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Is anyone listening?

**Women mathematics teachers'
experiences of professional
learning**

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October 2013

Doctorate in Education (EdD)

The Open University

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Abstract

This study explores women secondary mathematics teachers' experiences of professional learning. Life histories were elicited through semi-structured interviews in the form of guided conversations, supplemented by time-lines of mathematics and of professional learning. Analysis focused on constructed personal experience narratives. Although research demonstrates the features of effective professional learning, teachers' experiences of learning throughout their careers remains underexplored. A particular focus in this study is on the ways in which professional learning is supported, providing opportunities for re-engagement with mathematics, a subject frequently viewed as inaccessible and masculine.

The women's stories are peopled with significant others who provide both models and encouragement, frequently drawn from their own school days and early professional experience. Much professional learning is informal, arising from unstructured reflection on teaching, with teachers accorded neither agency nor consistent support for their learning.

The women's narratives provide a perspective on lived experiences of professional learning. Frequently learning is unsupported and spaces to discuss mathematics learning and teaching limited. Teachers appear isolated in restrictive school environments which contribute to a perception of reduced agency. Where opportunities for collaborative professional learning exist, women participate actively in the wider mathematics education community. Analysis of

the narratives suggests that teachers' agency over their professional learning needs to increase to create spaces for women to collaborate on mathematics-focussed professional learning. The allocation of resources to teacher professional learning should be prioritised.

These glimpses reveal the restricted landscape of women mathematics teachers' learning opportunities. Despite these restrictions, however, teachers push at the boundaries. The narratives will support teachers who may draw on the voices of others to help them to make sense of their own development. Further research is warranted to explore the way individuals might develop and utilise their own professional learning narratives.

1. Introduction

Background

Starting from my own experience as a mathematics teacher educator and former secondary mathematics teacher, I set out to examine the nature of women mathematics teachers' relationships with the subject and consider the extent to which career-long professional learning supports them to make sense of their roles.

Research in this area frequently takes professional learning initiatives as the focus, exploring factors which contribute to effective professional learning and increasingly considering evidence in terms of student outcomes. It is rare to find research which starts from the teachers, eliciting their stories of professional learning. Where research exists into the professional learning of mathematics teachers, it tends to focus on formal learning opportunities and is often undertaken by researchers who are, at the same time, stakeholders in the opportunities provided. Informal learning, including learning through teaching, is a neglected area of research, although recent years have seen growing interest in this area. This study aims to explore the sense that teachers make of the diversity of professional learning experiences over their careers. As I began the research, early analysis of literature on mathematics learning, coupled with work on my own mathematics and professional learning autobiography, sharpened the

focus of the research, leading to a decision to focus on the experiences of women mathematics teachers.

In exploring the issues in mathematics teacher professional learning from the perspective of experienced women teachers, I aim to see how they have navigated the challenge doing mathematics and being female presents. In part, this 'struggle' for girls (and women) in mathematics is evidenced by low participation in post-16 education. Probing beneath these statistics, it is clear that all is not well in the mathematics classroom; experiences of mathematics lead to many students dropping the subject as soon as they are able, with many of those that persist finding it difficult to identify with the subject. This study examines how women teachers address the philosophical and epistemological issues in mathematics education and the role that professional learning experiences play in their developing identities.

Chapter 2, the Literature review, establishes the theoretical foundations for the study through a critical review of relevant literature. I begin with an exploration of the current picture of mathematics education, focussing particularly on the achievement and experience of girls and women. As an understanding of teachers' relationship with mathematics is a central part of this research, I consider epistemological frameworks which offer a view of how women come to know mathematics. The challenge posed by the nature of school mathematics as it is often conceived is analysed, exploring the role of support from others and the notion of confidence in meeting this challenge. I consider how teacher learning

has been framed in terms of continuous professional development experiences, often in the form of external short courses, and question whether this is, in fact, how teachers learn. Factors contributing to effective professional learning are examined. Social theories of learning, with the central concept of identity, offer a framework for viewing teacher learning which can prove useful in analysing teachers' accounts of their development. This review creates a rationale both for the research questions and the overarching methodological frame which is described in Chapter 3.

The methodology chapter, Chapter 3, begins by examining my own assumptions and positionality as a researcher, building on this to justify the methodological frame. I demonstrate the rationale for adopting a life history approach to the research and for the choice of research methods. This section describes the interview conversations used to elicit the participants' stories of professional learning and the use of time-lines to aid the construction of a chronological account. The evolving approach to data analysis is described, this proved to be one of the most challenging aspects of the research as I endeavoured to represent participants' stories respectfully and completely. As traditional techniques of coding qualitative data served to fragment the stories, personal experience narratives were employed to represent the lives whole. Ethical issues are discussed throughout this chapter as a key feature of this research is the desire to produce research with and for women mathematics teachers.

These personal experience stories are examined in Chapter 4 - 7. Heather (all names are pseudonyms) began teaching as a mature entrant to the profession, spending ten years in one selective school. Nicole started to teach at around the same time, teaching all of her career in schools which struggled to meet national expectations for student attainment. Leila has around twenty years' experience of teaching in inner-city schools and Marta has over thirty years' experience of teaching and supporting mathematics learning. Chapter 8 synthesises and discusses the findings from the four women's stories, considering these in the light of the original research questions.

The final chapter, Conclusion and implications, emphasises the relevance of the research for the mathematics education community and for those involved in leading or supporting teacher professional learning in addition to its relevance for women mathematics teachers themselves. Suggestions are made as to how the research, in the form of the personal experience stories, might be used to stimulate teacher professional learning. This chapter also includes an evaluation of the research. Here I reflect on the research process and tools, identifying limitations and areas for further research.

In the next section I consider what has motivated me to conduct this research.

Rationale

At school, I liked mathematics: I took pleasure from the order and structure, the safety it seemed to offer. For the most part, I followed rules and algorithms; I was able to do mathematics but was rarely challenged to understand. It was not until

much later, as I began teaching, that I realised how little I had understood. Later still, Skemp's instrumental and relational understanding (1976) and Marton and Saljo's surface and deep learning (cited in Biggs and Tang, 2007) provided me with a framework to describe my experience. I now realise I am not alone in this lack of understanding nor in the search both to explain and to change. Driven to explore the competing discourses of feminine primary teacher and masculine mathematician by a quest to better understand her own position as a female mathematics educator, Llewellyn remarks 'In terms of understanding, I am not sure I ever sought it in maths, I just liked getting things right' (Llewellyn, 2009, p. 424). I wonder how differently I might have viewed myself in relation to mathematics if I had understood this ambivalence and the associated lack of confidence as part of a social phenomenon and not merely a failing on my part.

Despite many years both teaching and supporting teacher professional development, my relationship with mathematics remained difficult. As I began teaching mathematics in London in the 1980s, the issue of gender and mathematics attracted my attention and I studied the literature with interest. During the 1990s and early 2000s my attention was elsewhere, only for the issues to return to the spotlight, prompted by my experiences of working with teachers in Ethiopia (where gender roles are more traditional), by my own reflections on my mathematics learning through an Open University course and by an increasing focus on women in society, stimulated by activity encompassing the 'third wave' of feminism (e.g. Weiner, 2004). The ever present tensions for women doing mathematics are noted by Mendick as she recounts an incident

marking her 'sudden awakening to the salience of gender' (2006, p. 9) as she began her undergraduate studies in mathematics.

The impetus for this research was a desire to make sense of my own professional development as much as it was an attempt to uncover and make sense of the views of female mathematics teachers regarding their professional learning. At the outset my focus was not on gender, it was only as I began my exploration of the literature that it became apparent that this was a central construct. This refocused first question (see below) was the starting point for my research. In Chapter 2 I will establish a rationale for the further questions on community, epistemology and pedagogy as these developed from the literature review.

Research questions

1. What are women secondary mathematics teachers' experiences of professional learning?
 - a. What do they perceive as significant in their professional learning?
 - b. Are there 'critical persons'?
 - c. Do they identify critical incidents/phases?
 - d. Do they see their learning supported?
2. Does their professional learning help them to situate themselves in the mathematics community? Does it help them to develop their identity as mathematicians or mathematics teachers?
3. Does professional learning support women mathematics teachers in developing an epistemology of mathematics education?

4. Does professional learning help women teachers to become 'constructed knowers and connected teachers' (Becker, 1995, p.172)?

To contextualise the literature review I begin with an overview of education policy in England during my lifetime.

Historical overview: education policy

A historical outline of secondary education together with a brief overview of initial teacher education will provide the context for the discussion of teacher professional learning, and for the participants' own stories of their learning and their teaching experience.

Schooling

The pattern of secondary schooling in England post-World War II was founded on a belief that intelligence was fixed and measurable (Chitty, 2009). A tripartite system of secondary schooling, introduced in the 1944 Education Act, determined whether students would attend a grammar, technical or secondary modern school, the allocation depending upon their attainment in an examination at age 11 (Brine, 2006). Although the government declared its 'objective to end selection at eleven plus and to eliminate separatism in secondary education' (DES, 1965), signalling support for a comprehensive school system to replace the tripartite system, reform took some time to implement. This post-war period was

one of 'benign partnership' between central government, local government, schools and colleges, a partnership which left control of the curriculum to schools (Chitty, 2009, p. 24).

In the challenging times that followed the economic depression of 1971-3 and the oil crisis in 1973 'schools and teachers became convenient scapegoats for the failure of successive governments to cope with the economic downturn' (Chitty, 2009, p.10). From the mid-1970s education in England entered a new period of accountability (Whitty, 2006), underscored by the new Labour Prime Minister's speech at Ruskin College in 1976, launching what has become known as the Great Debate and signalling greater political involvement in education and in teacher learning (Chitty, 2009).

A dramatic rise in educational legislation from the late 1970s to 2000 signified a difficult relationship between government and teachers (Chitty, 2009). This period of Conservative government was one of choice and competition in education; by 1997 schooling was characterised as a 'divided system' (ibid, p. 57) comprising a range of specialist schools with different funding patterns. The Education Reform Act (*Great Britain*. Education Reform Act 1988) marked a clear change in education policy, bringing in a national curriculum and an associated assessment regime, financial delegation of funding to schools and further variety in school type in terms of specialisation and funding. The new National Curriculum went through continual revision, including a major one following the Dearing Review (SCAA, 1993) which had been set up to examine the curriculum

overload. Selected changes are highlighted in Figure 1 (English education timeline, p.12). When New Labour came into power in 1997 the focus was on raising standards, in part through the introduction of the National Strategies (Whitty, 2008).

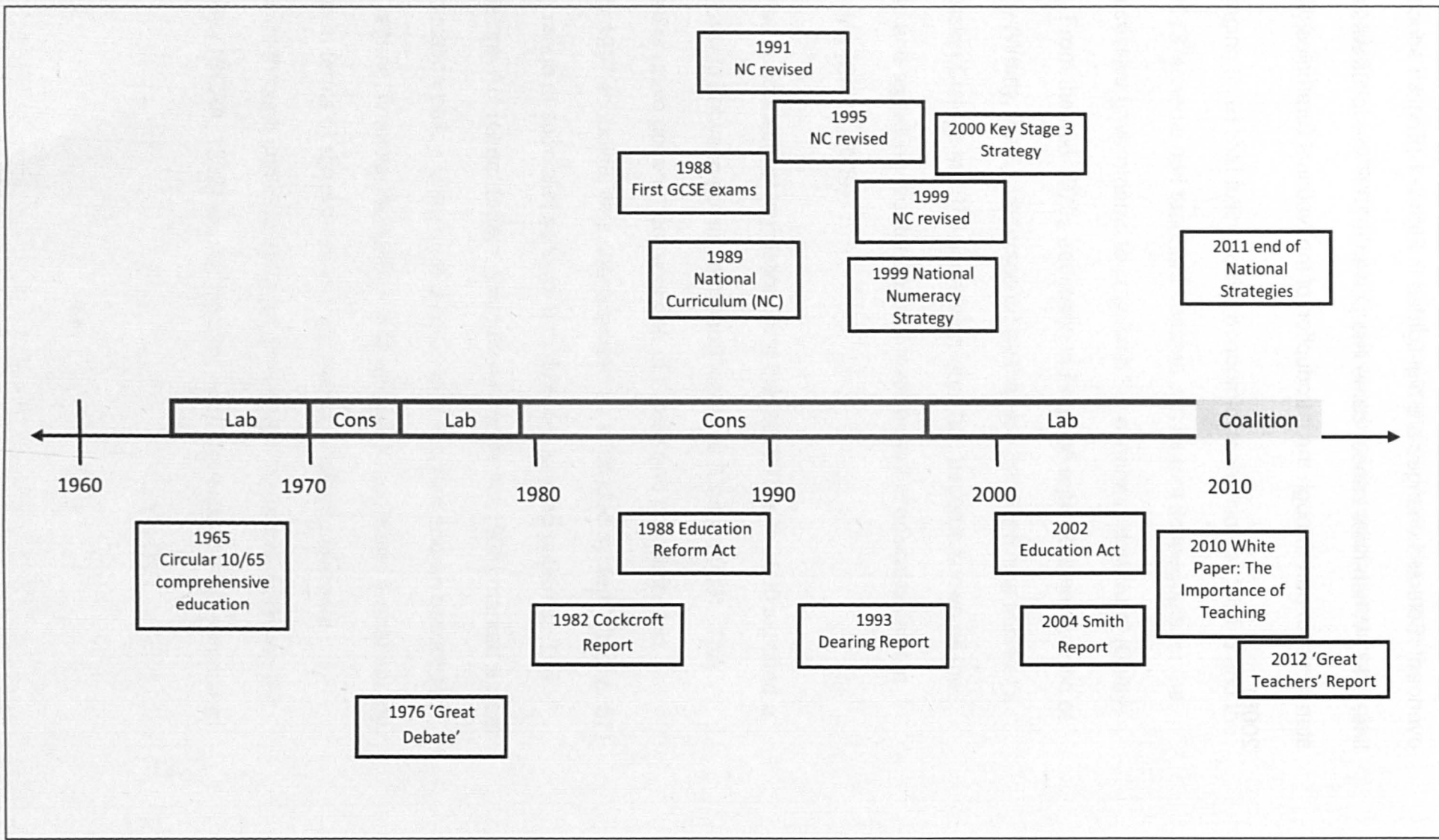


Figure 1 English education selected policy milestones

Teacher education

Teacher education is typically treated as two or three phases: initial teacher education, a period of teaching practice and study leading to Qualified Teacher Status; induction, generally a period of one year following qualification where the Newly Qualified Teacher (NQT) is further supported in their learning; and the remainder of professional life, where learning has traditionally been termed continuous professional development (CPD). A new group of Recently Qualified Teachers (RQTs) have become a focus in this last division, prompted by concerns over the disproportionate loss of teachers to the profession in their first five years of teaching (Smithers and Robinson, 2003).

