or needs of specific students (Alex, Ellen). Some teachers noted that they took a less 'instructional' approach with using resources (Ben, Alex), further evidence perhaps of changing their teaching under the new curriculum. Gathered resources were not always sufficient, even when repurposed, leading to regular preparation of bespoke lesson resources (Alex, Ben, David, Faith, Glenn, Helen, Ian) although this represented a significant investment of time (Alex, Helen).

Keyword-based internet searches, including YouTube (Ben), were a common starting point for locating resources for reuse or modification (Ben, David, Glenn, Alex, David), along with using online sharing platforms such as TES (Ian) and CAS (Alex, Ben, Faith, Glenn, Helen, Ian). Commercial and 'cottage industry' resource providers were also used (Alex, Helen, Ben, Faith, Ian) and sometimes discarded over concerns of cost and quality (David, Alex, Helen).

More broadly, a range of other sources to underpin teaching were used. These ranged from programming reference sites (Alex) to specific online (David, Ellen) and offline applications for programming (Ben, Alex, Faith), including textbooks (Faith). Multiple types of software were mentioned, the affordances of which were related more to general or technological pedagogy than Computing as a subject.

Drawing these findings together and relating them to the wider research questions of the current study, it can be argued that the role of teaching resources has a much more prominent part to play than may have previously been assumed. A key conclusion, which will be followed up in the conclusions chapter, is that teaching resources have the potential to be a proxy for PCK.

As a final summary for this sub-section, the individual participants' approaches to planning are condensed in Table 5.3: Summary of thematic findings from planning on page 188.

5.9 Chapter summary

This chapter has presented the findings in relation to the second research question: how do participant teachers approach the planning of Computing lessons? It has been structured to allow each of the sub-questions to be considered separately. The early part of the chapter focused on presenting findings in relation to the main approaches to planning undertaken by participant teachers in the context of the individual participants' background and experience. The chapter then moved to a table (Table 5.3, on p. 188) presenting the findings from the planning phase for each participant, before providing a cross-case summary of the findings in relation to each of the three sub-questions, reviewed in light of the research literature.

A thematic synthesis provides the framework for the findings from this research question. They are grouped into three overarching themes: transitional pedagogical reasoning, knowledge validation and developing subject and pedagogical content knowledge through professional learning networks and resources. This framework forms the basis for the structure of the concluding comments in Chapter Six.

TRANSITIONAL PEDAGOGICAL REASONING

- Pedagogical reasoning process evident but messy
- Lesson planning allows for evidencing and developing PCK
- Different purposes of planning and approach taken; confidence

KNOWLEDGE VALIDATION

- Need to enhance knowledge and Computing pedagogy; linked to beliefs
- Importance of resources and resource providers
- Constraints from exam boards and changing specifications
- CAS, Master teachers, hubs, support responsibilities

DEVELOPING SUBJECT AND PEDAGOGICAL CONTENT KNOWLEDGE VIA PROFESSIONAL LEARNING NETWORKS AND RESOURCES

- Internet searching, found/modified/created resources
- Specific role of resources: PCK by proxy; what teachers do with them
- Changing teaching; developing PCK

The next and final chapter is the conclusions chapter, where I shall summarise the findings, explain their implications and suggest areas for future research.

Chapter 6 Conclusions

6.1 Introduction

The proposal to disapply the English National Curriculum programmes of study for ICT was announced in January 2012. As an interim measure during the planned curriculum review, from September 2012 to September 2014 ICT as a National Curriculum subject would remain compulsory, but schools no longer had to follow the existing programmes of study. In February 2013, the government proposed to replace National Curriculum 'ICT' with 'Computing' at all four Key Stages. The new programmes of study for Computing at Key Stages 1 to 4 were published in September 2013, becoming statutory from September 2014.

In this study I set out firstly to investigate in-service teachers' perceptions of the transition from teaching ICT to teaching Computing following the 2014 curriculum change. In-service teachers had been teaching ICT as a National Curriculum subject prior to its disapplication. They subsequently had to make the transition to teaching Computing. Secondly, in addition to understanding the perceptual data, I designed the study to explore how teachers were planning Computing lessons that aligned with the new programmes of study, given their differing backgrounds, routes into teaching ICT and teaching experience prior to the curriculum change.

I conducted a literature review to provide conceptual and methodological direction for the research study. Literature from the field of ICT and Computing Education was discussed, highlighting key issues relevant to the curriculum change. Shulman's 1986 and 1987 concepts of Pedagogical Content Knowledge and pedagogical reasoning were explored to provide a conceptual framework with which to investigate and understand teachers' professional knowledge and skills, leading to the formulation of the research questions and sub-questions. PCK and pedagogical reasoning provided a lens through which to interpret the teachers' actions during lesson planning.

I designed the current multiple case study to explore the participants' perceptions of the curriculum change and its impact on their planning and teaching, allowing data to be collected about the way that different participants addressed the Computing subject knowledge requirement and planned lessons aligned to the new programmes of study. I collected data between April 2016 and January 2017 through semi-structured interviews and lesson planning sessions, which I video-recorded either in person or remotely through internet-call-recording software. I collected wider documentary data, leading to a rich and diverse set of case study material for each participant. I used Atlas.ti 7 qualitative data analysis software for thematic coding. I addressed and discussed the findings of the study in Chapters Four and Five, each relating to one of the overarching research questions.

The purpose of this final chapter is for me to discuss the significance of the findings, examine the study's contributions and limitations, and suggest recommendations and opportunities for future research on Computing Education in the UK. Rather than separate the potential areas for further research from the context from which they derive, I have woven them holistically into the discussions.

6.2 Summary of findings: perceptions of curriculum change

My first research question asked how participant teachers perceived the ICT to Computing curriculum change. It focused on their perceptions of the ICT and the Computing curricula, their perceptions of the transition from one to the other, and their perceptions of CPD that was available to them during that time.

Perceptions ranged from stoicism to frustration around the lack of clarity and ongoing uncertainty, fear over lack of subject knowledge, impact on career progression and perceptions of vulnerability. Participants were disturbed by the realisation of the shortage of specialist teachers, concerned but empathetic by teachers leaving the profession, while bearing the load of supporting others or being grateful for support provided. Support from senior leaders, governors and the government seemed lacking, generally attributed to a lack of understanding about the enormity of the impact of the curriculum change.

Influenced by their differing backgrounds, beliefs, values and experiences, the participants' perceptions of the ICT and Computing subjects and curricula can also be summarised thematically but do not fit neatly into mutually exclusive categories. With regards to ICT, perceptions ranged from describing the subject as choppy, didactic and task-based, boring when restricted to office-type software and less creative than Computing. Participants valued the flexibility of ICT, its inclusivity and vital, valuable, vocational skills, all the while recognising that it may well have served its purpose during its time and having been irretrievably damaged by the qualification gaming entered into by many schools in an effort to manipulate league table results.

Computing, usually in relation to programming specifically, was felt to be harder and more challenging than ICT, more like a science subject or a completely different language. It allowed much greater independence, control and creativity by students but at a cost to skills valued by employers since few would need programming in their work. Some felt that it was too complex, especially for younger pupils or less able pupils, and that it needed high levels of self-motivation. The focus was too heavily on Computer Science aspects at the cost of the other two strands of Information Technology and Digital Literacy.

Most participants reported a lack of access to CPD, but some made significant, independent efforts outside of school time to upskill. The costs of this approach were high in terms of teacher time, but those for whom CPD was not accessible recognised the opportunity cost of not being able to upskill as much as needed in the role, and as assessment continued to place subject knowledge challenges on them.

Most of the teachers referred to CAS as a significant source of support, either for themselves or for those supporting them. In addition to CAS, most of the participants had an immediate working knowledge of influential practitioners and sources of support and teaching resources. Notwithstanding this, one participant, also a Master Teacher, was concerned that the influence of CAS was not reaching far enough and suggested that there were still teachers struggling on their own, who had not engaged with CAS.

6.3 Summary of findings: planning Computing lessons

My second research question asked how participant teachers approached the planning of Computing lessons. It focused on the way that PCK was enacted through the process of pedagogical reasoning when participant teachers planned their lessons, and the way that the Computing subject knowledge was addressed by the participant teachers to enable them to plan lessons. It also focused on the extent to which participant teachers drew on subject-specific sources of support and teaching materials to enable them to align their planning with the new programmes of study.

For each of the participants, planning lessons followed a clear and logical process. The processes were observable and could be represented visually, aligning with research that suggests that the functions and components of PCK and pedagogical reasoning are widely operationalized (Alonzo et al., 2012; Ohrndorf & Schubert, 2013; Webb & Cox, 2004). That is not to say that the process was linear or straightforward, as it was often messy, but dynamic, recognising that nobody teaches the same way twice, and accommodating of ongoing and idiosyncratic development of PCK (Loughran et al., 2004; Mulhall et al., 2003). The literature provided a strong indication that lesson planning activities were fertile ground for evidencing and developing PCK (Aydin et al., 2015), especially when ensuring that the full process of pedagogical reasoning is carried through from initial planning to reflection (De Jong & Van Driel, 2004).

Depending on whether planning during the current study occurred at the unit level or the lesson level, there was a clear sense of planning involving developmental processes within processes, in line with research findings that this develops teacher confidence (Nilsson & Loughran, 2012), teacher efficacy and professionalism (Park & Oliver, 2008). Strong beliefs about the nature of Computing as a body of knowledge, about the need to develop programming skills and to incorporate real-world understanding influenced the way that participants approached their planning, as recognised by Hubwieser, Mühling, Magenheim and Ruf (2013) in relation to developing PCK in Computer Science teachers. Participants made use of multiple sources of knowledge and material to inform their professional knowledge bases, such as curriculum knowledge, assessment knowledge and knowledge gained from professional development activities, all aspects germane to enhancing PCK (Loughran et al., 2001; Shulman, 1987).

The stages and processes of pedagogical reasoning were evidenced across the full complement of participants, covering examples of teacher behaviour interpreted as being indicative of the spaces of comprehension, reflection and evaluation about instruction and assessment in line with Webb's (2002) model. This often led to participants questioning themselves and their approaches during and after the planning process thereby demonstrating reflection-in-action and reflection-on-action as discussed by Park and Oliver (2008) and Griffin (2003) as essential attributes for developing PCK. Within the process of transformation (Shulman, 1987), where participants' PCK works to develop the teachability of the lesson content, participants' planning processes were interpreted as indicative of preparation, representation, instructional selection, adaptation and tailoring to the needs of the students. This was based on knowledge of students generally and their own students, specifically. Efforts were consciously made to address misconceptions and develop programming pedagogy, both key themes in the contemporary literature relating to developing pedagogy post-2014 (Qian & Lehman, 2017; Sentance & Waite, 2017).

In each participant case, their prior knowledge, general pedagogy and teaching experience was useful, as evidenced in previous studies relating to experienced teachers' PCK (Lee &

Luft, 2008; Loughran et al., 2001), in terms of applying experience from other subjects and drawing in industry experience. Participants seem to exhibit coping strategies through the struggle for new professional knowledge and skills in a similar way to novice teachers described by Appleton (2008). It is clear that mixing and matching resources in planning contributes to developing new and better PCK even when a teacher is reliant on the subject knowledge and PCK of the person who created the resources, a theme which is evidenced very strongly in the case study schools reviewed for the Royal Society *Reboot* report (Pye Tait Consulting, 2017a).

Participants came to the study with subject knowledge ranging from undergraduate studies and industry experience to knowledge initially more suited to the primary phase or ICT curriculum. Whilst some required minimal knowledge enhancement, some actively sought it out, despite the difficulties of doing so, or wished that they had time or the scope to upskill further. The variety of teacher backgrounds, qualifications, confidence and access to CPD was a key theme discussed in the Royal Society *Reboot* report, based on almost one thousand teachers' responses (Pye Tait Consulting, 2017a).

Some participants felt comfortable with their level of subject knowledge but some recognised that this was an ever-changing situation that may well result in them having reached their capacity at the current time. For some, the subject knowledge struggles were evidence of the desire for ever-deeper knowledge and indicative of personal values and deep emotions in relation to professional identity, a point recognised by the Computing at School working group as the new curriculum was being introduced (Brown et al., 2014). For most of those who were comfortable with their knowledge, the perceived responsibility of passing it on by supporting colleagues was strong and indicative of the wider enthusiasm for the national network of Master Teachers (Boylan & Willis, 2015), although the responsibility placed on individual teachers in schools to support their colleagues had so far gained limited recognition. Five of the eight planning participants had significant support for others built into their roles at school and one was reliant on that type of support in their school.

Subject knowledge confidence was connected to beliefs about the subject itself, the pedagogies needed to deliver the knowledge and skills of the new curriculum (such as unplugged pedagogy), the capacity for its development, constraints imposed by the awarding bodies and the ways in which the subject was primarily expressed through

Computational Thinking constructs. Several teachers were optimistic about their subject knowledge developing over time, particularly through ongoing practice and support.

Three distinct categories of lesson resources for use in teaching were distinguished through the course of the current study. These were **bespoke lesson resources**, created by participant teachers for a specific purpose; **gathered, unmodified resources** located and used by the participants with little or no change and **repurposed lesson resources**, which were gathered and modified by the participant teacher to fit their lesson objectives more effectively.

All participants made use of gathered resources to plan lessons in line with the new programmes of study. These were often gathered to save preparation time but also to fill gaps in subject knowledge, in schemes of work or in specific lessons. However, it was also noted that locating resources and quality-assuring them was a time-intensive activity. Repurposing was common, especially to fit the current teaching context or needs of specific students. Some teachers noted that they took a less ‘instructional’ approach with using resources, further evidence perhaps of changing their teaching under the new curriculum. Gathered resources were not always sufficient, even when repurposed, leading to regular preparation of bespoke lesson resources, although this represented an additional investment of time.