In the early 1960s prospective teachers studied for a Certificate in Education in training colleges over 3 years, studying one or two main subjects in addition to education studies, curriculum studies and teaching practice (Robbins, 1963). Established with a remit to review Higher Education, the Robbins Committee (ibid) recommended that links between the existing teacher education colleges and universities be strengthened and students encouraged to study for a Bachelor of Education (BEd) degree. This suggestion was met with some resistance by the Labour government of the time (Chitty, 2009) and it was not until the 1970s that teacher education began to be subsumed into the university, though the BEd degree was introduced in 1964 (DES, 1979).

Although extensive recommendations for supporting teachers in-service were made in the James Report (1972), aiming 'to give every teacher an entitlement to

regular in-service education and training' (ibid, 1.9) they were not realised: budget cuts reduced funding drastically for initial teacher training places and curtailed plans outlined in the 1972 White Paper to support in-service education (Schott, 1979). Reorganisation of teacher education at the time of the economic depression in the 1970s more than halved the number of teacher training places and resulted in the closure and merger of many colleges; the thrust of policy was to integrate teacher education with higher education more broadly and to complete the move to an all-graduate profession (ibid). At the same time there was an increase in places on the one year PGCE courses for graduates (Gillard, 2011).

From the 1980s onwards there has been a 'growth in government micromanagement' (MacBeath, 2011, p. 378) of education which has extended to teacher education, reducing the autonomy of providers and shifting the focus from theory to practice. From 1984 those seeking to become teachers had to meet criteria set by government (Whitty, 2006) and initial teacher education providers were required to work in partnership with schools (Brooks, 2006). The terminology used to discuss initial teacher education is evidence of the contested ground, with 'training' rather than 'education' the preferred term in policy, implying the accomplishment of practical skills rather than critical engagement with knowledge (Stephens et al., 2004). At the same time as these policy changes teacher education began to place increasing emphasis on reflective practice and on the use of action research, supporting beginning teachers to develop a critical awareness of their practical knowledge (Korthagen and Russell, 1995). By the

end of the 1980s a marked shift had taken place; teacher education was no longer exclusively the work of colleges and universities. The 1990s saw rapid policy changes which, in addition to fundamentally altering the relationship between universities and schools, saw the establishment of school centred initial teacher training routes and a new framework for inspection of initial teacher education (Furlong et al., 2000). Also at this time, focus shifted to teacher subject knowledge.

Despite the intention to shift initial teacher education into schools, in practice it remained the preserve of universities, with university tutors continuing to play a key role in the 1990s (Brooks, 2006). In 1992 greater demands were placed on partnership arrangements, requiring school involvement in course planning and in recruitment for example (ibid). In 1994 the Teacher Training Agency (TTA) was established to oversee funding and recruitment to initial teacher education (*Great Britain. Education Act 1994*). Teacher education remained subject to scrutiny by Ofsted and a set of standards for teachers was introduced in 1997, developed from earlier competencies (Furlong, 2005). The focus on standards and on competition amongst providers not only sustains a market in initial teacher education but serves to simplify it, creating the impression that teaching is a straightforward task of meeting standards (Furlong, 2005). These professional standards for teachers are a key tool of the audit culture and a 'manifestation of the managerial discourses which have infiltrated education' in England, the USA and Australia, accompanying a 'diminishment of teacher professional judgement' (Groundwater-Smith and Mockler, 2009. pp.6-7).

Until the mid 1970s there was limited support for teachers' continuing learning beyond initial teacher education, apart from the possibility of individual study in higher education. At this time two approaches to continuing professional learning emerged, one a result of policy changes, the other arising out of the work of Lawrence Stenhouse (1975) and John Elliot on classroom-focused curriculum development and action research (McLaughlin, 2013). In mathematics, the Cockcroft report (Cockcroft, 1982) argued for an increase in in-service support for teachers in order to facilitate new ways of working required by curricular changes and to prepare those teachers without suitable mathematics qualifications. In-service education for teachers was recognised as important but a lack of strategic planning meant that resources were not always well used (DES, 1985), prompting proposals for changes to funding. Policy shifts were marked in 1988 with an acknowledgement of the importance of on-going teacher professional learning through the introduction of 5 days per year set aside for school-based learning (*Great Britain. Education Reform Act 1988*). This Act increased teachers' accountability and reduced both the role of the local authorities in education and the influence of professional educators (Hardy, 2012). Today, quantitative measures and global comparisons play an increasing role in shaping teacher professional learning (Bodman et al., 2012). 'Teacher professional development has been construed symbolically as a management tool to respond to centralised pressures for reform' (Hardy, 2012, p. 38) with large-scale programmes on core subjects (for example, in secondary mathematics, the Key Stage 3 National Strategies Framework for Teaching Mathematics (DfEE, 2001)) and assessment.

In the 2000s the Teacher Development Agency (TDA) extended its responsibilities to include continuous professional development of the school workforce, commissioning a large-scale study to inform developments (Peddar et al., 2010). At this time much CPD in England took the form of delivery of national programmes with teachers having limited responsibility for or engagement with their learning. Attendance at courses comprised the main form of teacher professional development in a representative sample of schools across 10 local authorities in 2000/1 (Ofsted, 2002). Alongside this there were a number of networks developing with the aim of supporting teachers to take a more active role in their learning (Pickering, 2007). Arguments against the instrumentalist discourse prevalent in policy and practice continue to be made, directing attention to issues of teacher agency and teachers' participation in transforming education (Atkinson, 2000; Mockler, 2011).

An examination of the impact of the government strategy for CPD, introduced in 2001, characterised CPD as a 'logical chain of procedures' comprised of a needs analysis, planning, participation, monitoring and evaluation (Ofsted, 2006, p.2). The commitment of senior managers to the process was key. Those schools deemed successful provided a range of opportunities, utilising internal and external expertise and balancing the needs of schools and individuals. This study, together with a subsequent review of progress, both of which included schools previously identified as having good practice in CPD, reported concerns regarding the identification of individual teachers' needs and the plans put in place to meet these needs (Ofsted, 2006; Ofsted, 2010). The later study noted

that those schools with the most successful policies regarding CPD provided time for collaboration and reflection.

Global comparisons are used to justify the focus on teacher quality today, with the raised profile of on-going professional learning and the introduction of new funding arrangements in the form of scholarships targeted at priority subject areas (DfE, 2010). Despite this recognition of the importance of ongoing teacher professional learning there continues to be debate about the form this might take and best ways of supporting it, an issue that will be discussed further in the following chapter.

2. Literature review

Mathematics education has been the subject of much debate in recent years, in particular with regard to the mismatch between the supply and demand for qualified mathematicians (Roberts, 2002). At the same time increasing attention has focused on teacher professional learning in an acknowledgement that pre-service education alone is inadequate preparation for the demanding roles teachers fulfil in the twenty-first century (Schleicher, 2011). These public debates mask others within the mathematics education community, debates which provide important context for this research. Beneath these lie my own, often internal, debates, as I struggle to understand how it is that despite (or perhaps because of) my experience, qualifications and position I still have a difficult relationship with mathematics.

My initial exploration of the issues focussed on data regarding participation and attainment in mathematics. This evidence suggested that my own struggles were not merely those of an individual negotiating a relationship with mathematics but formed part of a wider phenomenon. My enquiry became focussed on the particular perspective of women mathematics teachers, as I sought to contribute to knowledge of the ways in which professional learning experiences supported their developing relationships with mathematics. The way that mathematics is gendered is central to this understanding, with discourses of mathematics, and school mathematics in particular, constraining choices and provoking conflicts. My professional work, as a mathematics teacher, consultant and later as a tutor

in higher education supporting both experienced and pre-service teachers, and my own previous learning informed my initial research proposal. Through the literature review I aimed to explore existing research in a more systematic way in order to develop my knowledge and understanding of the way key constructs were related and provide a context for the research. The review resulted in a refinement of my original research questions and the addition of new questions.

The chapter begins with a brief foregrounding of perspectives on gender issues in the recent past in order to contextualise the subsequent discussion of mathematics education. The data that initially focussed my attention are followed by an examination of the nature of mathematics and mathematics education in an effort to understand why the subject is frequently rejected. Later, I build on the policy review in the introduction, exploring factors related to effective professional learning together with an examination of key theories and models proposed to explain these. Professional identity emerged as a key aspect of professional learning, albeit one that was little discussed in explicit terms by teachers themselves. As a component of learning theory it aids my study of how teachers come to know mathematics and understand mathematics teaching, both through their experiences as learners and their practice as teachers.

Perspectives on gender have varied through time; a brief overview of prevailing views from the 1960s, when the oldest of the research participants started school, to the present, reflects my own shifting understanding. In the 1960s a social constructionist view began to replace earlier naturalistic approaches. At this time

sex, a biological construct, and gender, a social construct, begin to be distinguished in the literature, supporting arguments that women's roles were socially produced (Richardson, 2008). The way gender roles were learnt and their role in gender inequality became a focus in the 1970s and 1980s, this view of socialisation receiving some criticism as it represented gender roles as stable and individuals as lacking agency (ibid). Postmodern theory views gender as performatively constructed, with gender identities constantly enacted (Butler, 1990). Understanding gender as a performance, 'something we do and are done by not something we are' (Mendick, 2006, p. 10) enables a move beyond fixed categories to an examination of the way these are socially constructed. Gender and mathematics were the focus of much debate throughout this period.

In my research proposal, the main question focussed on teachers' experiences of professional learning. This question was revised to incorporate a focus on gender:

1. What are women secondary mathematics teachers' experiences of professional learning?
 - a. What do they perceive as significant in their professional learning?
 - b. Are there 'critical persons'?
 - c. Do they identify critical incidents/phases?
 - d. Do they see their learning supported?

It was already apparent that there were particular issues for teachers of mathematics so it was to the literature on mathematics that I turned first.

Mathematics

This section identifies current issues in mathematics education, drawing on relevant statistics to provide an outline of the situation. This leads to an exploration of the philosophical foundations of mathematics education, considering how these underpin practice. Learners' perspectives on mathematics are examined through the use of epistemological frameworks which establish stages of coming to know the subject. These suggest an alternative to the often alienating public image of mathematics, an image which is borne out by the stories of learners prevalent in the literature.

Mathematics education: the data behind the stories

The last decade has seen increasing attention paid to mathematics education, highlighting the decline in numbers studying mathematics post-16 coupled with the increasing demand for people with science, technology, engineering and mathematics (STEM) skills in the economy (Roberts, 2002; Smith, 2004). Roberts (2002) noted a downward trend in the numbers of students studying mathematics at the same time as an increasing demand for those with mathematical skills, a shortage of mathematics teachers and poor experiences of students of mathematics. The Smith report echoed concerns regarding the numbers taking A-level mathematics, citing the 'dramatic decline' in A-level mathematics entries between 1999 and 2003 (Smith, 2004, p. 34). More recently, this decline appears to have been halted, with entries rising between 2002 and 2009 (Table 1, p.24). Researching the reasons given for not continuing with mathematics post-16, Brown et al. (2008) found these to be closely related to

predicted GCSE grade, with students predicted a grade B or C believing that mathematics was too difficult for them. The messages teachers communicate to students appeared to add to this conception, contributing to students' decisions not to study mathematics post-16.

Although recent data appears to show an upward trend in numbers studying mathematics post-16 the evidence regarding the participation of girls suggests that all is not well. An examination of the statistics shows that whilst the percentage of female undergraduates in mathematical sciences rose slightly from 39.1% in 2003/4 to 39.6% in 2007/8 the proportion of postgraduate students declined during the same period from 35.3% to 32.0% (Kirkup et al., 2010).

Transition points at all stages see huge numbers of women abandoning mathematics: 70% of women graduating in Science, engineering and technology (SET) do not go on to careers in STEM areas (UKRC, 2010). In Higher Education, for example, women make up 20.3% of researchers, 21.6% of senior lecturers and only 4.4% of professors of mathematics (Kirkup et al., 2010). This loss has been characterised as a 'leaky pipeline' but may also be viewed as a 'sex-based filter' with various layers contributing to the under-representation of women in STEM careers (Blickenstaff, 2005, p. 369). Smith (2004) makes no mention of this gender disparity; indeed the report makes no reference at all to statistics or issues regarding gender and mathematics despite such issues being well-documented in the literature (Ernest, 1995; Walkerdine, 1998; Mendick, 2006; Brown et al., 2008).

	No. of entries	Female entries	Grade A female	Grade A male
2009	64,519	40.5%	46.7%	44.4%
2002	44,156	37.1%	39.0%	34.2%
1999	56,100	36.5%	27.7%	26.6%

Table 1: A-level entries and A grades by gender (DCSF, 2010)

If 'the choice to study maths once it becomes optional remains highly gendered' (Mendick, 2006, p. 7), how do we explain the apparent lack of interest in girls (and women) in mathematics in this key report? Smart describes a 'profound and reactionary transformation in British education' in the 1990s (Smart, 1996, p.226) citing the demise of agencies promoting equality as evidence that gender issues were no longer a government priority. In the 1990s, as statistics demonstrated that girls were now outperforming boys, the public focus shifted from the experience of girls onto underachieving boys (Warrington & Younger, 2000; Griffin, 2000). Warrington and Younger use data gathered from twenty English schools in an attempt to refocus attention, maintaining that girls continue to feel alienated from 'traditional' male subjects (2000). In an effort to understand this alienation I turned my attention to the nature of mathematics itself.