Keyword-based internet searches, including YouTube, were a common starting point for locating resources for reuse or modification, along with using online sharing platforms such as TES and CAS. Commercial and ‘cottage industry’ resource providers were also used and sometimes discarded over concerns of cost and quality. More broadly, a range of other sources to underpin teaching were used. These ranged from programming reference sites to specific online and offline applications for programming, including textbooks. Multiple types of software were mentioned, the affordances of which were related more to general or technological pedagogy than Computing as a subject.

Drawing these findings together and relating them to the wider research questions of the current study, it can be argued that the role of teaching resources has a much more prominent part to play than may have previously been assumed. A key conclusion is that teaching resources have the potential to be a proxy for PCK.

6.4 Significance of findings

In this study I have achieved my aim of answering the research questions and sub-questions. In Chapter Four I presented a case study narrative for each of the individual participants in order to provide the context necessary to understand each case and establish the way that they perceived the ICT to Computing curriculum change. I was then able to present a cross-case synthesis in response to the sub-questions, providing data to establish the ways that participants teachers perceived the professional development available to them, their perceptions of the ICT and computing curricula and their perceptions of the transition from one to the other.

In Chapter Five, I summarised the main approaches to planning undertaken by participant teachers for the purposes of this study, interweaving the concepts of PCK, pedagogical reasoning, subject knowledge and use of resources to provide an account of the professional knowledge and practice of the participant teachers. The chapter discussion section of each chapter provides detailed responses to the sub-questions.

In this section, I will present the themes emerging from the findings, which I synthesised into analytic categories. These will form the basis for reflecting on the significance of the findings and their relevance to the study's aim and focus.

THEMES
TEACHER BELIEFS • Different beliefs about ICT and CS, • The need for a broad curriculum, real-world skills, • Concerns about marginalisation of IT, the prioritising of programming and Computer Science • Subject status, pupil abilities/vocational/academic, gender issues **TEACHER IDENTITY** • Vulnerability, imposter syndrome, specialist and non-specialist identities • Impact on career, perceptions of CS, dodging bullet, pressure, loss of core status, • Continuing uncertainty re: government policy, accountability, **PROFESSIONAL ISSUES** • Lack of support from senior leaders, lack of and importance of CPD, upskilling in own time, • Overt and covert costs • Importance of CAS, importance of professional networks, influential people, • Importance of resources and resource providers, the cottage industry • Transition issues (from primary to secondary school).

THEMES
TRANSITIONAL PEDAGOGICAL REASONING • Pedagogical reasoning process evident but messy • Lesson planning allows for evidencing and developing PCK • Different purposes of planning and approach taken; confidence **KNOWLEDGE VALIDATION** • Need to enhance knowledge and Computing pedagogy; linked to beliefs • Importance of resources and resource providers • Constraints from exam boards and changing specifications • CAS, Master teachers, hubs, support responsibilities **DEVELOPING SUBJECT AND PEDAGOGICAL CONTENT KNOWLEDGE VIA PROFESSIONAL LEARNING NETWORKS AND RESOURCES** • Internet searching, found/modified/created resources • Specific role of resources: PCK by proxy; what teachers do with them • Changing teaching; developing PCK

6.4.1 Teacher beliefs

It was clear from the outset that each teacher would bring their own unique perspectives to their practice. Teachers brought with them a range of beliefs about ICT as a subject and about what Computing, or rather, Computer Science as a subject meant ontologically. The distinction between Computing and Computer Science is significant because each of the participants highlighted that the Computing curriculum triumvirate consisting of Information Technology, Digital Literacy and Computer Science proposed by the Royal Society (2012) and encapsulated in the new programmes of study for Computing (DfE, 2013) was not receiving equal weighting. Part of that can be explained by the pragmatism of prioritising the unfamiliar Computer Science strand, but several teachers related a concern that ICT as a subject was being marginalised politically.

Qualification reform in the Computing sector seemed predicated on the continuing discourse of ‘harmful’ ICT (DfE, 2012) as all GCSE and A-Level ICT qualifications were scrapped, relegating the Information Technology strand to ‘merely’ vocational status. Whilst participant teachers mostly enjoyed, or at least coped with the introduction of programming, it produced concerns over the primacy of programming at the cost of a broader curriculum and real-world skills. This dichotomous battle over the differing statuses of ICT and Computing and Computer Science as subjects was made overt with the inclusion of Computer Science as a fourth Science subject in the English Baccalaureate calculation (EBACC) but also brought with it very high expectations and accountability from school leadership teams as to the type of assessment results expected at GCSE, particularly. This partly accounted for the concerns of participant teachers about the exclusivity of Computer Science and the need for different Computing provision for students who were less able, less motivated or who simply did not enjoy programming. Although outside of the scope of the current study, the issue of gender balance also arose as participants suggested that, unlike with ICT, fewer girls seemed to be selecting Computer Science or Computing at GCSE and A Level. Part of this may be accounted for because schools were no longer routinely entering all students in for a GCSE-equivalent course as many had done with ICT, which may have kept the numbers inflated, but student recruitment and retention remains an area for further future research.

6.4.2 Teacher identity

The new curriculum brought with it a change in most participants' perceptions of their own identity as teachers and as subject teachers. For those without a background in Computer Science, this was evident in frequent references to specialist and non-specialist teachers, categorising themselves in the non-specialist bracket. The same terminology was evident in those who had a more extensive subject background. There were no instances of non-specialist teachers 'mis-categorising' themselves as specialist. There was, however, a strong implication that specialist status was hard to reach, or unreachable, from those who identified as non-specialist, even in cases where significant engagement had been made with CPD, up to and including BCS certification and CAS hub-leader status. The perception of the most valued knowledge being gained from degree-level studies seemed very strong. Teacher identity issues were not the sole domain of the non-specialist, however, as 'imposter syndrome' was present as a concern from those who had entered teaching via industry and vocational training, or where degree-level subject knowledge had faded over time.

Subsumed into matters of teacher identity was a concern over the impact of the consequences of the curriculum change on participants' longer-term careers. Non-specialists were facing reductions in teaching hours because of the loss of National Curriculum core status, their inability to teach the more advanced aspects of Computing and potential moves into other subjects or responsibilities or out of teaching. They also faced additional pressures to take on teaching for which they felt ill-prepared, perhaps having managed to 'dodge the bullet' by only teaching vocational ICT qualifications or Key

Stage 3 Computing, or lower-ability classes. Conversely, specialist teachers were facing a rise in status as they became the mainstay of otherwise non-specialist departments or were able to seek promotion or new schools as the shortage of Computing teachers became apparent. However, the continuing uncertainty of government policy influencing the development of the subject meant that most participants expressed concern about the multiple pressures they were facing.

6.4.3 Professional issues

Participant teachers were concerned with the way the changes had impacted on aspects of their wider professional practice. Most prevalent was the lack of awareness of the differences between ICT and Computing and especially Computer Science from those outside the field, with the general perception from outside the subject area was that it was more or less the same, which frustrated participant teachers. The lack of awareness translated in practical terms into a lack of recognition of the need for CPD and the expectation that participants could pick up the new curriculum in their own time. The costs of this approach were significant in terms of teacher time, but those for whom CPD was not accessible recognised the opportunity cost of not being able to upskill as much as needed in the role, and as assessment continued to present them with subject knowledge challenges.

Most of the teachers referred to CAS as a significant source of support, either for themselves or for those supporting them. In addition to CAS, most of the participants had an immediate working knowledge of influential practitioners and sources of support and teaching resources. Notwithstanding this, one participant, also a Master Teacher, was concerned that the influence of CAS was not reaching far enough and had the opinion that there were still teachers struggling on their own, who had not engaged with CAS. More research is needed to better understand the types of teachers who need additional support and to ascertain their CPD needs. There is a risk that continued investment in one form of support will not identify or address the needs of all teachers of Computing, or of those who may need it most and have not reached out to the wider community.

A final issue, but one with the potential to impact all schools, is that of concerns with Year 6 to Year 7 transition. Since the study was limited to only two participants from the primary sector, it was not possible to assess a pattern in their comments about the skills of their students in comparison to the anecdotal comments from the secondary practitioners. The secondary practitioners related concerns around patchy IT skills in pupils coming from feeder primary schools, to the extent that children lacked basic awareness of desktop computer operation. However, the primary school practitioners in this study had developed effective curricula in their schools, but are unlikely to be representative of primary schools generally. The challenge now is to conduct further research at the transition stage to address this lack of knowledge and resolve the contradiction. In line with Waite's (2017) concern around primary teachers using unplugged computing strategies without relating them back to programming, this would appear to be a fruitful area of research.

6.4.4 Transitional pedagogical reasoning

One of the most interesting findings to emerge from this study centres around the way that participants engaged in the process of pedagogical reasoning. I applied Shulman's (1986, 1987) model of the pedagogical reasoning process to the planning activities undertaken by the participants of this study, using it as a framework with which to interpret the steps and decisions they made. From the diagram on page 32, this model can be understood as a process of comprehension, transformation, instruction, evaluation and reflection. As my study focused solely on planning, only the comprehension and transformation sub-processes are directly relevant. The transformation sub-process is theorised, as per Nilsson and Loughran (2012) as the location within which PCK is enacted as teachers integrate their constituent knowledge bases and engage in preparation, representation, instructional selection, adaptation and tailoring, resulting in a specific lesson plan. The working hypothesis was that teachers, 'comprehending' what they wanted to teach, would then move to the transformation stage. However, the data showed that this was not straightforward.

Where participants had confidence in their subject knowledge and their own ability to teach an aspect of Computing, they exhibited practices which indicated that they were able to proceed smoothly and fluidly from the comprehension stage to the transformation stage and from there through the different phases of the transformation stage outlined above. This was most evident in the practices exhibited by Glenn and David, whose clear understanding of the specifics of what they wanted to teach meant that they spent little time at the comprehension stage and moved very quickly to the transformation stage, where their planning steps and decisions mapped onto the phases therein.

Where participants struggled with the subject knowledge, it seemed to slow down the speed at which they were able to exhibit behaviour which indicated their ability to move to the next stage of the process. This was particularly evident in participant Alex's approach, where he spent considerable time wrestling with programming syntax and needing to teach himself the skills he thought he needed, only to find that this simply would not work as a set of ideas to be taught. Ultimately, he discarded the new skill and selected an alternative set of ideas to be developed in the programming language. Participant Helen demonstrated a similarly extended period of time at the comprehension stage. Her approach was to physically trial several versions of the ideas to be taught, using pre-prepared materials to supplement her lack of understanding, until she reached a point where she felt comfortable with the new concepts and was able to modify the pre-prepared materials, developing her PCK in the process.

To describe this phenomenon, I have adopted the term *transitional pedagogical reasoning*. By this I mean the process by which unfamiliar but necessary concepts are assimilated into the pedagogical reasoning process while the teacher develops sufficient knowledge and PCK fluency. When the new content is assimilated, and the knowledge and PCK feels secure, the pedagogical reasoning process seems fluent.

A limitation of the current study is that it did not proceed from a working hypothesis regarding the existence of a transitional pedagogical reasoning process, and so future studies focusing specifically on transitional pedagogical reasoning should be undertaken to understand it in more precise terms.

The findings of this study suggest that the lesson planning processes of Computing teachers provided sufficient evidence of indicators mapped to PCK and also sufficient evidence of indicators of their developing PCK, to confirm the findings of Rusznyak and Walton (2011) that lesson planning can be a scaffold for the development of PCK. The study is limited by the different purposes of planning and approaches taken by the participant teachers, so it was not possible to assess this in a systematic way, but a contribution of the study has been to demonstrate that exploring need-based planning undertaken at the lesson level may produce further insights, which could be useful for educating aspiring teachers of Computing.

6.4.5 Knowledge validation

Taken together, the findings of this study in relation to transitioning teachers' Computing subject knowledge and pedagogy raise an important question about their need to validate that knowledge through external sources. Whilst participants with secure subject knowledge were confident to a large extent, and therefore able to validate that knowledge via their background experience and beliefs, participants without secure subject knowledge were obliged to seek external validation. This came in the form of seeking out resources and resource providers who could suggest suitable strategies for structuring and segmenting content, ways of representing that knowledge and selecting instructional approaches. When these key aspects were in place, participant teachers were better able to engage in the activities interpreted as adaptation and tailoring of the content to the characteristics of their specific classes and students. One aspect of this knowledge validation is the prevalence of specific programming languages. By utilising a coping strategy focused on working with the most widely used languages, transitioning participants were able to increase their confidence and competence. Although this confidence was regularly challenged by new concepts, especially in relation to text-based programming, transitioning participant teachers did not seem willing to take risks by deviating from the accepted norm.

The study has also identified that changing qualification specifications act not only to validate the body of knowledge required by the Computing teachers, but that they also act as a source of concern and constraint, limiting and challenging teachers attempting to secure their Computing knowledge and PCK in order to become more confident and competent. Where some participants already possessed a secure knowledge and pedagogical base, they were able to act in turn as validators of the knowledge through Master Teacher support and by coordinating local hubs for teachers seeking to develop and validate their knowledge and skills. These spaces can be conceptualised as places to develop subject knowledge and PCK via co-located strands of their wider learning networks.