A philosophy of mathematics

Conceptions of mathematics provide a framework for understanding teachers' experiences as both learners and teachers of the subject. A popular image of mathematics as 'difficult, cold, abstract, theoretical, ultra-rational, but important

and largely masculine' (Ernest, 1995, p. 449) is aligned with an absolutist philosophy of mathematics, dominant for over two thousand years. This absolutist view, in which mathematical knowledge comprises certain and unchallengeable truths, is refuted, as its truths are founded on assumptions or beliefs which cannot be proved (Ernest, 1991). The myth of mathematical objectivity remains powerful however, setting mathematics apart from the socio-cultural context in which it is developed (Burton, 1995). The views of learners provide evidence of the challenges such a conception of mathematics presents. Research investigating declining participation in Australian secondary schools found that the perception of mathematics as difficult, boring and irrelevant were offered by 15 to 17 year olds as reasons for the decline (Murray, 2011). Analysis of interviews with undergraduate students of mathematics in England found that some struggled to engage in the discipline, as it is frequently presented as a body of knowledge to be learned rather than one with which they may actively engage (Solomon, 2007a). Research on mathematical images and identities largely confirms the popular image of mathematics presented by Ernest, finding it inaccessible, associated with masculinity and with mathematical abilities perceived as natural (Mendick et al., 2008).

In place of an absolutist philosophy, fallibilist philosophies of mathematics offer a more inclusive alternative, one which supports participation through enquiry, seeing mathematics as 'coming to know through meaning-making' (Burton, 2004, p. 27). Rather than mathematics being rigid and remote, a fallibilist philosophy values conjecturing and problem solving, seeing mathematical meaning as

constructed by individuals (Lerman, 1990). It is this perspective of mathematics as a social and cultural activity which frames this study, the struggle between this and the more prevalent images of mathematics is one focus of an examination of teachers' experiences.

Studies of teachers' beliefs and practices expose their emerging philosophies of mathematics and mathematics education. An absolutist philosophy of mathematics is often associated with a transmission pedagogy (Ernest, 1995) although some reject this link (Rowlands et al., 2011). Teachers may view mathematics as a set of facts, rules and techniques to master, a common experience in classrooms where traditional or didactic teaching is reported (Boaler and Greeno, 2000). In such classrooms teachers are often in authority, with students granted little agency. Research from the United States typifies pedagogical practice as either traditional, based on demonstration by the teacher followed by student practice, or reform, encompassing a range of more open, investigative approaches, which have students actively engaged in knowledge production (Boaler, 2002b). A study of primary mathematics teachers' beliefs and practices identified three orientations to teaching, transmission, discovery and connectionist orientations (Askew et al., 1997). A discovery orientation is characterised by a focus on student exploration, using a variety of often practical approaches. A connectionist orientation emphasises connections between mathematical ideas, with dialogue having a prominent role in learning (Askew et al., 1997; Swan, 2006). These categorisations have been utilised to develop an understanding of teachers' beliefs and practices in order to ascertain how these

develop as a result of professional learning interventions (Askew et al., 1997; Swan, 2006). Teacher belief systems were associated with effectiveness, as measured by student attainment of learning outcomes, with those teachers holding a connectionist orientation the most effective (Askew et al., 1997). Teachers may simultaneously hold beliefs from different orientations, particularly as they consider different pedagogic situations (Swan, 2006).

Epistemological frameworks

At the core of any philosophy of mathematics and mathematics education is epistemology, a theory of knowledge and coming to know mathematics. Several frameworks have been developed to account for the general epistemological development of learners though the first of these was drawn from an exclusively male sample. This early work on intellectual development by Perry in 1970 identified a developmental scheme with individuals moving through various stages or positions of knowing (Safford-Ramus, 2008). Perry's epistemological theory, developed from research conducted solely with white, middle and upper class males, was developed further by Belenky et al. in the 1980s, drawing on interviews with 135 women from a variety of socio-cultural backgrounds (Belenky et al., 1986) and by Baxter Magolda (see Moon, 2005). This work was stimulated by a desire to understand the problems that women reported in their experiences of learning, including doubts about their own ability and an alienation from academic life. Several stages of knowing were identified, comprising silence, received knowing, subjective knowing, procedural knowing and constructed knowing, though the stages may not be experienced sequentially (Belenky et al.,

1986). Two types of procedural knowing can be identified: separate knowing, with an emphasis on rules, and connected knowing, which emphasises relationships, though individuals may move between the two. In fact constructed knowing, the final stage in the model, brings these two voices together, as rational thought is tempered with experience in the creation of knowledge (Becker, 1995). These frameworks have been utilised in a model to support students in the development of their epistemological beliefs, aiding critical thinking (Moon, 2005). They appeared to be useful tools to aid teachers' analysis of their own philosophies of mathematics education, offering a framework for understanding and naming experience. This led to my third research question:

3. Does professional learning support women mathematics teachers in developing an epistemology of mathematics education?

Becker (1995) applies these ways of knowing to mathematics, concluding that the way mathematics is taught alienates many women and suggesting that teaching which emphasises connection, understanding and collaboration in mathematics may affect student performance and attitudes. Brew (2001) uses the theories developed by Belenky et al. and Baxter Magolda (see Moon, 2005) to examine the mathematics learning of women in the further education sector. This study describes women moving from a position of silence, learning mathematics by rote through absolute knowing, transitional, independent and contextual knowing. It is only in this final stage that learners feel they have a voice, understanding that

knowledge is socially constructed and that context and evidence are important (Brew, 2001).

The epistemological framework suggested by Belenky et al. (1986) is further developed by Povey (1997) in an exploration of beginning mathematics teachers' ways of knowing. Her model rests on the concept of author/ity: combining authorship with authority and thus recognising 'each of us as the originator of knowledge' (Povey, 1997, p.332). Four perspectives on knowing are identified: silence, external authority, internal authority and 'the author/ity of self and reason' (ibid, p. 333). Her initial stage, that of silence, is similar to the position described by Belenky et al. (1986) but differs in one significant aspect: Povey maintains that teachers may return to this position despite having access to other ways of knowing. '...even though usually transitory, the perspective of silence is likely to be evoked when one is under threat. In addition, also significantly, it is immobilising.' (Povey, 1997, p. 334). This psychological retreat may trigger actual retreats from mathematics, such as that recounted by a primary teacher-researcher (Hodgen and Askew, 2007). Here the teacher tells of a pivotal moment in her secondary school career, when, at an after-school class for a group of high attainers, she was presented with an 'enormous algebraic equation going across the board' (ibid, p.475). Unable to comprehend it or to access the help she needed, she walked out; the moment signifying her disconnection with mathematics.

An epistemological perspective which views authority as external perpetuates existing structures and systems as knowledge is received, unchallenged. These perspectives of silence and external authority may be prevalent amongst those becoming mathematics teachers as the nature of mathematics knowledge and of school mathematics frequently views authority as external (Povey, 1997). In contrast is an epistemological position which sees authority located in the self, that of internal authority; however this position also views knowledge as fixed. The final perspective, author/ity, is characterised by dialogue and reason where meaning is co-constructed and contextual. From this perspective it is possible to question, to consider alternative possibilities and examine underlying assumptions (Belenky et al. 1986). This final 'emancipatory epistemology' (Povey, 1997, p.338) may be an important starting point in the drive for real change in mathematics classrooms, engagement with epistemological models offering teachers an alternative lens through which to view their experience.

For Boaler and Greeno (2000) the widespread rejection of mathematics at higher levels is due to the apparent prescription of the subject, the demand to follow and apply rules, at a time when students are at a crucial stage of identity formation.

Drawing on Holland et al. (1998) they view social systems as 'ecologies of participation' (Boaler and Greeno, 2000, p. 173), considering students' mathematics learning, positioning and authoring in two quite different figured worlds (the didactic and the discussion based classroom), making use of Belenky et al.'s epistemological framework to categorise students' ways of knowing. They paint a bleak picture of didactic classrooms, suggesting that 'we perpetuate a

cycle of received knowers, teaching received forms of knowing' (Boaler and Greeno, 2000, p. 196). In order to challenge this view, teachers must be supported to review and reconstruct their own notions of mathematics, of learning mathematics and of mathematicians. Burton acknowledges the challenge we face:

It is exceedingly difficult to dismantle the beliefs which have been integral to our learning experiences of mathematics and almost impossible to construct in our imaginations alternatives to the processes which we have been taught and with which we have gained 'success'.

(Burton, 1995, p. 281)

This research aims to establish whether professional learning does support teachers to probe their own learning in order that they may begin to imagine an alternative to these bleak and silent classrooms.

Philosophy enacted

Building on their analysis of women's ways of knowing, Belenky et al. focus on teaching, offering up possible pedagogical alternatives. Drawing on interview data they present a metaphor of 'midwife-teachers' in opposition to Freire's 'banker-teachers' (Belenky et al., 1986, p.217). These midwife-teachers '...assist the students in giving birth to their own ideas, in making their own tacit knowledge explicit and elaborating it' (ibid, p.217). 'They encourage the students to think in their own active voices' (ibid, p.218), valuing students' existing knowledge, supporting them to develop further through dialogue. Connected teachers must

somehow manage to represent the process of their thoughts, their struggles to understand, in order that their students are presented with 'models of thinking as a human, imperfect and attainable activity' (Belenky et al., 1986, p. 217). Ernest emphasises many of the same characteristics in his call for 'inviting public images of mathematics' (Ernest, 1995, p.459), as he elaborates on Gilligan's (1982) connected and separated positions. These positions are viewed as stereotypically feminine and masculine respectively, with the connected perspective linked to fallibilist philosophies of mathematics. The connected teacher supports her students to find their own way, encouraging them to speak, to develop their voices, to work together to seek understanding. These characteristics of connected teaching have strong similarities to Povey's 'social justice curriculum' (Povey, 1998, p.132), one which explores the cultural and historical roots of mathematics through problem posing and critical engagement with personal and public knowledge. Rather than seeking to impose upon students, teachers support them to collaborate. This is not without challenge; Ernest (1995) notes how even teachers who value connected teaching can be forced to comply with external constraints.

This work on a connected pedagogy that was built on firm philosophical foundations, though not new, excited me and helped me to understand my own experience. And yet I questioned why it was new to me. It appeared to me that developing a critical understanding of prevalent pedagogies, together with alternatives, ought to be an aim of teacher professional learning. Thus the fourth

and final research question for my study is:

4. Does professional learning help women teachers to become 'constructed knowers and connected teachers' (Becker, 1995, p. 172).

The following section provides further evidence of alienation in mathematics through learners' experiences, with a particular focus on women and girls.

Experiences of studying mathematics

The recollections of Louise, a student nearing the end of the formal study which would qualify her to teach English, focus attention on aspects of learners' relationships with mathematics (Boylan and Povey, 2009). Drawing on an interview with Louise, the researchers create a story of her experience, capturing memories of her experience of school mathematics. They invite the reader to examine 'the extent to which Louise's relationship with mathematics is and is not a chosen one' (ibid, p.49). Louise is constantly asking 'why?', although not often encouraged to ask out loud, more often lost in the fog 'just randomly hoping for the best' (ibid, p.52). Louise's struggle to understand, her search for meaning, is echoed in the voices of female undergraduate mathematicians (Solomon, 2007a). Solomon analyses first year students' accounts of their experiences of mathematics learning according to Wenger's (1998) framing of identity in terms of three distinct modes of belonging to communities of practice: engagement, imagination and alignment. Rather than finding the students engaged in 'legitimate peripheral participation' (Lave and Wenger, 1991, p.35), Solomon finds

them in a world of mathematics that they do not understand, feeling excluded from the process of negotiation of meaning (Solomon, 2007a).

This alienation from mathematics is not solely the province of students of mathematics. It is articulated by one mathematics educator, who, after obtaining a first class degree in mathematics was left feeling that she had not succeeded at mathematics and that to do any more would be 'indulgent and pointless' (Black et al., 2009, p.26).

Being lost in a fog, not understanding, struggling to grasp the complete picture appears common when engaging in mathematics; a typical cultural response in England is to see this struggle as a sign of lack of 'ability'. An alternative perspective is to see that 'being stuck is an honourable state and an essential part of improving thinking' (Mason et al., 1982, p. ix). A study of the experiences of research mathematicians provides further evidence that this is a key part of doing mathematics, noting an emotional attachment to mathematics; mathematicians talk of grappling with problems, of excitement and uncertainty, of a sense of euphoria when they solve a problem (Burton, 1999, p.135). This view of mathematics is at odds with the prevailing view in school (and university mathematics):

There is a chasm between this perspective on coming to know, and the transmission pedagogy of the classroom dependent as it is on acquiring the knowledge of the expert.

(Burton, 1999, p.135)

Mathematical development

Women who have negotiated these issues and developed successfully as mathematicians provide an alternative perspective on these views of mathematics. When women mathematicians speak about their career experiences (Case and Leggett, 2005), it is difficult to find a single account that does not mention the importance of the encouragement and support given by mentors and other significant figures. The collection of articles by more than one hundred female mathematicians shares fragments of stories of their lives from the late eighteenth century to the early 2000s. One of these women, then a professor of mathematics in the US, recalls a conversation with a mathematics professor:

He said, 'You're not going to get a Ph.D.?'

"I don't know if I can do that," I replied.

"You can do it!"

It was at that moment I really believed I could do it.

(Darden, 2005, p.186)

Other women note the significance of the support and encouragement they received from mathematicians, citing this as instrumental in their decisions to continue to study mathematics, convincing them that they were capable (Walker, 2005; Roberts, 2005).

One striking aspect of these comments by female mathematicians is their own uncertainty and lack of confidence in themselves as mathematicians. Once

noticed, this lack of confidence and perceived failure to measure up as a mathematician pervades the literature. Extracts from the autobiographies of successful mathematics educators paint similar pictures with three of the (female) authors recounting their own feelings of failure and inadequacy in mathematics (Black et al., 2009). Shaw, writing in the same volume reflects on this:

Now if this is true, something is seriously amiss, because if objectively high-achieving teachers do not know, personally, what it means to be good at mathematics, they cannot offer models of success to their students,

(Shaw, 2009 p.89)

A lack of confidence is one reason for the under-participation of girls in mathematics post-16 (Brown et al., 2008). Attempts to attribute a lack, in this instance of confidence, in girls and women, are resisted through post-structural analyses of the 'modern order' that focus attention on how we are positioned by dominant discourses (Walkerdine, 1998, p.164). The disconnected way that mathematics learning is structured contributes to female undergraduates feelings of 'not belonging' as they are marginalised by practices in mathematics (Solomon, 2007a).