6.4.6 Subject knowledge and PCK via professional learning networks and resources

Although participants used a wide range of sources, including keyword internet searches to locate, create, use and/or modify resources, the majority of participants did so within a framework of developing a professional learning network online. Key providers and social media channels contributed to the teachers' strategies for changing their teaching by developing PCK in the new subject material through dialogue with others. The study has raised important questions about the nature of teaching materials and their use in developing PCK. By working with materials developed by others, participant teachers were, in effect, tapping into the others' PCK by proxy. More research is needed to understand the meta-data furnished through the PCK inherent in shared teaching materials. It would be interesting to assess whether articulations of PCK could be encapsulated explicitly into materials that authors were willing to pass on. It is recommended that, in order to effect a step-change in the collaborative development of PCK in the wider Computing Education community, specific meta-data be applied to resources so that all shared resources accessed through a moderated forum such as CAS would be designed to have an educative impact on the teacher as much as on the pupils with whom the materials were intended to be used.

6.5 Research contributions

6.5.1 Theoretical contributions

The pedagogical reasoning and PCK frameworks developed by Shulman are not concepts routinely embedded in the ICT and Computing Education field, despite over thirty years of existence. This is one of the first tranche of studies that has brought Shulman's frameworks into the sphere of Computing Education post-2014, building on work done in ICT Education by Webb (2002). The empirical findings of this study suggest a role for PCK and pedagogical reasoning as frameworks to understand a pedagogically reasoned approach to lesson planning that allows insights into the way that content knowledge and PCK can be developed implicitly through the process, especially where gathered materials may be used as a proxy for accessing the content knowledge and PCK of others. The challenge now is to make Shulman's frameworks explicit and use them to anchor the development of content knowledge and PCK in the field of Computing Education. There is so much to be learned about how to teach the Computer Science and programming aspects of Computing to schoolchildren. Shulman's frameworks have the potential to operate as catalytic tools for thinking about planning and teaching using a language that is accessible to teachers and researchers alike. A natural outcome to this study would be the wider adoption of pedagogical reasoning and PCK in initial Computing teacher education, thereby building a new generation of teachers with the capacity to analyse their own practice and that of others, leading to new research directions in Computing pedagogy. Shulman called for "a well-organized and codified case literature" (1986, p. 13) to be developed, and the optimal time to embed that project is at the start of this new curriculum era.

I suggest that the current study's findings have informed the relationships between the in-service teachers and the way that they perceived the curriculum change. In addition, I propose that the extent of their existing Computer Science and programming subject knowledge has highlighted the way they approached the process of pedagogical reasoning because of the findings that participants with more extensive subject knowledge were able to move quickly and smoothly from the comprehension stage of the pedagogical reasoning process to the transformation stage, whereas participants with lower levels of knowledge tended to struggle at this stage. I further suggest that, although stronger subject knowledge backgrounds seemed, as expected, to be allied with observable behaviour indicating strong PCK, the process of working with gathered lesson resources had an educative, scaffolding effect and allowed those with lower levels of subject knowledge to develop their PCK by working with the PCK inherent in the found materials. I suggest that interacting with others' PCK and trialling the resources and inherent lesson structuring and segmenting allowed the new PCK to be fed forward as part of the process of evaluation and reflection.

Curriculum change is likely to be a continual phenomenon across a range of subjects and educational stages. It is possible to apply the same theoretical propositions as I have outlined here to other, similar situations where teachers are faced with significant curriculum changes and are presented with a set of knowledge or skills not currently part of their knowledge base and teaching repertoire. I suggest that teachers of other subjects, with varying levels of background knowledge, may well operate within the same transitional framework derived from the current study. In line with Cronbach (1975), I assert that this suggestion operates more like a "working hypothesis" echoed by Lincoln and Guba (1985), by which new research in the form of new case studies investigating teachers facing curriculum change in other subject areas might also produce similar findings and help to expand the partial typography developed in the current study.

6.5.2 Methodological contributions

The methodological contributions of this research involve the use of desktop-sharing via internet telephony for researching teacher practices. The research itself was initiated in practice, where "questions, problems [and] challenges are identified and formed by the needs of practice and practitioners" (Gray, 1996, p. 84), which also provided the stimulus to use methods that could capture those practices in an authentic manner. Having been open to matching the timing, location and method of data collection to individual requirements, one of the options was to record the interview and planning process via desktop sharing using Voice Over IP (VOIP) telephony, or internet-calling. Six of the nine participants elected for the online desktop-sharing approach. One conclusion that can be drawn from the methodological approach is that desktop-sharing over VOIP telephony has merit as a method of data collection, although it appears to be mostly absent from recent literature on digital research methods, with the exception of Paulus, Lester and Dempster (2014), where it is presented as tool for collaborative research projects rather than a data collection method and Hidson (2018) which reports on pilot data from the current study, collected partly through desktop-sharing. This absence is surprising, given the increasing acceptance of VOIP telephony itself as a data collection tool (Fielding, Lee, & Blank, 2008; Paulus et al., 2014; Weller, 2015). A natural progression from this study is to analyse the affordances and constraints of desktop-sharing over VOIP as a digital research method to contribute to the ever-developing field of digital research methods.

Another contribution of this study's methodological approach is the considerable extent to which it enabled the breadth and authenticity of the conversations anchored around the lesson planning process undertaken for the study. Although the interview followed a semi-structured approach in that it had an interview protocol, much of the data came from the dialogue that occurred in a naturalistic way around the process of planning. Participants were comfortable to talk at length while they were engaging in the planning process, thereby covering a far broader range of topics than those covered in the interview questions. Being engaged in the act of planning, mediated through technology, seemed to have an enabling effect. This is not a new phenomenon for online interviewing, as it confirms the findings of Weller (2015), whose study used online interviewing as part of a longitudinal study with young people: "the lack of 'pressure of presence' and the encroachment of the researcher on the personal territory of participants aided rapport and disclosure" (Weller, 2015, p. 44). The current study, however, reports a similar advantage by using the affordances of the desktop-sharing method to share working processes combined with a think-aloud as well as dialogic strand. Further investigation of this method is strongly recommended.

It is unfortunate that the scope of the current study meant that a multimodal analysis of video data was not possible within the timescale. Although the commitment of remaining close to the participants' voices was key to the methodological rationale outlined in Chapter Three, there remains a wealth of audio-visual analytical possibilities that have yet to be explored. This would be a fruitful area for further work, even within the existing dataset, to see whether the data might be revisited and analysed in order to develop a better understanding of multiple modes of data about practice.

6.5.3 Implications for practice and practitioners

This study was rooted in a research problem affecting ICT teachers' knowledge and practices as they faced a significant curriculum change. It has asked and answered specific questions about the perception and practices of a sample of teachers, which may resonate with other teachers, teacher educators and academics and practitioners in the wider Computing Education field. A better understanding of teachers' perceptions of the curriculum change and their practices following it will contribute to a more informed perspective from which to continue the transition from the ICT curriculum to the Computing curriculum. As such, the following implications and recommendations are addressed to the different stakeholder groups because one of the major issues inferred from the comments made by the participant teachers was about the lack of understanding of the impact of the curriculum change. They felt no-one was really listening, and no-one really understood. This section is written in order that the participant teachers can be heard and the implications of the findings laid out for those who need to hear.

Implications and recommendations for schools and senior leadership teams

This study has demonstrated that teachers making the transition from teaching ICT to teaching Computing need opportunities for professional development that go beyond a day of training on the use of a programming language, or a day of familiarisation with the latest exam specifications and should focus instead on developing the pedagogy and pedagogical content knowledge to help teachers to develop as Computing practitioners. Schools, as publicly-funded institutions, have a shared responsibility towards teachers' subject knowledge and pedagogical developmental needs. The teachers who are tasked with implementing the new curriculum must be given time for development. The curriculum change for many teachers has been a critical point in their careers to date, a point which has not been given sufficient recognition. That the teachers do their best in difficult circumstances is not good enough for them or for their students. It is for schools, who must receive the additional funding they have lacked, to address this issue urgently through effective and empathetic line management. Where there are teachers who have been unwilling or unable to focus on the changes needed to make the transition to upskill, they must be supported in their career development opportunities. At the school level, an appreciation of the experiences of teachers and departments is important in terms of school self-evaluation, line management, professional learning and school improvement processes.

Implications and recommendations for the initial Computing teacher educators

This study has shown the value of pedagogical reasoning and PCK as frameworks for understanding Computing teachers' professional knowledge and skills. Initial Computing teacher education should incorporate these frameworks into the pedagogical studies of trainee teachers, thereby building a new generation of teachers with the capacity to analyse their own practice and that of others, so that they can become pedagogically self-aware and architects of their own continuing professional development. It is vital that new teachers are able to develop a language with which to articulate the implicit aspects of their practice. As these new teachers join their colleagues who have made the transition from ICT to Computing, they will share a common understanding about teaching their subject. At the local and regional levels, these are aspects that should inform wider coordinated developments.

Implications and recommendations for the wider Computing Education field

This study has found that there are many sources of teaching materials, which can be useful to teachers making the transition from ICT to Computing. The study has shown that teaching materials have the potential to act as a proxy for the sharing of subject knowledge, PCK and pedagogical reasoning strategies. However, this meta-data is often implicit. The onus is now on resource providers to develop the educative aspects of the materials they share. In the first instance, funding the further development of online resource-sharing repositories such as the CAS website should be a priority. Despite the presence of thousands of shared resources, it is a manageable project to use the academic knowledge of the CAS community to develop meta-data categories and summaries to accompany each resource, and to employ suitably qualified people to apply the meta-data retrospectively. This will help teachers who are looking for resources to fill curriculum gaps to reflect on the pedagogic quality of the resource using the language of PCK and pedagogic reasoning. If a teacher inspected a potential resource and could accurately assess the decision made around the structuring of the content and representation of ideas, along with suggestions for adaptation and tailoring, this would have an educative effect and they would further develop their PCK through the process of evaluation and reflection. The wider Computing Education field should make a commitment to developing the pedagogy of the new Computing curriculum.

Implications and recommendations for those responsible for Computing curriculum policy

This study has shown that the participant teachers making the transition from ICT to Computing have significant concerns about the pace and direction of policies that impact on the subject. Firstly, that although the new curriculum is built on a triumvirate of Information Technology, Digital Literacy and Computer Science, only the Computer Science is legitimated in terms of meaningful high-stakes assessments. The Computing field is more than just Computer Science, and to neglect the rest of the components is to create a problem that will recur when students lack wider digital skills or are disenfranchised if they do not wish to study the current conception of Computer Science beyond Key Stage 3.

In addition, the continuing uncertainty around qualification specifications acts as a limiting factor for teacher and curriculum development. The pace of qualification change needs to be slowed down and qualifications should be updated on a pre-reported cycle so that teachers can be kept up-to-date with impending modifications.

At the national level, policy must engage with the theoretical underpinnings of Computing pedagogy. This understanding could inform and underpin ongoing approaches to Initial Teacher Education in Computing and continuing professional development for serving teachers as well as strategies for the development of the subject in the longer term.

6.6 Limitations

A key consideration in respect of potential limitations is to do with the choice of case study as a research design. Critics may point to the narrow sampling and time-bound nature of the research carried out for this study. Section 3.7 of Chapter Three debates and responds to some of the perceived methodological critiques. The robustness of the design and the ways in which the findings can be related to other contexts by the use of theoretical generalisation (Gobo, 2008) in which the selection of cases on the principle of variance are closely tied to the phenomenon being researched, leading to representativeness are key counter-arguments for this.

The conclusions drawn from this study are interpretations based on the eleven hours of audio-visual recordings of interviews, dialogue and planning sessions as well as wider documentary review undertaken in relation to the nine participants in the study. Each participant was an experienced professional and contributed a wealth of data to the study. I took an approach whereby the research questions shaped the direction of the discussions but did not close off any fertile avenues. However, it is incumbent on me to complete the research cycle by responding to the specific research questions, leaving the other threads in the data for consideration in future research.

It was not possible to access or track the participants any earlier in the transition from ICT to Computing; therefore, it is unknown whether participants' perceptions had changed over time. Taking January 2012 as the earliest official announcement of the change, the first data collection did not take place until April 2016, by which time the participants had experienced the change and were into the second year of statutory teaching under the new curriculum. Whilst some of the sub-questions, specifically around access to CPD, and those relating to planning, required either an element of retrospective reflection or the application of current practice, it is widely accepted that the accuracy of respondent recall is optimised by minimising the length between the events to be recalled and the time of the interview (Grotpeter, 2008; Lyle, 2003; Theobald, 2008). Additionally, in research design terms, the natural experiment scenario presented by the sudden disapplication of the ICT curriculum meant that a post-hoc type of design was the only one possible. However, that the study proceeded with essentially a one-group snapshot of perceptions and practice meant that it lacked any information with which to gauge either the participants' disposition towards development over time or the extent to which opportunities to improve PCK were part of a longer-term process.

The scope of this study was limited in terms of not having followed any planned lessons through to observation, which would have completed the full cycle of pedagogical reasoning. Instead, the concepts of evaluation and reflection were restricted to the planning of the lesson and lessons that had previously been taught by the participants. Whilst useful to the overall study and having generated evidence with which to answer the research questions and sub-questions, it would be interesting to compare the development of PCK during lessons with its development through the lesson planning process. The contribution of the current study is that it has added to the growing body literature on PCK in Computing Education in the UK. More information on PCK would help practitioners in the subject to establish a greater degree of understanding around how to teach different aspects of Computing.

The study proceeded from the assumption that the experienced participant teachers were of sufficient quality to be able to generate suitable data for the study. Being self-selecting by virtue of agreeing to participate, it was further assumed that, had they lacked the competence or confidence in their own teaching, they would not have agreed to participate. The research has thrown up anecdotal examples of teachers who had not coped with the curriculum change and were in the process of switching subjects or careers. The extent of the impact of the curriculum change on the current shortage of Computing teachers (Ward, 2017) is not known. Considerably more work will need to be done to establish the effects of school-level logistical planning and non-specialist-teacher attrition on the teacher shortage.