Increasingly attention has moved from the concept of confidence, which refers to self-belief without any indication of specific activities, to the construct of self-efficacy which '...includes both the affirmation of capability and the strength of that belief' (Bandura, 1997, p.382). Self-efficacy beliefs are constructed from

several sources of information (mastery experiences, vicarious experiences, verbal persuasions and physical and emotional states) (Bandura, 1997). Human agency, the capacity to plan, direct and reflect on actions, has self-efficacy at its core (Bandura, 2006). As mathematics self-efficacy has been shown to be a significant factor in students' subject and career choices, developing mathematics self-efficacy is seen as increasingly important (Pampaka et al., 2012). Gender differences in mathematics self-efficacy are apparent at school and in higher education, with females having lower self-efficacy scores than males (Pampaka et al., 2012; Zeldin & Pajares, 2000). One study of women in mathematics-related careers found vicarious experiences and verbal persuasions to be influential in the development of self-efficacy beliefs (Zeldin & Pajares, 2000). 'Experiences involving significant others in the women's lives were pervasive in their perceptions of why and how they arrived at their career decisions' (ibid, p. 227). This is supported by the statements from women mathematicians cited earlier. Further consideration needs to be given to career development and the role of communities of practice (Wenger, 1998) in developing self-efficacy beliefs. In the next section teacher professional learning is the focus, ultimately narrowing to examine the learning of mathematics teachers.

Teacher professional learning

Ongoing professional learning is acknowledged to be an important factor in teacher quality, a crucial tool in school effectiveness and, ultimately, a means of improving student outcomes (Wei et al., 2009). Although issues of teacher supply remain important influences on policy, there is increasing support for a shift in attention to in-service learning (Frost, 2012; Schleicher, 2011). Research comes from a variety of perspectives, exemplified in the terminology employed, with references to education, training, development, growth and learning utilised at different times and within different paradigms. Education and training are typically reserved for discussion of pre-service or initial courses (Lerman, 2001), the two terms revealing distinct conceptions of the nature of teaching (MacBeath, 2011).

A commonly adopted definition of professional development in the literature (e.g. Cordingley et al., 2007; Tang and Choi, 2009) involves both planned and naturally occurring learning experiences (Day, 1999, p. 4). Use of the term 'professional development' has drawn attention to particular aspects of teacher learning (individual programmes or activities for example) to the exclusion of the context in which learning takes place (Opfer and Pedder 2011) and there is increasing acknowledgement that this focus is inadequate. The shift from a discourse of professional development to one of professional learning marks the range of opportunities and contexts which may contribute to teacher learning whilst acknowledging that professional development does not always lead to professional learning (Wei et al., 2009). Furthermore it draws attention to teacher

agency, beginning to recognise the importance of teachers' leading their learning. Professional learning is increasingly recognised as an overarching term encompassing individual knowledge creation, with professional development of the 'delivery' kind being just one aspect of this (Timperley et al., 2007). Teacher-directed collaborative learning is incorporated in this definition of professional learning (Cordingley, 2008). In this thesis, the term professional learning is deliberately adopted, with its implicit demand for more active engagement by teachers, for learning which is 'on-going and in-depth' (Timperley, 2011, p.5). The following definition of teachers' professional learning will be used:

... the processes that, whether intuitive or deliberate, individual or social, result in specific changes in the professional knowledge, skills, attitudes, beliefs or actions of teachers.

(Fraser et al., 2007, p.157)

Where sources employ the terms professional development and CPD these terms will be employed in the text.

The variety of terminology in use is reflected in the search terms for the literature review, which focussed on both professional development and professional learning. Studies included in this chapter employ a range of research methodologies; they include large scale surveys together with smaller scale qualitative studies providing a broad overview of professional learning alongside more detailed glimpses. The systematic reviews produced by CUREE provided

useful starting points as did a best evidence synthesis of local and international research commissioned by the Ministry of Education in New Zealand to explore the kinds of professional learning opportunities that impacted on student outcomes (Timperley et al., 2007, p.1).

Traditional models of teacher learning or CPD were based on a training or deficit model, comprised of one-off courses offered by external providers (Hoban and Erickson, 2004). They were founded on the assumption that to facilitate change it was sufficient to present a new initiative to teachers and train them in its use (Hoban, 2002), training them in order to rectify a perceived deficit in knowledge and skills (Clarke and Hollingsworth, 2002). The language of 'delivery' was common when referring to CPD (Timperley et al., 2007), with learning seen as the acquisition of knowledge (Sfard, 1998). Increasingly, questions were asked about the effectiveness of this CPD as much money was spent on teacher professional development initiatives with little apparent effect (Borko, 2004; Clarke and Hollingsworth, 2002; Timperley, 2011). Explanations offered for this point to weaknesses in the strategic planning and organisation of learning opportunities (Pedder and Opfer, 2011), difficulties in evaluating the success of professional learning in terms of student outcomes (Muijs and Lindsay, 2008) and, perhaps most importantly, restrictions imposed by the conceptual framework adopted to characterise professional learning (Opfer and Pedder, 2011). Many of these opportunities are characterised by a lack of teacher agency and are often divorced from practice.

The failure of these early training models led to increased research into teacher development and resulted in a

...shift in focus from earlier conceptions of change as something that is done to teachers (that is, change as an event with teachers as relatively passive participants), to change as a complex process that involves learning

(Clarke and Hollingsworth, 2002, p. 948)

Although a cognitive perspective emphasising learning as individual construction (Cobb, 1994) can aid an understanding of teacher learning, for example through deliberate reflection, it does not fully explain individual identity construction or the failure to transfer learning from one context to another (Hoban, 2002). A situated perspective on learning addresses these issues, emphasizing the role that context plays in learning.

In Wenger's (1998) social theory of learning, four components of learning: meaning, practice, community and identity are integrated. Learning is viewed as 'an integral part of our everyday lives' (1998, p.8); our challenges arise from the way that we problematise learning, trying to manage it, by acceleration for example. Practice is learning in action, the process by which communities of practice recreate themselves. Community is characterised by mutual engagement, joint enterprise and a shared repertoire (ibid, p.73). For teachers, often working in isolation in their classrooms, this community is recognised in formal and informal structures for collaboration. Wenger's model is relevant for

thinking about teacher learning, as learning through practice is increasingly recognised as an important way in which teachers learn (Hatch et al., 2005; Hoekstra et al., 2007; Wei et al., 2009). Learning...

...changes who we are by changing our ability to participate, to belong, to negotiate meaning. And this ability is configured socially with respect to practices, communities, and economies of meaning where it shapes our identities.

(Wenger, 1998, p.226)

Viewed in this way it becomes apparent that traditional models of teacher learning through attendance at 'training' courses, separated from the workplace, which frequently demanded little in the way of active engagement from participants, are likely to have limited success. Professional development is re-conceptualised as teachers learning within and through a community of practice, teachers as learners with the school viewed as a learning community (Clarke and Hollingsworth, 2002).

Professional learning can encompass a range of experiences, both formal and informal. One framework classifying professional development in terms of teacher agency identifies nine models (Kennedy, 2005). Those which aim to prepare teachers to implement reform (transmissive models) are distinguished from those which support teachers to engage as active participants, contributing to policy and practice from an informed, critical stance (transformative models) (ibid). Action research is the key model in this transformative CPD. Models

which could be used in either a transmissive or transformative way are termed 'transitional'; included here are mentoring/coaching and community of practice models. The framework illustrates the changing discourse and evidence base in the field of professional learning: award bearing courses are described here as transmissive, based on the Scottish model of accreditation leading to Chartered Teacher Status (Kennedy, 2005) whereas more recent research examining teacher professional learning through participation in Master's degree courses demonstrates the transformative potential of these courses (Turner and Simon, 2013; Kersher et al., 2013; Edwards, 2008). Nonetheless, this focus on the purpose of professional learning highlights the importance of teacher agency.

Effective professional learning

Recognition that professional learning has an important role to play in improving student outcomes led to an increase in funding to provide opportunities for teachers. Comprehensive syntheses of in-depth studies of continuous professional development (CPD) and teacher learning seeking to ascertain characteristics of effective learning have pointed to a range of significant factors which can be broadly categorised as relating to:

- the activities through which learning takes place and the resources required (activities which are increasingly recognised as embedded in practice),
- the individual teacher and

- the sociocultural context (at school and national level).

Each of these will be discussed below and later related to key models and theories of professional learning in education.

Learning as situated practice

Key features of effective professional learning include active participation, collaboration, the need for learning opportunities to be sustained, coherent and intense, the importance of content, access to research and to external support. There is some agreement that five of these features (a focus on content, active learning, coherence, duration and collective participation) result in effective teacher learning (Desimone, 2009). This supports a view of learning as engagement in, and development of, practice (Wenger, 1998) and implies a transformative model of teacher professional learning. Such a model explains those studies that find that the forms of professional learning that have the most impact demand active participation by teachers, typically structured around enquiry, collaboration, coaching and mentoring, observation and networks (Opfer and Pedder, 2010).

A focus on content and the importance of active learning is supported by the findings from an empirical study of over 1,000 mathematics and science teachers (Garet et al., 2001, p.935) and borne out by large-scale reviews of research emphasising the relevance of content, the role of active experimentation and the link to practice (Timperley et al., 2007; Darling-Hammond et al., 2009). Effective professional learning content incorporates specific tasks related to practice,

including pedagogical skills, teaching aspects of content and analysis of student learning (Wei et al., 2009). What teachers are learning is the focus rather than how, with knowledge and skills meeting 'the double demand of being both practical and understood in principled ways that can be used to solve teaching and learning challenges encountered in the future' (Timperley, 2011, p.7).

In the UK the positive impact of collaborative CPD on teaching and learning was established through a comprehensive review of over 250 studies, with an in-depth review of 17 studies (Cordingley et al., 2003). Benefits of collaboration included increased teacher confidence and willingness to try out new practices together with improvements in student performance and attitude. Collaboration also helped to sustain changes in practice. Research from the United States identified strong working relationships as one of four key features for the design of professional learning (Darling-Hammond et al., 2009 p.11). Here, peer observation and feedback, the use of video followed by peer analysis and collaborative planning were all found to support the development of professional learning communities which focused on the resolution of issues arising from practice. Collaboration with specialists, including those external to the workplace, can support and challenge teachers, build confidence, encourage experimentation and impact on student outcomes (Cordingley et al., 2007; Timperley et al., 2007).

A large-scale empirical study reported that 'sustained and intensive professional development is more likely to have an impact' on practice than more traditional

short courses (Garet et al., 2001, p.935). The importance of both intensity and duration in professional learning experiences has been widely recognised. A key study from the United States noted that teachers participating in programmes comprising over 80 hours of professional learning in one year were more likely than those who had much reduced access to make changes to their practice, with subsequent gains in student outcomes (Darling-Hammond et al., 2009, p.9). Furthermore, the prominence of professional learning in a teachers' working week is a distinguishing feature in those countries that perform well in the international surveys Programme for International Student Assessment (PISA) and the Trends in Mathematics and Science Study (TIMSS); countries allocating less than half of a teacher's working week to teaching were able to support teachers' participation in coherent and sustained professional learning (Wei et al., 2009). The relationship between time and impact is not straightforward however, as extended time for learning was found to be necessary but not sufficient for promoting professional learning; what was more important was how it was used (Timperley et al., 2007).

Teachers engaging in and/or with research into a range of aspects of learning and teaching can have a positive impact on student outcomes (Bell et al., 2010). Critical friends (often from outside the teachers' workplace), peer collaboration, and institutional support were all important in supporting this, with teacher learning needs derived from a focus on student learning needs (ibid). Support for teachers to develop or participate in small-scale research projects focussed on classroom practice has continued to grow over recent years.

The focus on teachers developing their knowledge and practice throughout their careers is now accepted as a key part of teaching, with teaching viewed as 'disciplined enquiry', requiring 'ongoing study of oneself' (Mason, 2009, p.205). Many of the studies reported above note the importance of opportunities to embed professional learning in practice rather than making it distinct from it, with reflection on practice a central component. Recent research devoted to understanding teacher learning points to the important role that informal learning may play in teacher development (Hoekstra et al., 2007). Such informal learning situated in the workplace gives learners greater freedom and increased agency (Eraut, 2004, p.247). A study of one teacher's experience over the first four years of her teaching career (Hatch et al., 2005) demonstrates that teachers do not necessarily learn from experience; both workplace culture and individual teacher factors affect learning (Day and Gu, 2010).

The individual teacher

The influence of an individual's biography on their professional learning is increasingly recognised as important (Hoban and Erickson, 2004; Day and Gu, 2007). A review of research into informal learning identified several factors influencing individuals' learning at work: challenge, feedback and support, confidence and commitment (Eraut, 2004). Eraut notes 'the overwhelming importance of confidence', stating that 'if there is neither a challenge nor sufficient support to encourage a person to seek out or respond to a challenge, then confidence declines and with it motivation to learn' (ibid, p.269).

An analysis of the informal learning of four teachers over the course of one year adopted a broad perspective on professional learning, finding that often neglected emotional, motivational and behavioural aspects need to be considered in addition to cognitive aspects (Hoekstra et al., 2007). Expanding on Eraut's (2004) typology of informal learning, three categories of learning were identified: deliberative (conscious, planned activities with clear goals), reactive (conscious, unplanned activities which can be characterised as 'reflection-in-action' (Schön, 1983)) and implicit learning (unconscious). These levels of awareness of learning, together with the importance of individual and contextual factors, need to be incorporated into any theory of teacher learning. The authors raise questions about the extent to which teachers consider themselves as learners, recommending that affect and emotion are considered when planning for teacher professional development and support is given for teachers to practice new approaches in the classroom (Hoekstra et al., 2007).

One construct which has received increasing attention in the study of teachers' professional lives is resilience, or the ability to withstand adversity. Resilience is 'both a product of personal and professional dispositions and values, influenced by organisational and personal factors and determined by individuals' capacities to manage context-specific factors' (Day and Gu, 2010, p.158). Whilst there is considerable research into factors which promote resilience in children (e.g. Oswald et al., 2003; Wang, 1997), much less is understood about teacher resilience, though it is apparent that it may be developed through the interaction of individual and contextual factors (Day et al., 2011). In addition to personal

attributes, relationships and the social context, the degree of agency that teachers are able to exercise contributes to resilience. At one extreme, teacher resilience can direct attention to an individual's ability to manage stress, carrying no implications for workplace change (Price et al., 2012); more positive possibilities include work to ameliorate the increasingly challenging working conditions that teachers face for example by re-appropriating curriculum development or improvements in work-life balance.