A further potential limitation is that the study did not attempt to regularise the planning approaches taken by participants, either through the use of a specific research instrument, such as the Co-Res and PaP-ers discussed in the literature on PCK (Bertram & Loughran, 2012; Loughran et al., 2001; Williams & Lockley, 2012) or by asking them to plan a lesson on the same topic or objective. Whilst either of these approaches would have produced data with potential for comparison and contrast, part of the research aim in this study was to contribute to the minimal research base available in this new field of Computing Education. The field has only recently begun to explore its own nascent pedagogy, and so this study is situated at the very beginning of the research trajectory. Further research into Computing, Computer Science and programming pedagogy is needed to examine the development of PCK in this field.

6.7 Concluding comments

When I first started work on this study, I was not sure what to expect. I knew that teachers were continuing to teach, but I was not sure how they were managing the process. I expected that they would find some functional way to work with the new curriculum and that they would be largely resigned to the changes. What I found were practical and useful approaches, much more focused around collaboration and communities of practice than I had anticipated. The way that teachers worked to locate, use and modify resources elevated the resources to a higher status than I had imagined. That the resources could be a proxy for thinking is an exciting finding, in my opinion, and one that I suggest warrants additional research so that their educative role is recognised more widely.

In adopting Shulman's frameworks I was able to explore at much greater depth than before, the way that teachers carry out aspects of their professional roles. Combined with the desktop-sharing method, I was able to see the beauty in teachers' planning through think-aloud processes. Watching and listening while a teacher grappled with subject knowledge deficits while teaching themselves a new programming technique was inspirational. This was a process that would have remained largely hidden. The research aims and methods have brought it out and it acts as a promising site for future research into developing programming pedagogy.

As a practitioner, I feel strongly about the importance of a shared language with which to describe our pedagogical practice, as per Gunstone (2015). I have repeatedly considered how helpful Shulman's framework would have been when I was supporting colleagues, allowing us to ascribe shared meaning to what practitioners say and do, especially as some of those practices, such as lesson planning, are often carried out in isolation.

Finally, as a piece of work that has developed from a specific and sudden curriculum change, I feel that this study is important because it challenges the speed of the curriculum overhaul, which has risked destabilising Computing education by failing to pre-empt the professional development needs of the teaching body. In addition, it challenges constructions of Computer Science which prioritises computer programming at the expense of wider functional ICT skills and capability and runs the risk of increasing the gender divide in the field. Furthermore, it highlights the lack of understanding about the professional knowledge and skills required of teachers. The curriculum change policy seems to have assumed and presumed that teachers and subjects are fungible and therefore that teaching one computer-related subject is the same as teaching another computing-related subject: this study has shown that this is clearly not the case. By examining teachers' beliefs, planning practices and ongoing struggle with developing sufficient knowledge, skills and understanding to enable them to operate as effective practitioners in a new discipline, this study argues for a more granular understanding of the impact of curriculum change in terms of the pedagogical development of transitioning teachers, and one that takes account of educational research and the theories which underpin educational practice.

Appendix A: Glossary

Abbreviation / term	Definition
14-19 phase	The phase of education relating to pupils between the ages of 14 and 19, usually focused on working towards public examinations and qualifications.
A Level or GCE A Level	The General Certificate of Education (GCE) Advanced Level, or A Level, is a secondary school leaving qualification.
All through school	A school which typically provides both primary and secondary education (ages 4 to 18).
AS-Level: Advanced Subsidiary Level	In the older modular courses, A Levels are split into two parts, with first known as the Advanced Subsidiary Level, commonly referred to as the AS Level, which serves as a qualification in its own right aiding university admission, and the second part is known as the A2 Level.
BCS: British Computer Society	The Chartered Institute for IT, promotes wider social and economic progress through the advancement of information technology science and practice.
BERA: The British Educational Research Association	A member-led charity which exists to encourage educational research and its application for the improvement of practice and public benefit.
Block-based programming	Instead of traditional, text-based programming, block-based coding involves dragging “blocks” of instructions. Scratch is a block-based programming application.
BTEC, DIDA, ECDL, Key Skills, Functional skills • **Business and Technology Education Council (BTEC)** • **Diploma in Digital Applications (DiDA)** • **European Computer Driving Licence (ECDL)**	Vocational qualifications designed to enable the learner to acquire knowledge and skills that meet recognised standards.
CAS hub	Computing at School local forum (Hub) for teachers to share ideas and mutual interests, run by CAS master teachers
CAS Master Teacher	CAS Master Teachers are experienced, high-performing classroom teachers with a passion for Computing, enthusiasm, energy, and a desire to support others.
CEOP: The Child Exploitation and Online Protection Centre	CEOP helps keep children and young people safe from sexual abuse and grooming online.

Abbreviation / term	Definition
CHAT (Cultural Historical Activity Theory)	Cultural-historical activity theory (CHAT) is a theoretical framework which helps to understand and analyse the relationship between the human mind (what people think and feel) and activity (what people do).
CK: Content Knowledge	The term content knowledge refers to the body of knowledge and information that teachers teach and that students are expected to learn in a given subject or content area (Shulman, 1986).
Coding / programming	Computer programming, also known as coding, is the process of creating software.
Computer studies	A course of study devoted to using and programming computers. Offered in secondary school in the 1980s.
Computing	The National Curriculum subject relating to the study of computers, as introduced in 2014 in England. It replaced the ICT curriculum in place from 1999.
Computing at School (CAS)	The Computing at School working group (CAS) was born at Microsoft Research Cambridge, at a meeting in 2008. Their goal was to establish computer science as a proper, rigorous, high status school subject discipline —the “fourth science” — and to build a network that supports teachers as they engage with computer science in their classrooms.
Content Representations (CoRes)	An overview of the particular content taught when teaching a topic (Loughran et al 2004).
CPD: Continuing Professional Development	The skills, knowledge and experience gained both formally and informally during work, beyond any initial training.
CS: Computer Science	The study of computers, computation and information, including the design of software and software systems.
CT: Computational Thinking	The thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out. Computational Thinking was introduced with the Computing curriculum in 2014.
DfE: The Department for Education	Government department responsible for children's services and education, including higher and further education policy, apprenticeships and wider skills in England.

Abbreviation / term	Definition
Digital Literacy	The general ability to use computers, as defined by the Royal Society (2012).
EBACC: The English Baccalaureate	The EBacc is a school performance measure. It shows how many pupils study the core academic subjects at key stage 4 in state-funded and independent schools. The entry measure shows the proportion of pupils who take GCSEs in the core subjects. Computer Science is counted as a one of the single science subjects.
E-Learning Credit	eLearning Credits (or eLCs) was a government initiative in the UK which put money aside for schools for multimedia resources up to the end of 2008.
FE: Further Education	Any study after secondary education that's not part of higher education (that is, not taken as part of an undergraduate or graduate degree).
GCSE: General Certificate of Secondary Education	An examination set especially for secondary-school pupils of about age 16 in England, Wales, and Northern Ireland.
HE: Higher Education	UK higher education (HE) offers a diverse range of courses and qualifications, such as first degrees, Higher National Diplomas (HNDs), and foundation degrees. It includes any qualification at Level 4 and above.
Hermeneutic unit	In ATLAS.ti software, a Hermeneutic Unit (HU) is a project container for all documents, quotations, codes, memos, and associated with the project.
ICT: Information and Communication Technology	The school subject defined in the 1999 National Curriculum.
IT: Information Technology	The use of computers, in industry, commerce, the arts and elsewhere, including aspects of IT systems architecture, human factors, project management, etc., as defined by the Royal Society (2012).
ITE: Initial Teacher Education	A course of initial teacher training designed to lead to Qualified Teacher Status in the UK.
Key Stages: KS1, KS2, KS3, KS4, KS5	The national curriculum is organised into blocks of years called 'key stages'. Key Stages 1 and 2 relate to primary education (ages 4-11); Key Stages 3 and 4 relate to secondary education (ages 11-14) and KS5 relates to post-16 education (16-18).
Lead Practitioner (Specialist Schools and Academies Trust London ICT Network)	DfES-funded initiative to develop a series of London specialism networks conceived and delivered by teachers for teachers.

Abbreviation / term	Definition
L2/L3; Level 2/Level 3	Qualification levels in the UK. Level 2 is equivalent to GCSE. Level 3 is equivalent to A Levels.
MA (Master of Arts)	Postgraduate qualification
Middle school	Part of a three-tier system introduced in the UK in 1964, allowing for separate schools for children age 9-13. Most have been phased out.
MIT: Massachusetts Institute of Technology	A US research university offering free Computing resources.
MOOC: massive open online course	An online course aimed at unlimited participation and open access via the web.
NC: National Curriculum	The English National Curriculum introduced through the Education Act of 1988 sets out the programmes of study and attainment targets for all subjects at all 4 key stages.
NFER: The National Foundation for Educational Research	A centre for educational research and development in England and Wales
NQF: National Qualifications Framework, later QCF: Qualifications and Credit Framework	The Qualifications and Credit Framework (QCF) is a new credit transfer system which has replaced the National Qualification Framework (NQF). It recognises qualifications and units by awarding credits.
OCR, AQA, Edexcel	Examination boards responsible for setting and awarding secondary education level qualifications in the UK.
Ofsted: The Office for Standards in Education, Children's Services and Skills	The body that inspects and regulates services that care for children and young people, and services providing education and skills for learners of all ages.
PCK: pedagogical content knowledge	Pedagogical content knowledge is the integration of subject expertise and skilled teaching of that particular subject. It was first presented by Lee Shulman in 1986.
PGCE: Postgraduate Certificate in Education	A one- or two-year postgraduate academic qualification achieved during teacher training, usually leading to Qualified Teacher Status.
PHP, HTML, CSS, PHP, MySQL, SQL Server	Programming languages
PLN: Personal Learning Network	A personal learning network is an informal learning network that consists of the people a learner interacts with and derives knowledge from, often online.
POS: Programme of Study	Statutory requirements which underpin each subject of the National Curriculum.

Abbreviation / term	Definition
Pre-service (teachers)	Pre-service teacher education is the education and training provided to student teachers before they have qualified as teachers.
Primary education	Relating to the education of 4-11-year-olds in the UK.
Professional-experience Repertoires (PaP-eRs)	Accounts of practice intended to illuminate aspects of a CoRe in a particular classroom context (Loughran et al., 2001).
Python	A text-based programming language
QCA: Qualifications and Curriculum Authority	QCA was responsible for maintaining and developing the national curriculum and associated assessments, tests and examinations; and accredited and monitored qualifications in colleges and at work. It was replaced by Ofqual and Qualifications and Curriculum Development Agency in April 2010.
Randomised Controlled Trial (RCT)	A research design aiming to measure and compare the outcomes of two or more interventions.
Raspberry Pi	The Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation to promote the teaching of basic computer science in schools and in developing countries.
Scratch	Scratch is a block-based programming application.
Secondary education	Relating to the education of 11-18-year-olds in the UK.
SLT: Senior Leadership Team	School senior leadership teams, accountable for the school's performance. Usually comprises the Headteacher, Deputy and Assistant Headteachers and others with whole-school responsibilities.
SOW: Scheme of work	A guideline that defines the structure and content of an academic course.
TeachFirst	An employment-based teaching training programme whereby participants achieve Qualified Teacher Status through the participation in a two-year training programme that involves the completion of a PGCE along with wider leadership skills training
Text-based programming	Programming languages that are typed using a keyboard and stored as text files.
Transition; Year 6/7 transition.	The process of making the transition from primary school to secondary school at age 11.
VOIP	Voice Over Internet Protocol: telephone service over the Internet.

Appendix B: Ethical approval

Durham University
School of Education

Shaped by the past, creating the future

29 January 2016

Elizabeth Hidson
EdD

e.f.hidson@durham.ac.uk

Dear Elizabeth

A study of teachers' professional knowledge and pedagogical practices in computing education.

I am pleased to inform you that your application for ethical approval for the above research has been approved by the School of Education Ethics Committee. May we take this opportunity to wish you good luck with your research.

P. M. Holmes

Dr. P. Holmes
Chair of School of Education Ethics Committee

Leazes Road
Durham, DH1 1TA

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Durham University

School of Education

Research Ethics and Data Protection Monitoring Form

Research involving humans by all academic and related Staff and Students in the Department is subject to the standards set out in the Department Code of Practice on Research Ethics. The School of Education Ethics Sub-Committee will assess the research against the British Educational Research Association's *Revised Ethical Guidelines for Educational Research* (2011).

It is a requirement that prior to the commencement of all research this form be completed and submitted to the School of Education Ethics Sub-Committee. The Committee will be responsible for issuing certification that the research meets ethical standards and will, if necessary, require changes to the research methodology or reporting strategy.

The application should contain:

a. This completed (and signed) application form;
b. Completed **appendix A**:
    a. A summary of the research proposal. This should be no longer than one A4 page that details:
        i. objectives of the study,
        ii. description of the target cohort / sample,
        iii. methods and procedure of data collection,
        iv. data management, and
        v. reporting strategies;
    b. Outline of the interview schedule / survey / questionnaire / or other data collection tools (if applicable depending on the methodology you plan to employ);
c. Completed **appendix B**: the participant information sheet (if applicable), and
d. Completed **appendix C**: the consent form (if applicable).