Contextual factors

In addition to factors related to individual teachers and those relating to the nature of the professional learning opportunity, context plays a significant role in the effectiveness of professional learning for teachers. There is some evidence from large-scale reviews of research that professional learning is more effective when it is aligned with practice and policy at school or wider local level (Darling-Hammond et al., 2009) with coherence with school practice facilitating the integration of new practices (Garet et al., 2001). Related to this, consistency of content with broader policy and the active involvement of leaders were found to be important factors (Timperley et al., 2007, p.xxvi).

Support for teachers' professional development was the focus of a study of effective, motivated and experienced high school teachers in the US. Teachers referred to their professional development as a 'self-journey' with school leadership playing an insignificant role; colleagues were the most significant

persons (Meister, 2010, p.889). One teacher described a 'community of conversation' (Meister, 2010, p.890) with colleagues, using this as a critical lens through which to view practice (Brookfield, 1995). These professional learning communities, found to be important in bringing about change in mathematics teachers' practices and in terms of student learning, provide an important forum for supporting and challenging teacher learning (Borko, 2004).

A focus on the 'professional' in professional learning helps to illuminate the significance of wider contextual factors. The concept of professionalism in teacher development is complex and contested, with usage of the term shifting from 'a means of sociological classification to an instrument of political control' (Kennedy, 2007, p.96). The debate focuses on the interrelated concepts of knowledge, autonomy and responsibility; the nature of professionals' work means they need specialist knowledge and autonomy in order to exercise judgement with responsibility (Furlong et al., 2000, p.5). Changes in the nature of knowledge for teaching together with changes in teacher autonomy affect teacher professionalism. A managerial perspective enforced through a process of compliance with teaching standards appears as a dominant discourse (Kennedy, 2007; Sachs, 2001). This restricts opportunities for democratic professionalism, a concept which has collaboration at its core (Whitty, 2006), instead directing attention towards professionalism as an individual venture, aimed at meeting standards. In response, emerging from the discourse of the democratic professional is a call for teachers to develop an activist professional identity (Sachs, 2001). This is not without challenge although Sachs proposed that the

development of reflexive self-narratives exploring the social and political contexts of teachers' lives, together with the development of communities of practice will support teachers to develop an activist identity. Timperley calls for 'a defensible theory of professionalism', one which uses critical reflection to consider the evidence about student learning, actively seeking solutions to longstanding issues (Timperley, 2011, p.8).

Theorizing professional learning

Approaches to learning theory posit that both cognitive and situated perspectives can be used, deepening understanding (Sfard, 1998; Hoban, 2002). Hoban likens this to using two different lenses: a close-up lens, focussing on the individual (cognitive perspective) and a wide-angle lens to examine the wider context (situated perspective) (Hoban, 2002, p.58). To counter the loss of middle-vision, 'the interplay between these two perspectives' (ibid, p.58) he proposes using a systems unit of analysis, the 'individual in related action' (ibid, p.59) emphasising key features of a cognitive and situative perspective but focussing on relationships between elements such as culture and knowledge. This view of teacher learning as a complex system foregrounds the conditions necessary for teacher learning: a view of teaching as a profession, the role of reflection, the need for a clear purpose for learning, a sustained programme, the support of a community, opportunities to try out new ideas in practice, a range of sources of knowledge to stimulate learning and feedback from students to gauge

effectiveness (ibid, p.69). This approach was consolidated in complexity theory in the 1990s, drawn from work in the sciences and gaining currency in the business world; as further research identified factors which contributed to successful change in education, recognise the complex relationships between them, it became a more prominent approach in education (Hoban, 2002). It offers a perspective on professional learning which acknowledges the uncertainty and unpredictability of change whilst enabling us to establish the conditions in which learning is likely to flourish (Knight, 2002).

The interconnected model of professional growth (Clarke and Hollingsworth, 2002), grounded in empirical research drawn from three projects, including longitudinal studies of primary and secondary mathematics teachers, together with videos of science and mathematics lessons and teacher interviews, acknowledges the complex, individual nature of professional learning. Characterised by four domains (external, practice, personal and consequence) within a change environment the model identifies a variety of networks which result in learning through a process of enactment and reflection. A strength of the model is that it allows for these external sources to be information or stimuli in addition to professional development programs, thus broadening the scope of the model to encompass learning through engagement with research, with communities of practice or through teacher inquiry. Here again the significant role played by the 'change environment' or broader socio-cultural context within which teachers work is highlighted, affording or constraining teacher learning.

This interconnected model of professional growth continues to provide a useful framework for understanding professional learning (Goldsmith et al., 2013).

Complex systems theory aids an examination of teacher professional learning, highlighting the importance of models which view professional learning as embedded in teachers' professional lives (Opfer and Pedder, 2011). Much earlier research has simplified teacher learning, focussing on particular activities or programmes (the micro context) and neglecting to consider teachers' complex working environments. This oversimplification is countered through complex systems thinking which 'assumes that there are various dynamics at work in social behaviour and these interact and combine in different ways such that even the simplest decisions can have multiple causal pathways' (ibid, p.378). Three nested systems are identified, each interacting to different degrees: the individual teacher, the school system and the activity. Through a rigorous literature review process Opfer and Pedder identify key features of these systems which may facilitate teacher learning. Activities which have been shown to be effective are those which incorporate the features of effective professional learning noted earlier. The intensity of collaboration is one important dimension: although studies have shown that collaboration is important there are situations where this may not facilitate learning, for example a group of teachers working together may establish group norms which restrict growth. Teachers' past experiences and beliefs affect the individual teacher system, with their pedagogical decisions influenced by the teaching they themselves experienced. A teacher's orientation to learning is formed through a dynamic process of interaction between their

knowledge, beliefs, practices and experiences (ibid, p.388); any dissonance in this system can provoke change.

Teacher learning opportunities described as transformative, predicated on critical enquiry and teacher autonomy, and including action research and other approaches which consider issues of power, open up the possibility of teachers contributing to the policy debate (Kennedy, 2005). Such opportunities appear to be more effective when the individual teacher works alongside colleagues, often from the same workplace. Teacher learning through inquiry and action research has a long tradition, offering important opportunities to contribute to a 'transformative educational agenda' (Groundwater-Smith and Mockler, 2009, p.4). In English schools this work gained momentum in the work of Stenhouse and the Humanities Curriculum Project in the 1970s (Stenhouse, 1975) and continues to be an important tool for teacher learning. The evidence points to the centrality of teacher agency as a key aspect of effective professional learning yet the models of professionalism discussed earlier identify limits imposed on this agency.

Reflection on practice, the means by which teachers move from 'perplexity to improvement' (Tripp, 2012, p.xii), supports teacher learning through reflection on emotionally troubling experiences. What appears to be missing from the accounts of professional learning is an explicit, on-going focus on teachers examining their own knowledge, beliefs and practices, looking critically at what they know, do and understand. Action inquiry through the study of critical incidents is one approach to address this through a structured, collaborative

approach to developing professional judgement (Tripp, 2012). This approach provides the opportunity to examine in depth the 'practical, political and epistemological problems' (ibid, p.153) that teachers face in their working lives, enabling them to explore the tensions and constraints experienced as a result of competing discourses of schooling, in particular school mathematics.

Identity

The dynamic process of identity development is a significant, yet often overlooked, aspect of professional learning. Although there is a proliferation of education research focussing on identity, until recently it was less common in mathematics education (Black et al., 2009) and rarely the subject of explicit focus in teacher professional learning. A variety of perspectives on identity are evident in education research including sociocultural (with a focus on practices and participation), discursive (focussing on language and power) and psychoanalytic (exploring the role of the unconscious) amongst others (ibid), creating a shifting framework to aid critical reflection. This process of identity formation emerged as significant in the literature on learning mathematics (Boaler and Greeno, 2000; Solomon, 2007b), offering me a useful frame for further exploration of teacher learning.

The concept of identity is central to Wenger's model of learning, '... a way of talking about how learning changes who we are and creates personal histories of becoming in the context of our communities' (Wenger, 1998, p.5). The concept of

identity narrows the social theory of learning to focus on the individual whilst simultaneously expanding the gaze to include broader social structures. It acts as a bridge between the individual and the community, acknowledging that our development as individuals is set within the particular communities we inhabit. Our acts are always a negotiation of our individuality and the practices of communities. This consideration of the role of communities in identity development focuses attention on the support and challenge available to mathematics teachers throughout their careers and the impact this is perceived to have on their identity. That identity is viewed as ‘...the constant work of negotiating the self’ (ibid, p.151) legitimises the study of identity over time.

Identity is enacted in practice; it is about how we live, not merely the stories we tell about ourselves, a ‘very complex interweaving of participative experience and reificative projections’ (Wenger 1998, p.151). As a constant process of negotiating self, it is temporal, ongoing and complex. This view is supported by research findings from a longitudinal research project studying 300 teachers in both primary and secondary schools (Day and Kington, 2008). This study demonstrates that teacher identities are neither intrinsically stable nor intrinsically fragmented but that they vary over time according to the interaction of personal, professional and situated factors. Defining identity as ‘the way we make sense of ourselves to ourselves and the images that we present to others’, Day and Kington (2008, p.9) note the ‘unavoidable interrelationship between cognitive and emotional identities’ (ibid, p.8) and the importance of emotion in the construction of identity. They highlight the need for teachers to be resilient, recommending

that policy makers and school leaders consider the implications of policy change on teachers' professional identity.

Despite, or perhaps because of, the proliferation of research focussing on identity, there are considerable challenges in attempting to define the term. These difficulties become apparent when researchers try to use identity as an analytic tool (Sfard and Prusak, 2005). Whilst acknowledging the influence of Lave and Wenger in exploring the culture of learning, together with the subsequent work of Gee (2001 cited in Sfard and Prusak, 2005) and Holland et al. (1998), Sfard and Prusak nonetheless find the definitions of identity posed in these works incomplete, relying as they do on 'who one is' or 'being a certain kind of person' (ibid, p.16), implying a fixed state and denying agency.

In their quest to operationalize identity Sfard and Prusak refer to it as 'stories about persons' (ibid, p.14), a narrative definition of identity that foregrounds human agency and permits change; identity is not static, implying freedom and responsibility, an interrelationship between individual and community. Identity is viewed as a vision of experience rather than the experience itself, making identities 'discursive counterparts' of our lived experiences (ibid, p.17). The relationship between identity and learning is reformulated; learning is seen as the means by which we move from our actual identity, our narrative of the actual state, towards our designated identity, or expected state. Crucially, these designated states are not always chosen or desired; although they are often perceived as inevitable and are resistant to change, they are created from

fragments of stories. Our 'identities are products of discursive diffusion – of our proclivity to recycle strips of things said by others...' (ibid, p.18). Our narratives about ourselves then, are shaped both by the stories we tell about ourselves and the stories that others tell about us. The most important influence on our actions comes from both 'significant narrators' and 'institutional narratives' (ibid, p.18), the latter being external recognition (for example certificates, diagnoses) and self-fulfilling prophecies build our stories of success or failure. The power of discourse in shaping identity directs attention to teachers' narratives, to the relationship between identity and agency and the influence of context, pointing to the importance of an explicit focus on professional identity work in initial teacher education, building on reflection (Beauchamp and Thomas, 2009).

A consideration of community and identity in teacher professional learning led me to my second research question:

2. Does their professional learning help them to situate themselves in the mathematics community? Does it help them to develop their identity as mathematicians or mathematics teachers?

Professional learning in mathematics

In this section I consider the professional learning of mathematics teachers, building on the more generic factors explored above and considering the extent to which the conditions necessary for effective professional learning are present in teachers' working lives. The particular focus on mathematics education, discussed earlier, has resulted in a corresponding focus on mathematics teacher

learning. This recognises the variety of activities involved, often acknowledging the role of the teacher in planning an individual programme (ACME, 2002). A review of the literature, commissioned by the National Centre for Excellence in the Teaching of Mathematics (NCETM), recognised the importance of informal learning whilst cautioning that opportunities were not fully exploited or supported (Joubert and Sutherland, 2009). Formal opportunities, categorised in terms of structural features, include learning focussed on aspects of mathematics, classroom enquiry and groups of teachers working together. Often these are supported by researchers or teacher educators. The review identifies three aspects of mathematics knowledge for teaching, building on Shulman's (1987) categories: knowledge about mathematics, about students' understanding of mathematics and pedagogic knowledge (Joubert and Sutherland, 2009, p.27). The complex interrelationship of knowledge, belief and awareness is highlighted as an area for further research.

In the synthesis conducted for the New Zealand Ministry of Education considered earlier twenty-one studies focussing on mathematics were examined, although only one of these core studies focussed on the professional learning of secondary school teachers (Timperley et al., 2007). There appeared to be greater involvement by policy makers in mathematics than in other subject areas, perhaps in the main due to the concerns raised earlier and the importance of mathematics to the economy. Dissonance between the teachers' existing views of mathematics and the approaches promoted through the professional development was an important feature: 'Teachers whose student outcomes

improved resolved their dissonance and implemented new approaches to the teaching of mathematics' (Timperley et al., 2007, p.89). Most of the studies allowed the opportunity for teachers to develop their own mathematical knowledge, to construct meaning and to experiment in practice over time. The majority of studies found that 'multiple approaches to mathematical problem solving were encouraged' (ibid, p.78); supporting more connected, student-centred ways of learning and teaching.