Templates for the summary of the research proposal, the participant information sheet and the consent form are provided on pp.5-7 as **appendices A-C.**

Please include all the relevant documents above within one combined document

Notes:

- As all applications should be submitted electronically, electronic (scanned) signatures should be used.
- You will be informed of the outcome of your application within two weeks of submission. If a specific application deadline has been notified, and this is missed, then the turnaround time will be 4 weeks from date of submission.
- No research should be conducted until ethical approval is obtained.
- Incomplete applications will be returned without consideration.
- **Please send all documents to ed.ethics@durham.ac.uk, School of Education Research Office, tel : (0191) 334 8403.**

Application for Ethics Approval

Name of applicant	Elizabeth Hidson
Email address	e.f.hidson@durham.ac.uk
Category *[choose from list]*	Postgraduate student - Research programme
If "Other" please specify	
Programme *[students only – choose from list]*	EdD
If "Other" please specify	
Name of supervisor *[students only]*	Professor Steve Higgins
Title of research project	A study of teachers' professional knowledge and pedagogical practices in Computing education.
Date of start of research *[must be a future date]*	22/02/2016
Is the research funded *[staff only – choose from list]*	Click here to select yes or no
Name of funder *[staff only]*	
Name of Co-Is if applicable *[staff only]*	
Is this application subject to external ethical review? *[choose from list]*	No
If "yes" please specify who	

FOR OFFICE USE ONLY

REVIEWER RESPONSE	REVIEWER COMMENTS
Date of reviewer response – click here to select	
Reviewer to complete – click here to select	

1) a. Does the proposed research project involve data from human participants (including secondary data)? *If 'no' please provide brief details in Section 10 of this form.*	Yes
b. Is the research project *only* concerned with the analyses of secondary data (e.g. pre-existing data or information records). If yes then please continue with Q6-10	No
2) Will you provide your informants – prior to their participation – with a participant information sheet containing information about the following: a. The purpose of your research?	Yes
b. The voluntary nature of their participation?	Yes
c. Their right to withdraw from the study at any time?	Yes
d. What their participation entails?	Yes
e. How anonymity is achieved?	Yes
f. How confidentiality is secured?	Yes
g. Whom to contact in case of questions or concerns? *Please attach a copy of the information sheet (template available at **appendix B**) or provide details of alternative approach in Section 10 of this form.*	Yes
3) Will you ask your informants to sign an informed consent form? *Please attach a copy of the consent form (template available at **appendix C**) or provide details of alternative approach in Section 10 of this form.*	Yes
4) a. Does your research involve covert surveillance?	No
b. If yes, will you seek signed consent post hoc?	Not applicable
5) a. Will your data collection involve the use of recording devices?	Yes (if yes, please answer question 5b below)
b. If yes, will you seek signed consent?	Yes
6) Will your research report be available to informants and the general public without restrictions placed by sponsoring authorities?	Yes
7) How will you guarantee confidentiality and anonymity? *Please comment below.* All video data collected will be transcribed and anonymised. All participant data will be anonymised. Participants and their schools will not be identifiable visually. Any still frames, screenshots or document extracts used for illustrative purposes will be screened to ensure that there is no identifying data visible.	

8) What are the implications of your research for your informants? *Please comment below.* I do not anticipate any adverse implications for my informants, either from engagement with the study or results from the study. All observations and interviews will be non-judgmental and require a level of professional reflection which may be of benefit to the informant.
9) Are there any other ethical issues arising from your research? *Please comment below.* In the case of any lesson observations being undertaken, the focus will be on the teacher's delivery of planned lesson material and not on pupils as such. Additional permission will therefore be sought from the school and parents. Anonymity and confidentiality will also be maintained for pupils as in section (7) for teacher participants.
10) Please provide any additional information relevant to your application See summary below.

Declaration

I have read the Department's Code of Practice on Research Ethics and believe that my research complies fully with its precepts.
I will not deviate from the methodology or reporting strategy without further permission from the School of Education Ethics Sub-Committee.
I am aware that it is my responsibility to seek and gain ethics approval from the organisation in which data collection takes place (e.g., school) prior to commencing data collection.

Applicant signature* [illegible]	Date 21/01/2016
Proposal discussed and agreed by supervisor *[students only]* Supervisor signature* S. G. Higgins	Date 22/01/16

**To enable electronic submission of applications, electronic (scanned) signatures will be accepted. Please note that typed signatures cannot be accepted.*

APPENDIX A

Summary of the research proposal

Objectives of the study
My research question asks how experienced teachers of ICT/Computing are responding to the changes in professional knowledge and pedagogical practice necessitated by the disapplication of ICT in 2012 and implementation of the National Curriculum in England Programmes of Study for Computing introduced for first teaching from September 2014.

The new Programmes of Study centre on Information Technology, Digital Literacy and Computer Science as three core areas, with particular emphasis on programming. Given that serving ICT/Computing teachers may not have sufficient subject knowledge in Computer Science or programming, the changes have required teachers to upskill on-the-job in order to teach these elements.

Arguably, the locus of teachers' professional knowledge and skill is at the level of classroom practice and can be conceptualised using Shulman's (1986) Pedagogical Content Knowledge construct. It is during the lesson planning process that teachers draw on their professional knowledge bases to inform their PCK.

This study will explore the lesson planning process of ICT/Computing teachers with a comparative deficit in subject knowledge and PCK relating to the teaching of Computer Science and programming. The aim is to understand how teachers are 'filling in the gaps'.

Description of the target cohort / sample
The sample will comprise in-service teachers who:

- were following the statutory 2008 requirements for ICT as a National Curriculum subject to pupils in the 11-18 age range prior to their disapplication in 2012
- are now teaching the new Computing Programmes of Study.

In order to gauge subject knowledge and PCK, participants will be selected by:

- pre-service subject background: (IT/Computer Science/other subject),
- initial teacher education (IT/ICT specialism/other subject).

Methods and procedure of data collection
Participants will be observed while planning lessons. They will be recorded while doing so, whether in person by the researcher or remotely through digital communication technologies e.g. Skype's shared desktop and web cam data streams, which can be simultaneously recorded by Evaer software. The resultant video, regardless of collection method, will be used in a video-stimulated semi-structured interview, which may also be carried out remotely. A range of documentary evidence will be collected to provide rich data of the teacher's context. It may be useful, if feasible, to observe the teacher during the planned lessons being taught, and these would also ideally be recorded, with appropriate agreement and permissions, to capture moments of pedagogical significance.

Data management and reporting strategies
All research data generated will be logically organised and actively managed. It will be stored on a password-protected personal desktop computer and backed up to the University network and to an encrypted external portable storage device. Consent and confidentiality will be ensured. Beyond submission of the thesis, the research does not require external reporting but may form the basis of conference presentations and journal articles.

Appendix C: Participant information and informed consent

Durham University
School of Education

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APPENDIX B

[DATE]

Participant Information Sheet

Title:

You are invited to take part in a research study of teachers' professional knowledge and pedagogical practices in Computing education. Please read this form carefully and ask any questions you may have before agreeing to be in the study.

The study is conducted by Elizabeth Hidson as part of her PG studies at Durham University. This research project is supervised by Professor Steve Higgins (s.e.higgins@durham.ac.uk) from the School of Education at Durham University.

The purpose of this study is explore the ways in which teachers plan and teach Computing lessons following the 2014 English National Curriculum Programmes of Study for Computing at Key Stages 3 and 4.

If you agree to be in this study, you will be asked to allow the researcher access to the process of planning and teaching a lesson, as well as to the materials and resources used and produced. Digital video data relating to this process will be collected for further study. You will be asked to answer questions in a video-stimulated interview.

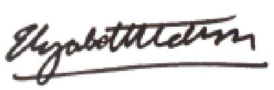
Your participation in this study will take approximately three hours, in several stages.

You are free to decide whether or not to participate. If you decide to participate, you are free to withdraw at any time without any negative consequences for you.

All responses you give or other data collected will be kept confidential. The records of this study will be kept secure and private. All files containing any information you give are password protected. In any research report that may be published, no information will be included that will make it possible to identify you individually. There will be no way to connect your name to your responses at any time during or after the study.

If you have any questions, requests or concerns regarding this research, please contact me via email at e.f.hidson@durham.ac.uk or by telephone at

This study has been reviewed and approved by the School of Education Ethics Sub-Committee at Durham University (date of approval: 29/01/2016)



Elizabeth Hidson

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APPENDIX C

Declaration of Informed Consent

- I agree to participate in this study, the purpose of which is to study teachers' professional knowledge and pedagogical practices in Computing education.
- I have read the participant information sheet and understand the information provided.
- I have been informed that I may decline to answer any questions or withdraw from the study without penalty of any kind.
- I have been informed that data collection will involve the use of recording devices.
- I have been informed that all of my responses will be kept confidential and secure, and that I will not be identified in any report or other publication resulting from this research.
- I have been informed that the investigator will answer any questions regarding the study and its procedures. Elizabeth Hidson, School of Education, Durham University can be contacted via email: e.f.hidson@durham.ac.uk or telephone: xxxxxxxx.
- I will be provided with a copy of this form for my records.

Any concerns about this study should be addressed to the School of Education Ethics Sub-Committee, Durham University via email to ed.ethics@durham.ac.uk.

Date Participant Name (please print) Participant Signature

I certify that I have presented the above information to the participant and secured his or her consent.

Date Signature of Investigator

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Appendix D: Data collection matrix

Data	Source	Collection Method	Description	Purpose	Significance	Analysis	Outcomes	Triangulation	Other
UK policy documents relating to computing available publicly	DfE website	Download	Policy documents	Contextualise changes to official presentation of ICT and Computing	- To trace the process of the curriculum policy changes - Aetiology of the name changes	- Document analysis	- Change process timeline -Documents reviewed and coded for analysis - Codes to inform ongoing project	- Literature review - Computing at School website - Media reports	Consider comparing archived versions using a site such as the Internet Archive Wayback Machine https://archive.org/web/ to see how far back the process of change can be traced
School website and policies relating to computing available publicly	Online	- Save webpages for future reference - Screenshots of pages (saved as images)	Webpages saved as text and images	Example of the way that computing is outwardly presented by 'the school' (query authorship)	Potential connections and disconnects between policy and practice (see Hine, 2015 p. 88)	Webpages / screenshots as images to be imported into NVivo as project data to be coded	Webpages / screenshots reviewed and coded for analysis	Compare to data from interviews, departmental resources, DoE policy documents	

Data	Source	Collection Method	Description	Purpose	Significance	Analysis	Outcomes	Triangulation	Other
Communications with teacher (email etc.)	Via direct communication with teacher	- Screenshots of emails (saved as images)	Emails saved as text and images	Audit trail	May offer informal useful information	Artefact for coding	Artefact for coding	Via interviews or further communications	
Teacher CVs / education & training	Via direct communication with teacher	Via email	List of education and qualifications	Case selection	Teacher 'specialist' status	Judgment on how far case fits case selection criteria	Case included or excluded from project	Member checking	Needed very early on in the process
Computing department promotional material e.g. newsletters, competitions, posters	Range of sources: website, school social media, during site visits etc.	Depends on location – in person, via internet research etc.	News item, event or artefact relating to computing in the school	Evidence of subject presentation and promotion	How subject is perceived and promoted by the Computing department	Webpages / screenshots / scanned images to be imported into NVivo as project data to be coded	Evidence of the subject/ curriculum 'enactment' – its translation into school life	Compare to official policy, interviews	
Computing department schemes of work and resources	Direct from teacher or via electronic means, dependent on the teacher	Direct request from teacher or by electronic means	Curriculum plan, schemes of work, lessons plans, resources / links etc.	Compelling evidence of what subject content is to be taught	How policy is being received, interpreted and transformed into practice by teachers	Document analysis	Evidence of the subject/ curriculum 'enactment' – its translation into teaching practice	Compare to official policy, interviews, member checking	May also be able to access department meeting minutes etc.

Data	Source	Collection Method	Description	Purpose	Significance	Analysis	Outcomes	Triangulation	Other
Dialogic encounters relating to computing in case study sites	Via informal conversati-ons during site visits	Through informal contact with at site	Notes about conversations	May offer additional insights	Potential confirmation about computing in the school	Adding text memos of conversati-ons will integrate with data coding	Adds breadth: may add new insights	Compare to other data	
Field notes from classrooms (inc. environment and displays)	Formal field notes made during and after site visits	These are notes and photos I will generate during and after site visits	Written notes, photos, artefacts gained from site visits	Adds to the rich detail needed to explore the case	How computing is being presented in the school; what is being prioritised	Can be analysed for a priori themes and codes; may provide new insights	Evidence of practice over time; evidence of what is taught and what is prioritised	Follow up though interviews; compare to schemes of work and lesson plans	Visual ethnogra-phic approach
Planning process video(s)	Digital video of planning process	Either recorded face to face or via Skype	Digital video recording of planning process	Direct evidence of instructional strategies	Evidence of pedagogical reasoning, PCK and SMK in practice	Video of planning process can be coded	Video of planning process as physical project artefact as well as interview stimulus	Through video stimulated interview; compared to other data	Careful attention to technical requirem-ents as per Kilburn (2014)

Data	Source	Collection Method	Description	Purpose	Significance	Analysis	Outcomes	Triangulation	Other
Video-stimulated interview(s) and semi-structured interviews	Interview(s) either face to face or via Skype	Either face to face or via Skype	Video of interview between researcher and participant with video as a discussion prompt	To generate key evidence of pedagogical reasoning and teacher reflection on PCK	Teacher's reflection on practice and perception of changes	Thematic analysis and coding	Video of interview about video; project artefact providing key evidence	- Observation - Documents - Member checking	To be given most weight
References and resources referred to or used in lesson planning process	From teacher	As appropriate e.g. a web-based reference or resource	Any resources that the teachers refer to during lesson planning	To generate evidence of pedagogical reasoning and teacher reflection on PCK	Different resources influence the lesson plan	Thematic analysis and coding	Evidence of pedagogic reasoning and re-purposing of resources as part of PCK	Compare to other documents, references, schemes of work	Teachers as knowledge producers not knowledge receivers (Park & Oliver, 2008)

Appendix E: Semi-structured interview guide 1

Teaching

1. What specific courses have you taught – what ages?
2. What does a typical lesson look like for you?
3. What topics do you enjoy teaching most?
4. What topics do you enjoy teaching least?
5. How do you get students interested in computing/computer science/programming?
6. How do you organise pupils for learning computing/computer science/programming?
7. Do you make much use of unplugged activities?
8. What do students find difficult?