A more comprehensive review of research into the professional learning of practicing mathematics teachers considered over one hundred articles written between 1985 and 2008 (Goldsmith et al., 2013). The majority of studies focussed on the primary phase, with only 17% exclusively researching secondary teacher learning. This synthesis utilises the interconnected model of professional growth developed by Clarke and Hollingsworth (2002) from empirical studies of mathematics teacher learning discussed earlier. A large number of studies reported a focus on teacher beliefs and teacher identity, in particular noting an impact on teachers' beliefs about practitioner inquiry, collaboration with colleagues and self-efficacy. The focus on collaboration and community was recognised as one of the six key categories identified in the review, with benefits including the articulation of tacit knowledge, the development of shared understandings and peer support. This collaboration with colleagues on a range of activities was also found to impact on teachers' mathematics content knowledge. The recent review upheld the view that

'professional growth is more likely to proceed through a series of incremental changes in knowledge, beliefs, dispositions, and classroom practices –changes that eventually lead to improved outcomes for students – than to be a direct path from a single professional development experience to a change in practice to improvement in student outcomes'

(Goldsmith et al., 2013)

Their findings suggest that the impact of professional learning varied between individuals and across contexts, highlighting the significance of the individual and social factors discussed previously. In addition they note that the studies reviewed typically focussed on the effectiveness of particular professional development programmes rather than on understanding teachers' learning (Goldsmith et al., 2013).

In Chapter 1, policy shifts in teacher professional learning were explored, identifying a recent focus on teacher subject knowledge. In mathematics, it is noticeable that existing research on teachers' knowledge is predominately conducted with those in initial teacher education and/or with primary teachers; much less is known about secondary mathematics teachers' subject knowledge (McNamara et al., 2002). Historically, having a degree was seen as adequate preparation for entering teaching (Galvin, 1996) with graduates tending to enter teaching in the secondary phase. However, an examination of research studies shows some evidence that subject knowledge, measured by qualifications or by amount of instruction, is not a reliable indicator of teacher effectiveness

(McNamara et al., 2002). For these researchers, secure knowledge of mathematics, by which they mean 'its modes of inquiry and the integrity or 'connectedness' of its content' (ibid, p.17) is associated with teaching judged effective though they find scant evidence that this knowledge is developed through teaching.

There has been considerable interest recently in researching teachers' beliefs and practices, particularly in the field of mathematics education. These beliefs inform thoughts and actions, steering decisions and affecting practice, hence consideration of teachers' beliefs is important in the planning of professional learning opportunities (Swan, 2006). In one study, an instrument designed to evaluate changes in teachers' beliefs and practices following a professional development intervention also became a stimulus for reflection amongst participants (ibid). Exploring the knowledge, beliefs and practices of primary teachers in an endeavour to find the distinguishing features of effective numeracy teaching, Askew et al., (1997) found that the teachers' beliefs were important; those 'connectionist' teachers, who had an understanding of appropriate methods of calculation, who emphasised reasoning and justification, who encouraged their students to apply knowledge and understanding in problem solving, promoting dialogue as a route to understanding believed that most students could become numerate, were the most effective.

Examining the role of research in the professional development of mathematics teachers De Geest (2010) studied thirty CPD initiatives, finding over 75% of these

used research in some form, either utilising published research or by participants' active engagement in research. Teachers were overwhelmingly positive about the benefits, reporting that engagement with research stimulated their thinking about practice, heightened their awareness of alternative perspectives and increased their confidence to explore new ideas in practice.

Since I began my research interest in the area of teacher professional identity has continued. Focussing on the co-constructed biographical narratives of two mathematics teachers working in sixth form colleges, Williams (2011) analyses the way that individuals author themselves dialogically in 'figured worlds' (Holland et al., 1998). He notes the way in which their own teachers assume significance as either model or 'anti-model' figures in the construction of their identities (Williams, 2011. p.140). Their own learner selves are important figures in their biographies; their own relationships with mathematics and the figures of their teachers are used as a justification for the type of teacher they are. Williams suggests that that these narratives may be used to prompt critical engagement with identity work.

School mathematics: teaching and learning

Teacher beliefs and teacher knowledge have received increasing attention since the late 1980s, prompted by concerns over standards in mathematics. In part this concern was due to the availability of performance data, allowing comparisons with other countries, and to a 'national audit culture of league tables, targets, and inspection evidence' which exposed variation within this country (McNamara et

al., 2002, p.7). Policy developments traced in Chapter 1 add to this picture; here I will turn to a brief consideration of teacher knowledge.

Noting that the competency-based curriculum for initial teacher education was dominated by a desire for knowledge of procedures, Shulman (1986) remarked on the absence of subject matter knowledge. 'No one asked how subject matter was transformed from the knowledge of the teacher into the content of instruction' (ibid, p.6). In an attempt to address this 'missing paradigm' he set out seven categories of knowledge for teaching (Shulman, 1987, p.8). Of these categories, pedagogical content knowledge, 'subject matter knowledge for teaching', includes an understanding of ways of representing the subject to learners and an awareness of challenges, common misconceptions and strategies for overcoming these (Shulman, 1986, p.9). Content knowledge requires an understanding beyond mere facts and concepts to the structures, both substantive and syntactic, of the subject. The limitations of this cognitive model of teacher learning, together with the restrictions implied by an alternative focus on teacher learning through reflection, provoked Shulman and Shulman (2004) to revisit earlier conceptualisations of teacher learning, acknowledging that these needed to be situated within communities and within the contexts in which teachers operated. They developed a new model to explain teacher learning, drawing on six dimensions: vision, motivation, knowing and understanding, being able to do (i.e. put into practice), reflecting on practice and working in communal ways (Shulman and Shulman, 2004). Much of Lee Shulman's earlier work on knowledge for teaching is hence subsumed into this new model within the dimension of knowing

and understanding. Though not without criticism (see McNamara et al., 2002), Shulman's model has been further developed by mathematics education researchers, finding that in addition to their beliefs or philosophy of mathematics education, primary teachers' classroom practice is also influenced by their pedagogic content knowledge (Askew et al., 1997).

Summary

Existing research notes the complexity of teacher professional learning, identifying the interaction of teachers' knowledge, beliefs and practice and the influence of social and contextual factors. Although much is known about the factors likely to lead to effective professional learning, less is known about individual teachers' experiences of professional learning throughout their careers. Teacher identity emerges as significant in professional learning, beginning to be the subject of explicit focus in initial teacher education programmes. In mathematics, teachers' relationship with the subject informs their epistemological stance and contributes to their professional identity formation. The association of mathematics with masculinity presents additional challenges in identity work. Research on mathematics teachers' experiences of professional learning throughout their careers and on informal learning at work is limited; research on mathematics teacher professional learning is largely focussed on primary teachers. This study will explore women mathematics teachers' experiences of professional learning throughout their careers, considering the role of community in ongoing identity work. Attention will focus on the role of professional learning in

aiding teachers to make sense of mathematics through their experiences as learners and as teachers.

3. Methodology and methods

The purpose of this chapter is three-fold: to describe the research methods, to justify the methodology and methods as appropriate means of addressing the research questions and to explore the underlying assumptions, values and issues in relation to the research. These underlying assumptions form the foundations for the methodological design of the study and will be considered here first in relation to the research questions, followed by detailing the practical enactment of the research methods themselves.

From the outset my concern was to elicit teachers' stories of their professional learning experiences, to work with them to construct personal life histories. The main tool for data collection was the interview conversation. Alongside the research, entwined with it, were two other strands: my own development as a researcher ('becoming a researcher') and an exploration of my own life story ('how did I get here?'). As I worked I became increasingly aware of the 'becoming a researcher' strand, picking my way through paradigms, approaches and methods, borrowing and reshaping in order to craft the tools that would do the main research project justice. The approach evolved and in a way that is perhaps best described as 'bricolage' (Kvale and Brinkmann, 2009, p.233) as I explored narrative approaches together with discourse analysis in order to maximise my ability to hear what the women were telling me.

Methodology

Research methodology encompasses a justification of methods but is much more than this; the overall plan or research design is constructed in order to meet the identified research outcomes (Crotty, 1998). Underpinning this methodology is an epistemology embedded within a philosophical approach or theoretical perspective. These fundamental aspects of research have been the source of many of my challenges through the course of this research, challenges exacerbated to some extent by those texts which imply, perhaps inadvertently, that research is a straightforward process of deciding on a design and justifying it. My own experience is much messier. This thesis began to take shape as a research proposal three and a half years ago; during that time, my knowledge and thinking about research have been transformed. I am still bound to that original proposal; it serves as a point of reference for me as I construct this account. Rather than being confined to this chapter, the research methodology will be evident throughout the thesis; the process of continually justifying my approaches, a methodological self-consciousness (Clough and Nutbrown, 2012, p.39) resulting in what can be termed an emergent design (Merz, 2002). The research reported here is grounded in my experience; the story of the research is also, in part, my story, as researcher and research cannot be separated (Wellington et al, 2005).

This research is conducted from a feminist standpoint; here I outline my understanding of this and the implications for my research. There is no one accepted view of feminist research. Definitions of feminism itself are debated, a

point acknowledged in a definition of feminist research methods as those methods used by people identifying themselves as feminist (Reinharz, 1992, p.6). This self-identification rejects an authoritative definition of feminism and feminist research methods and avoids difficulties caused by shifts in definitions over time and between disciplines. There are, however, common themes apparent in feminist methodology, amongst them that feminist research aims to promote social change, frequently includes a discussion of the researcher's positionality and often strives to place the researcher and participant on a more equal footing, creating special relationships with both the participants and the readers (Reinharz 1992; Brayton, 1997). The researcher is in the research, rather than a detached outsider looking in. During the early stages of the research, my reading, coupled with my own engagement with autobiographical work focussing on my professional learning, led to a realisation that the focus of the research must be on women mathematics teachers. This focus was aligned with the common methodological features of feminist research: it concentrated attention on women's experiences, set out to produce research for women and located the researcher in the research through a reflexive stance (Harding, 1987). It allowed me to explore issues of gender and mathematics, building on work discussed in the previous chapter.

Positionality

Feminist research methodologies are emancipatory, aiming to empower and give voice to women. My aim in this research is to explore women's experiences of professional learning in order to aid women's understanding of themselves and

their work; research designed for women in this way is one aspect of feminist analysis (Harding, 1987, p.8). Feminist researchers locate themselves in the research, exploring the influence of their own background (Harding, 1987; Ezzy in Cohen et al., 2007, p.35-36; Mies, 1993), this stance necessitating a 'critical reflexivity' (Burns and Walker, 2005, p.67). An 'auto/biographical process' which notes the researcher's role in knowledge construction, the contextual nature of knowledge and the influence of the knowledge-producer, asserts that the autobiography of the researcher is 'epistemologically crucial' (Stanley, 1993, p.49-50). Engaging in autobiographical work and adopting a reflexive approach throughout support me to explore my positionality and enables readers to consider how my values influence the research (Wellington et al., 2005; Greenbank, 2003).

Ethical considerations, including those of power and relationships, permeated the study as I attempted to work backwards from the (imagined) final research report: how could I make the stories accessible, give voice to participants and satisfy the examiners? The relationship between researcher and participant was an important consideration in planning my research. For Mies the

methodological principle of a value-free, neutral, uninvolved approach, of an hierarchical, non-reciprocal relationship between research subject and research object...drives women scholars into a schizophrenic situation' having to constantly disregard their own experience of 'sexist oppression'.

(Mies, 1993, p.67)

To act against this implies actively involving participants throughout the research. The Initial Study provided me with the opportunity to consider the extent to which this was possible, the final research design represents a compromise between my own desire for collaboration, the teachers' own needs and the complex relationship between us.

A theme running through several accounts of feminist research methodology is that of the role of the research in consciousness raising (Mies, 1993; Reinharz, 1992; Cohen et al., 2007). From the outset, this research was conceived with the aim of providing teachers with stories against which they can compare their own experiences, 'inscribing a wider range of possibilities for women's lives by providing contrasting exemplars' (Stanley, 1993, p.46). In order to meet this aim a life history approach has been adopted. An early research task was to understand this method, as it had been utilised by others, then to shape it to fit my purpose (Clough and Nutbrown, 2012). In seeking teachers' stories of professional learning I am aware that these stories are fluid, told in different ways and with different emphasis to different audiences at different times. These '*versions of the past*' (Stanley, 1993, p.41, emphasis in original) will be interpreted in different ways by different readers. Within an interpretive frame, life history research can be located within the category of approaches termed case study, specifically story-telling or narrative case study: empirical research with a particular focus conducted with the aim of informing practitioners and policy-makers (Bassegy, 1999).

The issue of voice in qualitative research is complex. My own voice, as researcher and as a woman, as a mathematics teacher, can be heard throughout the research; my experience shapes the study. Balancing my quest for transparency against potential charges of self-indulgence I have decided not to include my own professional autobiographical work here although this has informed my critical engagement with the research.

Ethics

Ethical issues are considered throughout this thesis as they have been a constant focus from initial planning through to completion of the thesis; they will remain a focus as I proceed to publish my research. Ethical issues have shifted in and out of focus, inseparable from practical and methodological issues. This situated nature of decision making highlights the challenges in ethical review (Hammersley, 2009; Jones and Stanley, 2008). In this section I will outline the procedures followed before elaborating key ethical concerns: respect, the nature of participants' roles, the concept of 'informed consent' and the researcher role.

Ethical approval was sought from the Open University and subsequently also from the university at which I was employed. This involved the submission of an outline of the research, consideration of methodology, participants, consent and other ethical issues, together with copies of the information sheet and consent forms. Approval was sought from relevant gatekeepers: in the university it was important to ensure that those with oversight of school partnerships were informed and supported the research; where interviews were conducted on

school premises contact was made with headteachers and/or school governors. Following minor amendments ethical approval was granted at the end of 2011.

My own values, discussed in the previous section, permeate the research, affecting initial design and on-going decisions. These are evident in considerations regarding respect, reciprocity and beneficence. The ethic of respect extends beyond respect for participants to encompass respect for knowledge, values, research quality and academic freedom (BERA, 2011). Life history research has the potential to be emotionally and psychologically damaging (Goodson and Sikes, 2001) and although I strove at all times to conduct the study with the utmost respect for participants I acknowledged that the focus and nature of the study may lead participants into discussion of difficult personal experiences with unintended consequences. In order to minimise risk of harm I endeavoured to ensure that participants understood that they must choose whether or not to discuss particular issues, taking care that my questioning did not coerce them into sensitive areas. This respect is further evidenced throughout the research design, for example in asking participants to decide on the location for our meetings and in returning transcripts, stories and interpretation back to them for scrutiny.