Curriculum Change

9. Can you remember how you felt when the curriculum focus started to change?
10. How did it impact you as a teacher – what changed for you?
11. How did you manage the changing subject knowledge/assessment knowledge?
12. Are there aspects of teaching ICT that have helped you with teaching computing/computer science/programming?
13. Have you had to develop your subject knowledge?
14. Have you changed the way you teach?

Computing/computer science/programming

15. What good techniques or strategies have you found for helping students to understand computing/computer science/programming?
16. Where do you get your resources and ideas from?
17. Do you create resources from scratch? Use resources that others have created? Modify others' resources?
18. Do you have the chance to share ideas about teaching computing/computer science/programming?
19. What do you think is important about teaching computing/computer science/programming?
20. How do you approach teaching computational thinking?

Planning

21. How do you usually go about planning a lesson?
22. Does your school have a planning proforma?
23. How do you plan for an observation?
24. What's your bread and butter approach?
25. What's the last lesson you taught?
26. What's the next lesson you are teaching?

Examples

27. Can you send me a curriculum map?
28. Examples of a lesson plan?
29. Anything else you want to say that you think might be useful?

Appendix F: Semi-structured interview guide 2

Interview Questions

Background

1. Can you tell me about your teaching background?
    a. Undergraduate
    b. Route into teaching
    c. Postgraduate
    d. Any qualifications or background experience relevant to teaching ICT/Computing/CS?
2. How did you come to change sectors?
3. What specific courses have you taught – what ages?
4. What topics do you enjoy teaching most?
5. What topics do you enjoy teaching least?
6. What do you think is important about teaching Computing?
7. How do you think students learn Computing best?
8. Can you describe a typical Computing lesson?

Curriculum Change

1. Can you remember how you felt when the curriculum focus started to change?
2. How did it impact you as a teacher – what changed for you?
3. How did you manage the changing subject knowledge/assessment knowledge?
4. How have you brought computational thinking into your teaching?

Planning

1. How do you usually go about planning a lesson?
2. Anything else you want to say that you think might be useful?

Appendix G: Participant data matrix

The purpose of this document is to clarify the types and amount of collected research material from each participant to be used as data within the project.

#	ID	Main planning audio/video	Email or direct messages	Main planning transcript	Curriculum overview	Lesson resources relating to planning session	School publications relating to subject	Filenames
1	ALEX	Year 10 planning - programming Year 7 planning – devices	Messenger history	Transcript	Curriculum map	Powerpoint files	School website computing section	ap-computer-science-principles-course-and-exam-description.pdf Computing-Curriculum-Map.pdf CSTA Improving High School Computer Science Education.pdf CV-\ Graduate Jobs.pdf CV Sept 07.pdf Email from Lesson 1.pdf Lesson 2.pdf Lesson 3.pdf timetable 201617.png website.pdf _CV.docx _LinkedIn_CV.JPG _LinkedIn_CV_2.JPG _Y10_Planning_part_1.wmv _Y10_Planning_part_2.wmv _Y10_Planning_part_3.mp3 _Y10_Planning_Part_4.mp3 _Y7_Planning.mp3 _Y7_Planning.mp4 _Year10_Planning_Transcript_Part_1.docx _Year10_Planning_Transcript_Part_2.docx _Year10_Planning_Transcript_Part_3.docx _Year10_Planning_Transcript_Part_4.docx _Year7_Planning_Transcript.docx

#	ID	Main planning audio/video	Email or direct messages	Main planning transcript	Curriculum overview	Lesson resources relating to planning session	School publications relating to subject	Filenames
2	BEN	Year 3 & 4 planning – stop frame animation Year 3 & 4 planning – game programming	Twitter direct message history	Transcript	Curriculum cycle Game programming plan	Scratch sheet Prompt sheet	School website – class blogs	Class Blogs.docx class blogs.JPG Cycles-2014-2016-Computing.pdf Game plan.docx Game Programming.doc Scratch 2.JPG Scratch Prompt Sheet for Tinkering.docx Scratch screenshots.JPG _01.mp4~ _01_transcription _02.mp4~ _02_transcription.txt _Cycles 2014-2016 Computing.docx _twitter.docx _wallace and gromit.JPG~ _Year_3_4_Planning_Transcript.docx
3	CLAIRE	Interview – no longer teaching	Email trail	Transcript	n/a	n/a	n/a	.docx _09052016_interview_partB.m4a~ _09052016_main_interview.m4a~ _Interview_Transcription.txt~
4	DAVID	Planning for programming already done - interview	Messenger history	Transcript	Overview SOWs with programming	Coding resources list	Computing from school website	Options CS.JPG Prospectus Computing Middle Years 7-9.JPG Prospectus Computing.JPG TRANSCRIPT _01.docx _01.mp4~ _02.mp4~ _CodingResources.rtf~ _EMAIL.pdf~ _ICT_Overview_1 .pdf~ _LinkedIn_CV.JPG~ _Messenger.docx

#	ID	Main planning audio/video	Email or direct messages	Main planning transcript	Curriculum overview	Lesson resources relating to planning session	School publications relating to subject	Filenames
5	ELLEN	Interview – programming discussed – planning done by HOD	Messenger history	Transcript	Long term plan 16-17	Workbook	Computing from school website	Capture.JPG email2.JPG messenger.docx TEEP.JPG Unit 1 workbook.docx _interview_transcript.doc _Interview_trimmed.mp3 _interview_trimmed_final.doc CAS post.JPG _LTP 2016 -17 Year 9 SUMMER.docx _Python Challenges MTLP.docx _Year9-OptionsPowerPoint2016.pdf
6	FAITH	Planning KS3 Python	Email trail	Transcript	Overview & SoW	Python and theory booklets	School prospectus from website	CAS activities.JPG cas profile.JPG Computer Science 9-1 SoW.pdf Computing Years 7, 8 & 9-4 2016-17.pdf Email.docx PROSPECTUS-2015_final1.pdf SoW.pdf Theory Booklet LEARNER.docx Year 8 & 9 Python_Student_Booklet.docx _Interview.mp3 _Interview2.mp3 _transcript.docx _Video_Small.mp4

#	ID	Main planning audio/video	Email or direct messages	Main planning transcript	Curriculum overview	Lesson resources relating to planning session	School publications relating to subject	Filenames
7	GLENN	Planning for binary, logic, truth tables Y9 mobile app planning	Email trail	Transcript	KS3 long term plan	Resources for binary etc. Resources for Y9	Computing from school website	1.JPG 2 Binary Logic - Student.pdf 2 Binary Logic - Teacher.pdf 2.JPG 9 – Mobile App Testing Alpha.pdf AS CS Algorithms and Problems Solving [illegible] 15-16.docx CAS profile.JPG Computer-Science.pdf Email 02 Dece 2016.JPG EMail.docx Example Exam Answers.docx Final Exam Question.docx Flow lesson plan.docx GCSE Computing Long Term Plan.pdf INFO1 Sample Work Checklist.docx IT_BTEC_First_Level_21.pdf KS3-ICT.pdf KS3 Long Term pdf.pdf Lesson Plan.docx Lesson Presentation.pdf MY Notes.pdf _Interview.mp3 _Planning.mp4 _Transcript.docx

#	ID	Main planning audio/video	Email or direct messages	Main planning transcript	Curriculum overview	Lesson resources relating to planning session	School publications relating to subject	Filenames
8	HELEN	Planning for fetch-decode-execute &LMC	Messenger history	Transcript	Order of units & strands of learning 16-17	LMC lesson materials Powerpoint	Computing from school website	.8.2 L3 CPU.pdf .8.2 L3 CPU.pdf .award.jpg .Background.docx .CAS hub profile.JPG .CAS Posts.docx .CAS profile.JPG .fb.JPG .fb.JPG .Lesson 2 - LMC.pdf .messages.docx .Order Of Units 2016-2017.pdf .planning interview.mp4 .plot-Decoding System.pdf .Plot-Instructions_to_Decode Cards.pdf .Plot-to-Display.pdf .resources.JPG .School Publications.docx .Strands of Learning 2016-17.pdf _followup.JPG _Interview.mp3 _Transcript.docx

#	ID	Main planning audio/video	Email or direct messages	Main planning transcript	Curriculum overview	Lesson resources relating to planning session	School publications relating to subject	Filenames
9	IAN	Logic gates lesson planning	Messenger history	Transcript	Curriculum map &16-17 Year Plan	Logic gates materials	Computing from school website	2016-2017-CS-Year-Plan.pdf 2016-2017-Curriculum-Planning-CS-and-IT-New.pdf Capture.JPG Curriculum-Map-IT.pdf FB.docx Lesson Plan Logic Gates.pdf Logic gates - interview version.pdf Logic_Circuits Challenges.pdf messages.docx Truth Tables - Alarms.pdf video interview.mp4 website.pdf _explain_SOW.JPG _Interview_trimmed.mp3 _transcript.docx

Collected for each participant: background information and consent form

Appendix H: Published article based on pilot data

Video-enhanced lesson observation as a source of multiple modes of data for school leadership: A videographic approach

Elizabeth Hidson[1]

To cite:

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Abstract

A growing body of literature recognises the affordances of video in education, especially in relation to lesson observation and reflection as part of teachers' initial teacher education and continuing professional development. Minimal attention has been paid to the outcomes of video-enhanced observation as a source of multiple modes of data for reflexive school leadership. This paper focuses on the data of three participants from a larger set of nine teachers involved in an over-arching study exploring teachers' professional knowledge and practices following a recent curriculum change in England. Data from video-stimulated interviews revealed that recorded video can provide school leaders with a window onto the practices and processes of daily school life, illustrated here through a focus on evidence of policy in practice. It is argued that the leadership perspective provides school leaders and managers with the analytical frameworks and competencies for critical interpretation of the data.

Keywords: Interpretive frameworks, leadership, reflection, video, videography, video-enhanced observation

Introduction

The central thesis of this paper is that school leaders can use digital video strategically as a source of data. Adopting a broadly videographic approach involving 'the interpretive video analysis of social interaction' (Knoblauch & Tuma, 2011, p. 427), this study gives an account of video and video-stimulated interview data that have been analysed thematically, employing similar methods to those which school leaders might find useful in their own work with recorded video as data for reflexive school leadership.

The paper begins by examining some of the key concepts relating to the use of video and then considers the question '*in what ways can video offer additional data of use to school leaders?'*. It will then go on to give an account of the findings from three focal participants, concentrating on the most frequently expressed and evidenced theme.

Video in education

Research has shown that leadership activities lead to improvements in aspects of school work which in turn improves outcomes (Day et al., 2010). In order to identify and action improvements, leaders use a range of approaches to gather evidence and inform strategy. Traditionally, this could involve synthesising assessment data, learning walks, interviews, focus groups and pupil voice. Audio, video or photographic recording of evidence may be used informally, but up to now, there has been very little discussion of the systematic use of video for strategic leadership in schools, although the use of video is prevalent in specific leadership activities, such as coaching and mentoring relationships (R. Lofthouse, Leat, & Towler, 2010).

The need for school leaders to 'see' things more clearly invites a visual methodology, allowing a 'new view' with the luxury of meta-analysis and reflection (Lyle, 2003, p. 864). Video offers 'a fine-grained multimodal record of an event' (Carey Jewitt, 2012, p. 2), resulting in rich visual vignettes, situated in context. Despite the practical challenges of recording video (Kilburn, 2014), the resulting evidence base is far more detailed than notes or photos.

A growing body of literature recognises the affordances of video in teacher education in the US, UK and Europe (Calandra & Rich, 2014; B. Marsh & Mitchell, 2014; Zhang, Lundeberg, Koehler, & Eberhardt, 2011), especially in relation to lesson observation and feedback as part of teachers' initial teacher education (Blomberg, Renkl, Gamoran Sherin, Borko, & Seidel, 2013; A. R. Lofthouse & Birmingham, 2010; B. Marsh, Mitchell, & Adamczyk, 2010; O'Leary, 2016), self-recording of lessons for later review (Kane, Gehlbach, Greenberg, Quinn, & Thal, 2015) and continuing professional development activities (van Es, 2012), but minimal attention has been paid to the outcomes of video-enhanced observation as a source of multiple modes of data for reflexive school leadership. A notable exception is Kress and Silva (2009), who report on two different uses of digital video in educational leadership. In their study, a US middle-school administrator used video footage and the school district's teacher evaluation criteria to make the evaluation process transparent and helpful rather than threatening for teachers. They also discuss a professional development initiative where microanalysis of video in a group of ten high school English teachers allowed for meaningful community learning. In both cases video is used to develop understanding through professional frameworks.