The concept of informed consent is a key tenet of the ethic of respect in academic research in the social sciences (BERA 2011); at a merely procedural level this appears straightforward: participants must be supported to understand the research and consent given without coercion. This is more complex in its

enactment as it is difficult for a participant to understand fully the implications (Bold, 2012). Although I set out in the information sheet the possibility that a participants' story might be recognisable the impact of this is impossible to foresee. One teacher, on receiving a draft of her interpretive story for review, raised concerns about others being able to identify her (and her school) in it. This issue can be addressed through the creation of a representative narrative, reducing the chance that participants can be recognised (ibid) though this further distances the account from the stories told. In this instance I was able to reassure the teacher that any publication would draw from the interpretive story and that such identifying details could be removed.

In studies of this nature there is disagreement over the extent to which it is appropriate for researchers to share their own experiences with participants. For Lather (1991), reciprocity is key to emancipatory research; elsewhere, the ethics of this approach are questioned as manipulative (Goodson and Sikes, 2001) and concerns are raised about leading participants. I discuss this issue in more detail in my consideration of interviews.

A reflexive stance aided adherence to the principle of non-maleficence, doing no harm (Cohen et al., 2007) and the intention was that participation in the research would be of benefit. Participation in life history research can provide participants with the opportunity to consider the social forces at work, can enhance self-worth and provide stories of others' lives as a possible model to follow, though researchers must be cautious in claiming life history work as emancipatory

(Goodson and Sikes, 2001). Additional benefits of the role of autobiographical work in professional learning were discussed in Chapter 2.

Ethical dilemmas pertaining to roles, relationships, representation and voice constantly direct attention to questions of power. My research role in relation to participants was founded upon a prior professional relationship with each of them, this dual role of the narrative researcher frequently gives rise to ethical dilemmas (Bold, 2012). The roles that researchers may adopt in relation to those whose lives they are researching can be represented as a continuum, ranging from a distant relationship, the 'stranger role' through to a more involved 'acquaintance role' and on to a much more engaged 'friendship role' (Plummer, 2001, p.209), though this latter is not without criticism. Negotiating these roles and relationships was aided by a reflexive stance, with deliberative moments (Ackerly and True, 2010) recorded in my research journal. In order to keep my role as researcher separate from my role as university tutor, I ensured that I arranged research visits distinct from visits made in a professional capacity and stressed that another tutor could be allocated to the school if the research relationship appeared to compromise the professional one at any point. Initially I had thought of this to protect the informant but recognised that I may experience ethical issues which troubled the professional relationship. Sikes, working as a PGCE tutor herself, raises this issue, describing how information gained through the research situation gave her cause for concern regarding a professional relationship (Goodson and Sikes, 2001, p.92). As I entered the second phase of data collection, revisions were made to the ethical consent sought for the initial

Study in order to build in additional safeguards as professional relationships had changed. Despite these measures I was aware that my university role would inevitably impinge on the research relationship, an awareness that would remain important throughout the research.

Each stage in the analysis process brought me up against new ethical dilemmas. Mazzei and Jackson (2012) note the quest by qualitative researchers to allow research participants to speak for themselves, to liberate their voices and let them be heard, but note that there is not a single voice, waiting to be heard but a plurality, a multiplicity of voices. I continued to be concerned to let the women who participated in the study speak for themselves, without me overly shaping their accounts. This shaping does take place though – I decided who to invite to take part, I decided what questions to ask, I will decide what to present and how. As Mazzei and Jackson (2012, p.746) say: 'Letting readers "hear" participant voices and presenting their "exact words" as if they are transparent is a move that fails to consider how as researchers we are *always already* shaping those "exact words" through the unequal power relationships present and by our own exploitative research agendas and timelines.' Other factors are also at play; my own lack of confidence in my research in the early stages kept my attention on improving the quality through redrafting and meant a brief current report of progress (Adams, 2013) was published prior to being shared with participants. Anxiety too played a part in this, as I worried about how participants would read their stories.

Quality

In this section I outline the steps taken to ensure that any claims to knowledge made through this research are built on secure foundations. With a multiplicity of theories and approaches to conceptualising quality in research I sought a framework to guide my study. The key concepts of validity, reliability and triangulation, drawn from quantitative research located in the positivist paradigm, as traditionally defined (see, for example, Cohen et al., 2007), have limited use to those engaged in qualitative research. Much has been achieved in terms of developing principles for qualitative research (Maxwell, 1992; Lather, 1991; Arskey and Knight, 1999); here I will set out how they inform my work.

For the qualitative researcher, validity pertains to the trustworthiness or authenticity of research and as such has been a concern throughout this study. Nine types of validity procedures derived from three lenses or viewpoints (the researcher, the participants and those outside the study) and three paradigms (postpositivist, constructivist and critical) provide one framework for understanding validity (Creswell and Miller, 2000). These were employed at different stages in the research. The dual lenses of researcher and participants were utilised throughout the study, with formative feedback from supervisors on written progress reports contributing an important critical commentary. Others outside the study were involved as I shared my work in progress at doctoral seminars, with the Mathematics Education Research and Seminar Group within my own university and, more publicly, at a British Society for Research in Mathematics Learning conference. Following this conference I subsequently

contributed informal proceedings (Adams, 2012) and wrote a short report for the society's journal (Adams, 2013). Despite tentatively aligning myself with the critical paradigm I note that procedures derived from the post-positivist paradigm (triangulation, member checking and the audit trail) were employed (Creswell and Miller, 2000), in a process driven also by a desire for greater collaboration.

In addition to these procedures, further categories were utilised to develop a framework for the study. Descriptive validity or accuracy implies a commitment to ensuring that accounts are reported without distortion (Maxwell, 1992). In this study I have addressed this in part through an aim of methodological transparency. The justification of data selection is also important, particularly given the volume of data gathered in this study. The research design has drawn on the working definition of validity for critical social research founded on the four key concepts of triangulation, construct validity, face validity and catalytic validity (Lather, 1991). Construct validity (Maxwell's theoretical validity) necessitates a search through the literature to seek out alternative meanings of constructs in use, to demonstrate agreement and/or to justify differences (Cohen et al., 2007, p.138). In the emancipatory theory building proposed by Lather (1991), construct validity demands a constantly critical perspective, considering how the researchers own preconceptions may be influencing research coupled with a reflexivity which focuses on scrutinising the impact of the data on the researchers' perspective (p.67). In this project this is achieved through continued exploration of the literature (including revisiting research and theory in the light of new

understanding) and through an ongoing reflexive approach, supported by a research journal.

Face validity, where an instrument appears, on the surface, to be valid (Cohen et al., 2007; Lather, 1991) can be partially achieved through respondent validation, that is, providing transcripts, analysis and drafts for checking by participants.

This recycling of transcripts and accounts through participants was built in to the initial design and was continually reviewed throughout the study. Such checks are useful but I was aware of the need to be wary of 'false consciousness' '...the denial of how our common sense ways of looking at the world are permeated with meanings that sustain our disempowerment' (Lather, 1991, p.59). Perhaps the most challenging view of validity is catalytic validity '...the degree to which the research process re-orientes, focuses and energizes participants toward knowing reality in order to transform it' (Lather, 1991, p.68). Though one can question the implication that there is one reality to know, this call for an alternative perspective as a step toward action has much in common with feminist consciousness-raising.

At the data collection stage, validity was enhanced by a focus on interview techniques, prompts, timing, the relationship between researcher and participant, and recruitment of participants (Arksey and Knight, 1999). Critical reflection on these throughout the research, in part supported by the structure of progress reports and supervisor feedback adopted by the Open University Doctorate in

Education programme (The Open University, 2005) helped to ensure that the research is fit for purpose.

Triangulation, one of Lather's four key concepts (Lather, 1991), another research concept borrowed from positivist research but one which can add to interpretivist research, has the broad aim to utilise multiple methods in order to gain a richer picture (Cohen et al., 2007; Creswell and Miller, 2000). This research utilises methodological triangulation, employing time-lines, interviews, written reflections and documentary evidence to increase trustworthiness. In addition, data sources were triangulated over time through the use of further interviews and respondent validation.

The concept of reliability in qualitative research is also contested; the situated nature of qualitative research in a dynamic world questions replicability as a guiding principle (Silverman, 2011). Three key related concepts which help researchers to demonstrate credibility are consistency, truth value and neutrality (Arksey and Knight, 1999, p.54-5). Consistency emphasises the role of the researcher in making explicit the research process and any issues that have arisen; in this study this transparency includes standardising methods and conventions of transcription (Silverman, 2011). Truth value involves ensuring that the researcher reports as accurately as possible; here this is supported by triangulation and respondent validation. Where Arksey and Knight (1999) refer to neutrality, they are drawing attention to the influence of the researcher on the research; it may be more appropriate to discuss this in terms of bias (Plummer,

1983). I cannot pretend a neutral stance but I can make every effort to ensure I identify sources of bias and strive to reduce them (Cohen et al., 2007; Goodson and Sikes, 2001). For Plummer (1983) there are three sources of bias; the researcher, the participant and the interaction. These issues of quality will be considered further throughout this chapter.

Having set out the foundations of my research in terms of my positionality and over-arching approach, the next section describes the tools used to gather data and details the influence of my epistemological stance on the research design.

Methods 1: Data collection

In this section, methods of data collection are detailed, the justification for the choice of these tools strengthened by a reflexive account of the iterative process of research design and implementation. On first glance methods appear to be ready-made tools, requiring the researcher only to select and employ the most appropriate. In practice however, these tools are not strictly transferrable. Whilst much is to be learnt from the methods utilised by other researchers, ultimately they were crafted for a different purpose; new methods need to be 'painstakingly custom built' (Clough and Nutbrown, 2012, p.33). To the novice this is not always apparent and I repeatedly found myself lost in another's detailed description and exhortations, before realising anew that I needed to customise tools for my own purposes.

Interviews are commonly used to gather data in life histories, their selection for a small-scale, in-depth exploration of participants' perspectives is affirmed by Arksey and Knight (1999). Time-lines (a visual depiction of key events) and artefacts supporting participants' stories of key events or phases were also identified as potentially useful tools. In the following section I describe the approach and the data collection process, justify the methods and discuss the issues that arose.

Life history research

There are many examples of life history and narrative approaches being utilized to explore the careers of teachers (see for example Thomas, 1995; Nias, 1989; Kelchtermans & Vandenberghe, 1994). These approaches begin with life stories '... an account of one person's life in his or her own words' (Plummer, 2001, p.18) or '...lives interpreted and made textual' (Goodson and Sikes, 2001, p.16). These interpreted lives become 'life histories' when they are borrowed and re-interpreted, with a contextual layer added by the researcher.

The variety of studies presented as life histories can be differentiated by distinguishing firstly between long and short life stories, then between comprehensive, topical or edited life histories (Plummer, 2001). A topical life document illuminates a particular issue and these life histories can either be edited or not, an edited life document being one where '...the author speaks and edits his subjects into his accounts...' (ibid, p.27). This distinction is somewhat misleading as all documents are edited to a degree: even if the researcher's

voice is largely absent in the text it is present in the construction, in the decisions about who to involve, what to focus on; in decisions about which fragments to include and how these are juxtaposed. Acknowledging this, Shacklock describes life history inquiry as '...a dialogic event where participants act together in an ongoing, non-linear process that leads towards the construction of an account' (Shacklock and Thorp, 2005, p.157). This co-construction formed a key part of the design of this study and is in itself the beginning of the process of analysis; I will discuss later the challenges in reaching this goal.

A further distinction can be drawn between naturalistic, researched and reflexive life stories (Plummer, 2001). For this study, a short, topical life history, one which enables me to articulate my own place (as both researcher and former secondary mathematics teacher) in the story is developed. The researcher's own experiences are acknowledged as providing extremely good places to begin (ibid), often forming the basis of a final category, the 'reflexive and recursive life stories' which are self-consciously aware that they are crafted and compiled, including the author's voice in addition to the stories as told (ibid, p.34).

Auto/ethnography has been developed in response to this rapprochement of researcher/biographer and subjects. It is important to note that these distinctions do not define rigid, exclusive categories but overlap, merging into each other and continue to be reshaped. Two different approaches to life history research serve to clarify my own stance.

A topical, edited life history may be one approach to feminist research as it privileges the voices of participants, often using substantial extracts from interviews to allow them to be heard (Reinharz, 1992). One such story illustrates the power of this approach, combining the words of a teacher, Sue, with the researcher's narrative, producing a moving glimpse into a teacher's life as she struggles to implement a new curriculum initiative in her school (Halse, 2010). More than this, the story illuminates the relationship between the personal and professional and the zigzag path of Sue's professional development (Halse, 2010:27). Halse describes how she and Sue '...became collaborators in mapping the biography of her educational journey' (ibid, p.25). Kelchtermans' report (1993) stands in stark contrast to the account by Halse; in his report of his PhD study, in which he collects the life stories of 10 primary teachers, the researcher is notably absent. It seems far removed from the 'dialogic event' (Shacklock and Thorp, 2005) mentioned earlier, yet undoubtedly it provides insights into the professional development of teachers. For me, though, the teachers' voices are obscured, constrained by the conceptual framework and by the approach to analysis. Comparing the two approaches highlights the significance of both participant voice and researcher role and positionality. In this study I deliberately set out to hear the teachers' voices and provide a means by which they might speak to others.

Through the course of the research narrative came into focus for me both as an approach to research and as an analytic tool. Narrative approaches seek to privilege the voices of research participants, often presenting stories unchanged,

an approach which can be viewed as 'a form of abdication' (Gill and Goodson, 2011, p.158). Given that, as I will discuss later, the acts of interviewing and transcribing are in themselves acts of co-creation and interpretation, this view does now seem naive, a charge that is also levelled at early approaches to life history (Plummer, 2001, p.115). The life history approach appears now as a narrative method, one which begins with individual life stories and proceeds to explore and locate those stories in social history and culture.

Interviews

The traditional view of the social research interview has been criticised for the 'characterisation of interviewees as essentially passive individuals' and the hierarchical, masculine nature of the interview (Oakley, 1981, p.41). According to Oakley the most fruitful interviews are those where the participants have equal standing and where the interviewer is willing to reveal personal information. This self-disclosure or reciprocity is an important feature of emancipatory research (Oakley, 1981, Lather, 1991, Goodson and Sikes, 2001) and an aid to developing a trusting relationship. This 'mutual storytelling' (Connelly and Clandinin, 1990, p.4) may not always be welcome by participants whose understanding of the research process may lead them to question why the researcher is telling their own story. In my own research I was constrained by timescales and by concerns of imposing my story on others. It was difficult to judge an appropriate degree of disclosure; I was wary of my own views exerting undue influence but also conscious that they may leak out in other ways. As participants already knew me in my university role they had some awareness of my story, my beliefs and

practices. Ultimately speaking out felt more honest though the notion of self-disclosure is a contested one (Goodson and Sikes, 2001; Arksey and Knight, 1999).