Synthesising the practicalities of using video with professional learning conversations (Harrison & Lee, 2011) and reflective skills for observation (Rosaen, Lundeberg, Cooper, Fritzen, & Terpstra, 2008) encourages the ‘professional vision’ that van Es and Sherin (2008, p. 244) refer to in their study of “learning to notice” in the context of a video club. Sherin and Han’s earlier (2004) study points to teachers being able to reframe and expand their discussions over time. If teachers can learn skills to reframe discussions, there is scope to take them outside of the classroom and apply them to the larger school sphere to inform leadership strategies.

Having gathered video data, the question remains as to the way it can be triangulated to gain a deeper understanding. Video-stimulated interviewing, where video is used to elicit discussion, is used widely in educational research (Jones et al., 2009; Lyle, 2003; Moyles et al., 2003) and the resulting dialogue allows the opportunity to ‘read the pedagogical environment critically’ (Nind et al., 2015), offering the chance to focus on the thinking behind the action and glean understanding from reflection on practice.

Although the studies referred to here each illuminate a relevant aspect of video in education: for coaching, for reflection, for observation, for evaluation, as data for microanalysis, or video-stimulated interviewing, no research has been found that allows them to overlap with the reflexive actions of school leaders, and it is precisely within this intersection that the current study is located.

Methodology

Data for this study were extracted from an over-arching study exploring teachers’ professional knowledge and practices following the 2014 ICT to Computing curriculum change in England. The researcher was a former secondary-school deputy headteacher undertaking doctoral study, with a subject specialism in Information and Communication Technology (ICT). The participants were mostly recruited through subject-specific professional groups and networks, and two were former colleagues. Ethical approval covered the use of lesson video, planning sessions and interviews relating to teachers’ professional knowledge and practices.

Data in the form of lesson-planning sessions was audio and video-recorded either remotely through Skype desktop sharing or in person by the researcher and explored with participants using semi-structured and video-stimulated interviews. The interviews were also audio and video-recorded and transcribed for use as data. Four self-recorded lesson videos were provided by one participant in line with his school’s policy on video for professional development, subject to the agreement that no video footage or still images of pupils would be used in any publications.

The data subset described in this paper relates to three focal participants selected from the larger set of nine participants, consisting of approximately seven hours of lesson observation and lesson planning video footage and three hours of video-stimulated and semi-structured interview footage. Each of these three participants was an experienced teacher who had been teaching a minimum of eight years, and who each held significant school leadership and management roles involving the training and/or professional development of colleagues. Two of the participants taught in the English secondary school (ages 11-18) sector and one in the English primary school sector (ages 5-11).

All planning sessions and interviews from the study were transcribed into text for coding. During coding, it was noted that the high level of technology-related knowledge and competence of teachers of ICT and Computing led to a number of reflections on technology and specifically on video in relation to their professional practice. During the initial coding phase several themes relating to leadership began to emerge which were beyond the scope of the research questions of the main study, but were sufficiently interesting to warrant separate exploration. These three participants gave examples of how they were extending the application of video in their professional practices in order to draw inferences from details observed in the footage and offering interpretations through a leadership lens. Their data have been extracted from the larger study in order to focus on the ways in which video-recorded data can provide additional evidence for school leaders, remaining true to the exploratory goals of the interpretive research strategy (Bryman, 2012). Arguably, the value of interpretive research lies in the extent to which readers can understand and relate findings to their own context by ‘making meaning from authenticity’ (Jackson & Mazzei, 2009, p.5), so the data have been anonymised and presented here as brief descriptive vignettes.

Table 1: Focal teachers’ vignettes

Case 1: Adam	Adam’s school was using video in ungraded formative lesson observations carried out by school leaders to support teaching and learning. Video in lesson observations was part of the school’s policy for improving teaching and learning. Regular self-recording of lessons for later reflection was an expectation of all teachers.
Case 2: Bobby	Bobby’s role in his school was to team teach with class teachers, using his specialist technology knowledge to support other teachers. Bobby’s approach was to harness the use of technology to share professional learning points between teachers and provide a lasting record. This ranged from taking photos and videos of lesson activities and recording Skype internet calls to blogs and video for public sharing. Bobby’s use of video was focused on evidencing activities.
Case 3: Chris	Chris was using video when observing trainee teachers in her school, recording parts of lessons while also making notes. Chris found it useful to take video snapshots and snippets of episodes that piqued her interest, for review in feedback sessions with the trainees.

The video files, transcripts and documents were imported into a new hermeneutic unit in Atlas.ti 7 software for qualitative data analysis in order to focus solely on the emerging leadership-related themes. The malleability of video data described by Jewitt (2012), whereby it is possible to move through the data in a non-linear fashion, freezing frames and replaying sequences was balanced by selecting a systematic approach to the coding process. As a first step, each of the video-stimulated interviews was coded inductively. In video terms, an overview or establishing shot is best obtained using a wide camera angle, giving a high level, or macro view. Zooming in allows for a low-level, detailed shot: the micro view. Applying this concept to the treatment of data meant initially coding for macro data: data that would provide an overview of leadership-related themes, including explicit references and examples from the lesson observation and planning data. The macro coding approach led to an initial set of codes being developed from the data, which were then categorised into subthemes and then further condensed into an overarching set of main themes. Where the macro coding process encountered a specific application of the theme, these were coded as micro examples and reviewed in subsequent passes. Following on from the macro-coding process, the lesson footage and lesson-planning sessions upon which the video-stimulated interviews were based were themselves coded for micro data: data that would illustrate and exemplify the emergent leadership themes. A final analytical pass of the data was made, moving from macro to micro levels of analytical analysis.

Findings

Through a process of review and refinement, five key themes were developed, identifying evidence of policy in practice, pedagogy, classroom climate, school context and school culture as areas where video might provide data for school leaders and managers. This paper focuses on the evidence of policy in practice theme as the most frequently expressed and evidenced.

Evidence of policy in practice: Local issues

Policy may be defined in local, regional or national terms within different levels of accountability for its implementation. National policy agendas tend to be mandatory, especially within the UK maintained sector, with Ofsted inspectors tasked with establishing the extent to which a school follows the policy appropriately. At a local level, schools specify policies as part of their approach to ensuring positive outcomes. Adherence to local policies was a major theme from the perspective of the focal teachers. Within the overarching theme of policy in practice, each teacher identified policy as an area that could be foregrounded through the use of video. An example of macro and micro instances of policy in practice are presented in Table 2.

Focal teacher Adam related developmental experiences of video-enhanced observation, where his manager was keen for him to establish routines derived from a local Assessment for Learning (AfL) policy, whereby teachers would encourage students to develop independence as opposed to an over-reliance on the teacher through the use of the SPOT (Self – Peer – Other – Teacher) technique:

> Yeah, he's really good because, I think, he finds that there's very little routine-wise to look for now. Once he'd sorted out things like SPOT and other routines, there wasn't that much … then he was more interested in what they're learning [Adam].

In reviewing one of Adam's recorded lessons it was possible to view the inside of his classroom from an observer's perspective. The ability to freeze the video clip allowed for a frame-by-frame ethnographic-type scrutiny, leading to the identification of a SPOT poster on the classroom wall. In addition to the technique being used by Adam in his verbal feedback to students, it was also evident that Adam's intention to follow policy extended to the creation and display of materials for policy reinforcement. Classroom displays can be interesting sources of evidence of policy and practice over time, especially when student work is displayed, what Jewitt (2005) would describe as 'a material instantiation of pedagogic discourse' (Jewitt, 2005, p. 309), further evidence of how a teacher mediates policy.

Focal teacher Bobby's approach to the use of video involved gathering evidence, especially in relation to accountability.

> They don't see books [for this subject]… whether it's senior management looking at evidence or whether it's when inspectors come and things like that…. we'll blog these little videos… we've been blogging for about a year and a half and some teachers take to it more than others and some need a bit more reminding, so I make sure that I put opportunities to blog into the plan [Bobby].

Bobby's concern around evidence was two-fold. Firstly, that the use of technology in the lessons would not be represented in students' exercise books, so he was keen for video to be used to capture the evidence. Secondly, that the school had agreed a policy of blogging and sharing images and video and the videos were evidence of the policy in practice. Moving from macro to micro, the planning session footage showed Bobby entering these blogging reminders onto the curriculum plan and then switching to the school website to demonstrate the use of video in class blogs.

Table 2: Example data matrix taken from the policy in practice theme

Theme	Macro	Micro
Evidence of policy in practice	Evidence of specific instance of policy of developing student independence being used	Lesson observation: SPOT technique used by teacher in lesson to encourage student independence; SPOT poster on classroom wall
	Evidence of school blogging policy being used	Scheme of work document: instruction to create and publish video evidence
	Evidence of marking policy being applied	Lesson observation: recording of unmarked work in pupils' exercise books

Focal teacher Chris had harnessed the affordances of her miniature tablet device to take photos and video footage to back up her written notes when mentoring trainee teachers in her school. In her video-stimulated interview she described her work with one trainee. Chris had observed a lesson as previously agreed, and had looked through several pupils' exercise books as part of the process. She was surprised to find that the books had not been marked, despite it being a clear local policy that books would be marked in readiness for an agreed lesson observation:

> The good thing is I can quickly record what I see. It's a reminder to me to deal with the issue… If the marking had been done, it would be a different story… it would be 'well done [trainee]', tick, 'your books are up to date, let's talk about how you applied the department assessment policy' [Chris].

In terms of the micro view, Chris was able to immediately locate and play a clip showing several pupil exercise books, demonstrating that the books had not been marked. Chris, as with Adam and Bobby, had a very clear rationale for the use of video that went beyond just recording lessons.

Discussion

The affordances of video technology, combined with its relative ease of use and ubiquity meant that the focal teachers saw video as a logical addition to their professional tools. In each case, their leadership roles provided a framework for development and mentoring opportunities with colleagues where the application of policy in practice was an important factor. A key theme throughout is the relationship between the video and subsequent dialogue. For the focal teachers, video brought a social and situated aspect to their work, an intention for footage to be shared and for understandings to be shaped through dialogue. This is not video for covert surveillance, this is video for shared understandings. Unpicking this suggests two potential areas for discussion: video as data and interpretive frameworks for use with video. Limitations and challenges are also discussed to stimulate thinking about the practicalities of video for leadership in a school setting.

What counts as data?

Quality assurance and accountability processes in schools are inevitably criteria-based and require supporting documentation. There is a need to document and provide evidence, a thread which ran very strongly through the focal teachers' reflections. Accountability is often seen as a pressure of the leadership role, a negative aspect that detracts from 'real work'. However, in the words of focal teacher Adam, "school leaders want to share best practice. The only way to share it is to document it well." For the focal teachers, video provided 'visual evidence' of practice (R. Lofthouse et al., 2010, p. 22).

Taking a constructivist stance, Knoblauch argues that 'data are the products of the researchers' actions' (Knoblauch, 2009, p. 182) and that data are therefore produced rather than collected. As such, what counts as data, and what gets recorded will depend on the question, but it is clear that video data is a rich source. Leaders can produce video data in response to specific questions, but can also repurpose existing video as data. A recorded lesson observation will capture the enactment of a planned lesson, but also a myriad of other data to be filtered through the current interpretive framework of the viewer, which can be shared and form part of a leadership dialogue. Data doesn't just answer questions, it stimulates them. However, the management of data and building capacity for data-driven decision making (J. A. Marsh & Farrell, 2014) becomes an issue with video data as much as with other forms of data. Decision making can be guided by familiarity with the guiding frameworks of school leadership.

Interpretive frameworks

The increasing availability of mobile technologies and attendant technological convergence means that video is now far easier to capture, review and share and can encourage dialogue, collaboration and dissemination. Whilst no technology is neutral (Harris et al., 2009), the potential of video for transformation and its flexibility means that it should be considered for incorporation into a range of leadership practices. School leaders develop analytical and interpretive skills as they experience leading and managing people, projects, departments, faculties and school improvement strategies. In addition, engaging with accountability frameworks, such as Ofsted inspection criteria, teacher standards, policy implementation and evaluation facilitates being able to 'switch on' a particular set of expectations, as it did with focal teacher Chris, whose need to support colleagues with professional teacher standards meant that she was able to view a specific episode from that perspective: it gave her a key for the ensuing dialogue with the trainee. Reviewing video interactively away from its source allows for analytical distance (Jewitt, 2012) and therefore the ability to interpret the data according to a particular framework. For Chris, the video footage allowed dialogue in relation to the policy expectation: she and the trainee could review it and discuss strategies to improve practice.

The present study set out to contribute to the research about leadership by pointing a lens at the way video data can be used to provide evidence for a variety of strategic practices in schools. The most significant finding to emerge from this study is that it confirms that video episodes can be repurposed and interpreted for school leaders, and that the application depends on the frame of reference. It emerged that prevalent theme among the focal teachers was the potential for video to allow the capture and evaluation of evidence of policy in practice. Taken together, these results suggest a role for video in promoting the application of professional noticing in a more systematic way as part of the leadership mandate.

For school leaders open to the addition of video to their professional practice, suggested first steps include visiting a school where video is used for professional development, to experience the way that video-enhanced observation can be criterion-referenced to a framework. Existing policies can then be reviewed to include video and some of the local limitations and challenges can be addressed before beginning the process of piloting and adoption.

Conclusions

Several limitations and challenges need to be recognised in relation to video footage. Firstly, although this study was based on data analytically repurposed from a larger study, this could be a benefit as much as a limitation. Pragmatically, a school leader monitoring one aspect of school life could find evidence in relation to a different question. The ability to repurpose video in the service of school leadership "and to bring new research questions to the data" (Jewitt, 2012, p.6) is a technological as well as methodological feature of working with video.

The ethics of working with video needs to be thought through in terms of informed consent. In the UK educational context, issues around data protection and safeguarding are salient, especially where under-18s may be in shot when video is being recorded. As the use of video outlined in this article is for a legitimate educational purpose, it does not breach legislation. The school would continue to act within the terms of the 1998 Data Protection Act. More significant from a leadership perspective is the need for the school to develop a comprehensive policy and internal guidelines about the use of video in order to support staff in their work, a point highlighted by Lofthouse, Leat and Towler (2010).

Commercial video observation systems may prove to be a fruitful approach to the systematic implementation of video-enhanced observation that can be repurposed for school leaders. One study currently underway (Batlle Rodriguez, 2016) involves the use of a software application for video enhanced observation with a customisable tagging system, which allows review of the tagged episodes through a firewalled community of practice. Such an approach could support school leaders not only with a convenient method of capturing video, but also the potential to develop sets of customised tags to support different aspects of the leadership role, such as lesson observation tags or learning walk tags, which can be applied either during live recording or later review. As a system customised for the school, with approved users and secure storage, this addresses the data protection and ethical issues outlined earlier.

Although small scale, comprising three focal teachers and one researcher, these exploratory findings suggest a fertile vein for future research into video as a leadership tool. Further research is required to determine the extent to which school leaders may already be using video in some of the ways suggested in this paper, with follow-up to compare their experiences. A further study could usefully explore the provision of professional development involving video-enhanced observation for school leaders. Of course, the video methods outlined in this paper also offer a methodological approach with the potential to reach beyond the practical use of video for leadership: video methods and video-stimulated interviews can enable different facets of educational leadership to be studied.

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Appendix I: Table of codes

These are the additional codes from each participant

Ex-ante provisional codes
1. Adaptation {4-0} 2. Assessment knowledge {16-0} 3. CAS {14-0} 4. Classroom context {0-0} 5. Coding {5-0} 6. Computational thinking {18-0} 7. CPD {28-0} 8. Curricular knowledge {6-0} 9. Curriculum change {7-0} 10. DfE {0-0} 11. Differentiation {5-0} 12. Digital literacy {2-0} 13. E-Safety {5-0} 14. Evaluation {3-0} 15. Feelings {7-0} 16. ICT curriculum {7-0} 17. ICT Skills {34-0} 18. Impact {1-0} 19. Instructional selection {5-0} 20. Instructional strategies {6-0} 21. Knowledge of students {13-0} 22. National curriculum {5-0} 23. Pedagogical knowledge {9-0} 24. Planning {9-0} 25. Preparation {18-0} 26. Proforma {12-0} 27. Programming {13-0} 28. Progression pathways {4-0} 29. Reflection {2-0} 30. Representation {19-0} 31. Resource provider {34-0} 32. Resources – created {9-0} 33. Resources – found {18-0} 34. Resources – modified {12-0} 35. Scheme of work {5-0} 36. Subject knowledge {4-0} 37. Teacher background {26-0} 38. Teacher beliefs {4-0} 39. Transition from ICT to Computing {8-0} 40. Unplugged computing {6-0}

ALEX
1. 'it worked' moment {1-0} 2. a really nice error {4-0} 3. Addressing skills dip {1-0} 4. [redacted] {2-0} 5. Challenge {7-0} 6. Computing strands {10-0} 7. Curriculum map {4-0} 8. Curriculum planning {10-0} 9. [redacted] {1-0} 10. Engagement {11-0} 11. Exam board resources {2-0} 12. Extension {3-0} 13. Facebook groups {3-0} 14. Girls Who Code {1-0} 15. Good mood {2-0} 16. I'm not a very good programmer.. {2-0} 17. I am my own greatest student {1-0} 18. I don't get to reteach this so.. {1-0} 19. I lost my chain of thought com.. {1-0} 20. I see why this works but I'm n.. {1-0} 21. I'm more of a flip between dif.. {1-0} 22. I've struggled to program this.. {1-0} 23. Idiosyncracies {1-0} 24. integrate what we've learnt pr.. {1-0} 25. Internet search for resources {5-0} 26. irritated by interruption {1-0} 27. is this how real programmers p.. {1-0} 28. it's kind of like perfecting t.. {1-0} 29. learn the syntax off by heart {1-0} 30. misconception {1-0} 31. Modelling {9-0} 32. New content {1-0} 33. now I've got my own misconcept.. {1-0} 34. Objective {8-0} 35. paired programming {1-0} 36. Parents {1-0} 37. Pedagogical influences {5-0} 38. Planning ahead {1-0} 39. Planning for assessment {29-0} 40. Planning interruptions {1-0} 41. Planning speed {4-0} 42. Precision in the programming {1-0} 43. Presentation {3-0} 44. Programming strategies {10-0} 45. Pupil misconceptions {5-0} 46. Pupil prior knowledge {18-0} 47. Recap {1-0} 48. resilient {4-0}

ALEX
49. Resource costs {8-0} 50. Resources {10-0} 51. Resources - purchased {15-0} 52. [redacted] {1-0} 53. School policy {8-0} 54. Sequencing {3-0} 55. [redacted] {1-0} 56. Sources {2-0} 57. Starter activity {1-0} 58. [redacted] {1-0} 59. Teach myself {7-0} 60. that might confuse the student.. {2-0} 61. That's completely stumped me {1-0} 62. This is where the teaching net.. {1-0} 63. this is, I suppose the life of.. {1-0} 64. [redacted] {1-0} 65. tough learning experience {1-0} 66. vulnerability {2-0} 67. we'll just have to reprogramme.. {1-0} [redacted] 69. you can tell I love tabs {4-0} 70. you learn from your own mistak.. {2-0}

CLAIRE	IAN
1. Broad curriculum {1-0} 2. Computing is different from IT.. {6-0} 3. Dyslexia {1-0} 4. Exam specifications {1-0} 5. Gender {4-0} 6. I do what I do because I have .. {1-0} 7. I trained as a programmer. I h.. {2-0} 8. Industry standards {1-0} 9. Perceptions of computing {6-0} 10. Planning pressure {6-0} 11. Qualification changes {5-0} 12. [redacted] {3-0} 13. Real world skills {9-0} [redacted] 15. Student interests {3-0} 16. Subject name changes {2-0} 17. Technical design skills {1-0} 18. Uncertainty {5-0}	1. Different way of working {1-0} 2. I'm not sure having it all wri.. {1-0} 3. Impact on career {5-0} 4. IT marginalised {4-0} 5. nobody teaches the same way tw.. {1-0} 6. Pupil attitudes {3-0} [redacted] 8. Teach other subjects {3-0}

BEN	FAITH
1. break down the barriers {1-0}	1. Bigger picture {1-0}
2. Build on prior plans {3-0}	[redacted]
3. build their skills through com.. {1-0}	3. Exam boards {8-0}
4. [redacted] {1-0}	4. Inspection {9-0}
5. Curriculum tension {5-0}	5. KS4 options {8-0}
6. Detailed planning {2-0}	6. Marking {1-0}
7. digital music recording {1-0}	7. [redacted] {5-0}
8. Evidence {6-0}	8. Non-specialist lacks confidence {5-0}
9. Exercise books {6-0}	9. Non-Specialist Teachers {9-0}
10. gap in the curriculum {1-0}	10. Primary curriculum {3-0}
11. I kind of sketch it out, you k.. {1-0}	11. Programming languages {17-0}
12. Lesson Study {1-0}	12. Pushing Computer Science {7-0}
13. limits teacher choice {2-0}	13. Resource - booklet {7-0}
14. local CAS hub {5-0}	14. Resource - textbook {3-0}
15. master teacher {3-0}	15. Responsibility of planning {2-0}
16. [redacted] {1-0}	16. Struggle to prepare resources {4-0}
17. Multitasking {2-0}	17. Subject specialism {3-0}
18. New curriculum {1-0}	18. Teacher attitudes {2-0}
19. New teachers lack of confidence {1-0}	19. Teacher choice {3-0}
20. Old NC levels {2-0}	20. This is my syllabus I know wha.. {1-0}
[redacted]	21. Timetabling {4-0}
22. regular meeting for computing .. {1-0}	22. Understanding concepts {6-0}
23. school resourcing {5-0}	23. Web design {1-0}
24. [redacted] {7-0}	
25. Staff confidence {8-0}	
26. staff should be able to be ups.. {3-0}	
27. Structure learning around resource {8-0}	
28. team teaching {1-0}	
29. Technology Enhanced Learning {7-0}	
30. there isn't any planning that'.. {1-0}	
31. Transition issues {5-0}	
32. Twitter {2-0}	
33. Under-represented topic {1-0}	
34. what thought process kind of w.. {1-0}	

ELLEN
1. Physical computing {2-0}
2. [redacted]

HELEN
1. Ahead of the game {1-0}
2. Dodged a bullet {2-0}
3. EBACC {1-0}
4. I am on the back foot all the .. {1-0}
5. I'm more of a receiver than a .. {1-0}
6. Jump ship {1-0}
7. risk {2-0}
8. Support primary {1-0}
[redacted]
10. We still value both subjects {1-0}

DAVID
[redacted]
2. Multimedia {6-0}
3. Stick to my guns {1-0}
4. Time consuming {1-0}
5. Transferable skills {2-0}

GLENN
1. Lack of CS understanding from SLT {5-0}
2. Lack of programming skill {2-0}
3. marketing {4-0}
4. most teachers will beg, borrow.. {2-0}
5. motivation {2-0}
6. [redacted].. {1-0}
[redacted]
8. Qualification currency {13-0}
9. Student ability {8-0}
10. Student recruitment {3-0}
11. [redacted] {1-0}
12. vocational {9-0}

Key:

[redacted] indicates that identifying data have been redacted

Appendix J: Full list of codes

Ahead of the game
Barefoot Computing
Broad curriculum
Build on prior plans
CAS
CAS_local CAS hub
CAS_master teacher
Challenges
change back
Computational thinking
Computing strands
COMPUTING_Digital literacy
COMPUTING_E-Safety
CPD
Curriculum change
Curriculum map
Curriculum planning
Curriculum tension
Detailed planning
Dodged a bullet
EBACC
Engagement
Evidence
Exam boards
Exam specifications
Exercise books
Extension
Extra-Curricular
Feelings
gap in the curriculum
Gender
Government policy
I'm not a very good programmer..
I am on the back foot all the ..
I do what I do because I have ..
I lost my chain of thought com..
I see why this works but I'm n..
I trained as a programmer. I h..
I'm not sure having it all wri..
I've struggled to program this..
ICT curriculum
ICT Skills
Impact
Impact on career
Imposter syndrome
Influential people
integrate what we've learnt pr..
irritated by interruption
is this how real programmers p..
IT marginalised
Jump ship
KS4 options
Lack of programming skill
learn the syntax off by heart
Lesson Study
LESSON_PLAN_Proforma
Marking
MIT
Modelling
most teachers will beg, borrow..
Multimedia
Multitasking
National curriculum
New content
New curriculum
Non-Specialist Teachers
now I've got my own misconcept..
Objective
OFSTED_Inspection
Old NC levels
PCK Assessment knowledge
PCK Pedagogical knowledge
PCK_Curricular knowledge
PCK_Idiosyncracies
PCK_Knowledge of students
PCK_nobody teaches the same way tw..
PCK_Pupil misconceptions
PED_REASON_Adaptation
PED_REASON_decision
PED_REASON_Differentiation
PED_REASON_Evaluation
PED_REASON_Instructional selection
PED_REASON_Instructional strategies
PED_REASON_Preparation
PED_REASON_Representation
PED_REASON_Sequencing
Pedagogical influences
PERCEPTIONS_ of computing
PERCEPTIONS_Computing is different from IT..
PERCEPTIONS_Lack of CS understanding from SLT
PHYSICAL computing
PHYSICAL_MicroBits
PHYSICAL_Raspberry Pi
Planning
Planning ahead
Planning for assessment
Planning for lesson observation
Planning interruptions
Planning pressure
Presentation
Primary curriculum
Programming
Programming languages
PROGRAMMING Scratch
Programming strategies
PROGRAMMING_Coding
PROGRAMMING_Errors
Progression pathways
Pupil attitudes
Pupil motivation
Pupil prior knowledge
Pushing Computer Science
Qualification changes
Qualification currency
Real world skills
Recap
resilient
RESOURCE - textbook
RESOURCES
RESOURCES - booklet
RESOURCES - purchased
RESOURCES – created
RESOURCES – found
RESOURCES – modified
RESOURCES costs
RESOURCES provider
RESOURCES_Exam Board
RESOURCES_Internet search
Responsibility of planning
risk
safety blanket
Scheme of work
School policy
school resourcing
Social media
Staff confidence
Starter activity
Stick to my guns
Structure learning around resource
STRUGGLE - resources
STRUGGLE - Time
Student ability
Student interests
Student recruitment
Subject knowledge
Subject name changes
Subject specialism
Support primary
Teach myself
Teach other subjects
Teacher attitudes
Teacher background
Teacher beliefs
TEACHER CHOICE - limits
TEACHER CHOICE - positive
Technology Enhanced Learning
that might confuse the student..
That's completely stumped me
This is my syllabus I know wha..
This is where the teaching net..
this is, I suppose the life of..
TIME_Planning speed
Timetabling
tough learning experience
Transferable skills
Transition from ICT to Computing
Uncertainty
Understanding concepts
Unplugged computing
Upskill staff
vocational
We still value both subjects
we'll just have to reprogramme..
Web design
Y6toY7_Transition issues
you can tell I love tabs

Participant initial codes

1. FAITH
2. ALEX
3. CLAIRE
4. ELLEN
5. GLENN
6. HELEN
7. DAVID
8. BEN
9. IAN

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