Within life history research, interviews are often described as a conversation.

The term 'guided conversations' is used to describe the process, with the guiding coming from the purpose and the preparation the researcher has done beforehand (Cole and Knowles, 2001, p.72). Care must be taken to ensure that the researcher is not too driven and focussed, thus losing the authenticity of the exchange (ibid, p.72). I refer to the conversations as 'guided conversations' in order to create a more informal atmosphere with participants. These conversations can be characterised as semi-structured interviews, using questions and prompts to guide discussion on identified topics whilst permitting me the freedom to improvise, asking for clarification or exploring interesting topics in more depth (Arksey and Knight, 1999).

As the research requests participants reveal details of their professional lives, the early stage of gaining entry plays an important role in developing trust. In part this depended on my existing relationship with participants; in addition I ensured I was fully prepared for the guided conversation and that the participant was suitably prepared beforehand, sending them a copy of the information sheet and consent form. An initial discussion of the purpose of the conversation and the importance of the participant's story, coupled with a discussion of ethical issues, aimed to establish trustworthiness (Cole and Knowles, 2001).

New researchers find it difficult to gain clarity about interview processes for, as Kvale and Brinkmann (2009) note, there are no prescribed rules. Worrying too for the novice researcher, researchers note that semi-structured interviews require a high degree of skill and experience (Goodson and Sikes, 2001, Kvale and Brinkmann, 2009). My preparatory work consisted of listening to and analysing recorded interviews, developing my interview prompts and continuing my background research (Dilley, 2000). An important component of this preparation was the Initial Study, designed to clarify research questions and methodology. The Initial Study also enabled me to develop my skills in interviewing, reviewing the appropriateness of the interview prompts. Trialling the prompts led to a restructuring of questions (Appendix I, p.218), resulting in a sequence with clear opening questions to build rapport, more demanding questions for the middle stages and closing questions allowing the interview conversation to finish on a positive note (Charmaz, 2006).

Having conducted the Initial Study interviews with Nicole I reflected on my own intrusions into her story and the difficulty in striking a balance between putting her at ease and leading the dialogue. In an attempt to address this I explored the use of metaphor and Clean Language. The prompts, or 'Clean Language' questions, that were used to help participants understand when they were working at their best are developed from the work of David Grove (Sullivan and Rees, 2008, p.viii). One important aspect of clean language is 'behaving Cleanly' and refers to listening attentively and keeping your own views and assumptions to yourself (ibid, p.177). Although this is contrary to assertions regarding the necessity of

reciprocity it does enable the other person to explore their own ideas in depth, exactly what I wanted to achieve in the interview. Three simple, clear questions were used with participants; with Marta these appeared particularly successful, prompting some detailed responses, rich in metaphor. In addition, I became aware of the importance of silence in interviewing, thus providing participants with a space to reflect before continuing (Kvale and Brinkmann, 2009).

Time-lines

In the Initial Study, I utilised 'time-lines' (Goodson and Sikes, 2001, p.30) as the first part of the guided conversations. These time-lines provided a framework to aid the structuring of the data collected through interview. Participants' early recollections of mathematics learning were ordered temporally prior to a discussion of their professional learning in mathematics. In addition to providing background information to frame participants' stories, this task was designed to put participants at ease at the start of the meeting. I hoped that the construction of a time-line as a feature of the first meeting would aid me in developing a chronology; asking participants to bring a CV may have provided an alternative.

Following the Initial Study, I considered that it may be easier for participants to discuss a pre-prepared time-line rather than construct one in my presence. I amended the notes to participants, requesting that they prepared for our meeting by reflecting on their own mathematics learning, drawing a time-line and bringing with them two or three artefacts to support them in discussing their professional learning. In hindsight, perhaps this was ambitious; teachers are busy

professionals and struggled to find time to meet, this additional task was an added demand on their time, though participants may have simply found it difficult to know how to begin. None of the participants brought anything with them though all had thought about this preparation, with Heather keen to tell me about the two artefacts she would have brought. Ultimately, the time-line became a valuable part of the research analysis; constructed from the interview transcripts and returned to the participants for checking, it enabled me to contextualise the teachers' experience. Building on this I was able to situate their experience in the context of developments in mathematics education.

Research participants

Variation in advice on the selection of participants is evidence of the considerable methodological differences within life history approaches. Sampling strategies, associated with quantitative methodologies and derived from statistical methods for analysing data, appear out of place. In studies employing these strategies, a sample is selected from the population of interest, often on the grounds that it is representative of that population. An alternative definition of a sample is that of an illustrative case, presented in order that we might learn about a phenomenon (Ackerly and True, 2010) and this is adopted here.

There appears to be some agreement on the role of chance in identifying participants in life history research. This is variously described as 'happenstance' (Miller, 2000, p.76), 'serendipity' (Cole and Knowles, 2001, p.65) or, perhaps more commonly, as an opportunistic sample (Goodson and Sikes, 2001).

Ultimately the identification of participants was driven by my research questions (Ackerly and True, 2010) and influenced by both philosophical and pragmatic concerns. The experiences of all women were of interest to me, I did not set out to privilege one above another and yet by selecting women that were known to me I excluded those whose paths, perhaps for reasons of cultural difference, did not intersect with my own. Why these women and not others? In a sense, the women chose me, or rather my research, for they could simply decline to participate. The relationship between researcher and participant is important in life history research as participants are asked to reveal their private selves (Plummer, 2001). That these women and I already knew each other was advantageous as less time was needed to establish a relationship though our existing relationship inevitably affected participation.

Potential participants for this research were identified on the grounds that they were likely to meet the criteria of being prepared to work closely with me over a period of time on an issue of common interest (Cole and Knowles, 2001). Their participation was serendipitous to an extent as they were identified by the fact that they worked in the same region as I. Obviously, they needed to be women mathematics teachers; to this I added a constraint that participants would have at least ten years teaching experience as I was interested in the sense they made of their professional learning over their careers.

It is usual for life history research, where the aim is for depth rather than seeking representative groups, to focus on a small number of participants (Cole and

Knowles, 2001); indeed my aim was to hear the stories of only a handful of women. As a doctoral research project with limited resources to draw on, particularly in terms of time, this was appropriate. I sought individual, in-depth exploration of perceptions. What was important to me was the quality of the research relationship together with a consideration of what was manageable: 'It is much more important to work thoroughly, meaningfully, and authentically with one participant than to end up with very partial and sketchy understandings based on work with several or many' (Cole and Knowles, 2001, p.67). It is this tradition of thorough and meaningful life histories which was most suited to the questions I set out to explore, informed by the work of those who focus on only one participant (e.g. Sparkes, 1994) or a few individuals (e.g. Munro, 1998).

My initial plans were to include five women in the study however recruitment was more challenging than anticipated and I reviewed my plans as several potential participants did not respond to invitations to meet, despite having initially shown some interest. Given the desire for depth rather than breadth and better informed of the richness of the data following the Initial Study I committed to work with four participants. These women, Nicole, Heather, Leila and Marta (all pseudonyms), had been teaching for between ten and thirty-two years. I knew all four women professionally before starting my research having met them through my work as an academic tutor in a university. I was aware of the power differentials inherent in the research, exacerbated by this relationship, addressing these through a constant quest for transparency, a reflexive approach and safeguards discussed earlier.

Methods 2: Data analysis

Data analysis, the sense-making, organising, classifying and interpreting of data, guided by concern that the approaches adopted were fit for purpose (Cohen et al., 2007; Goodson and Sikes, 2001) was challenging. Advice to novices seems consistent on one point: think about analysis before you start (see for example, Kvale and Brinkmann, 2009). The analysis of the Initial Study served as an introduction to the process, my reflections on this work helping to set a direction. In the process of analysis, perhaps more than elsewhere, the principle of emergent design (Cole and Knowles, 2001) was evident. One aspect of analysis that was clear from the outset centred on timing: analysis would take place throughout the research, rather than just at the end. There are many justifications for this, one being that it offers the researcher the opportunity to return to the field to investigate issues arising from early analysis.

Various levels of analysis can be identified (Burgess et al., 2006), these include listening to interview recordings and transcription. This delineation is helpful, although the notion of 'levels' implies that progress is made from one to another whereas I found the process was, in fact, much messier, less ordered, and included a focus on tools to probe and view the data from various perspectives. Kvale and Brinkmann (2009) identify six steps of analysis: beginning from the respondent's story told in interview, to interpretation by both interviewee and researcher, the analysis of the interview recording by the researcher, through to re-interview and possibly action by the respondent, based on insights gained. An adaptation of these steps forms the structure of this next section, an account of

the analytic process in three broad phases: an initial phase which includes both the interview conversations themselves and the transcription of the recordings made; an immersion phase involving listening, verifying, coding and storying; and finally a re-presentation phase where themes were identified, further analytic tools employed and a contextual layer added. Although I present these as phases there was some degree of cycling back and forth between them. In addition, as the timing of the research with individuals was staggered I was simultaneously working across different phases with different participants' data, with work in each phase informing another. Important throughout all three phases was a process of scrutiny/verification. An overview of the analysis process can be found in Figure 2 (p.95), together with reference to detailed exemplification of key processes. Although many of these examples are drawn from the data gathered from one participant they are indicative of the process for all four participants.

The act of writing has, until relatively recently, received little attention in social research texts. A distinction can be made between a view of writing as a 'reflection of research' to a constructivist view of writing as an active process which plays a part in moulding the narrative (Plummer, 2001, p.171). This is important to acknowledge: a multitude of decisions are taken throughout the writing process, all of which affect the text in some way. An early stage in writing a narrative is the act of transcription. This process poses many challenges yet all too often quotations extracted from interview transcripts are presented without any reference to the background process. It is left to the reader to ponder what

decisions were made during transcription and afterwards, to wonder what is the participant's speech and where, why and how the researcher intrudes.

Transcription has been little researched, the processes perhaps assumed transparent, the product often viewed as a straightforward representation of the interview (Lapadat and Lyndsey, 1999). Instead, the transcribed interview is but one interpretation of the event, one shaped by the transcriber's position and purpose. An examination of alternative transcripts of the same discourse serves to demonstrate the complex issue of transcription (Mishler, 1991) and highlights the importance of transparency of approach, of the inclusion of technical details with decisions justified with reference to theory. In the next section I describe my approach to transcription in order to ensure transparency in data analysis.

Data analysis phase	Analytic processes (including scrutiny/verification)	Reference to worked examples
Initial phase	<p>Interview conversations</p> <ul style="list-style-type: none"> - interviewer's interpretation 'in the moment'; additional questions for clarification and elaboration - participants' reflections and interpretation - pre-planned follow-up questions for second interview, including questions for verification <p>Transcription</p> <ul style="list-style-type: none"> - development of consistent approach - checking of transcripts against audio recording - transcripts returned to participants for verification 	<p>Appendix II, p.220</p> <p>Appendix IV, p.223</p> <p>Appendix III, p.222</p> <p>Appendix V, p.225</p>
Immersion phase	<p>Immersion</p> <ul style="list-style-type: none"> - listening, intensive reading and re-reading - highlighting and annotating - verifying through re-checking against historical data and with participants <p>Coding and categorizing</p> <ul style="list-style-type: none"> - descriptive and analytic <p>Unifying through storying</p> <ul style="list-style-type: none"> - biographical timelines - identifying and reconstructing stories - individual interpretive stories combined into personal experience narratives - verification of draft narratives by participants <p>Critical commentary</p> <ul style="list-style-type: none"> - from supervisors on progress reports - sharing work in progress with colleagues - reviewers' comments on conference report 	<p>Appendix VI, p.226</p> <p>Fig. 3, p.108</p> <p>Appendix VIII, p.228</p> <p>Appendix IX, p.231</p>
Re-presentation phase	<p>Identification of themes</p> <ul style="list-style-type: none"> - within individual narratives, aided by consideration of similarities and differences across participants <p>Contextualizing the narratives</p> <ul style="list-style-type: none"> - further research of history of mathematics education and teacher learning - further development of timelines <p>Presentation</p> <ul style="list-style-type: none"> - edited personal experience narratives 	<p>See Ch. 1</p> <p>Fig. 3, p.108</p> <p>See Ch. 4</p>

Figure 2 Overview of data analysis process

Initial phase

The process of analysis began in the interview conversations themselves. Here, participants began to analyse their experience (see for example Marta's reflection on her experience as an advisory teacher, p.156) through the accounts they gave in response to my prompts, followed by their own interpretations as they made new connections or came to new understandings (Kvale and Brinkmann, 2009). My own first step began as I listened to participants' stories, interpreting 'in the moment' and using questions in order to seek affirmation or elaboration (ibid, p.195) (see Appendix II, p.220). This interpretive aspect of analysis (Gibbs, 2007) is more commonly taken to begin once the data has been collected but in reality these tentative interpretations are made from the outset in the semi-structured interview. This happened spontaneously during the initial conversations with each participant and developed further in the subsequent meeting as I returned with pre-planned follow-up questions (Appendix III, p.222) as I sought to clarify meaning. During the second conversation it became apparent that between the two meetings, at least two of the participants had engaged in further reflection on and analysis of their experiences, using the interview transcript sent to them for verification to facilitate this (Appendix IV, p.223). The power dynamic at play in research is evident in the way that participants may be asked to verify transcripts; what I wanted was greater involvement, the 'life historians' (Munro, 1998, p.10) working with me as co-researchers. Perceiving them in this way adds strength to the view that they were engaged in analysis along with me.

Transcribing the interview data formed the second part of this initial phase. Each conversation was recorded on a good quality digital recorder. In order to reduce inaccuracies in transcription I transcribed all the interviews myself, ensuring familiarity with both the subject matter and the speakers (Gibbs, 2007) and recognising the value of coming to know the data as I worked on it. I listened to each section many times, during and immediately after transcription and again after some time had elapsed. I returned several times to the recordings to check meaning during analysis but acknowledge that there will always be some inaccuracies despite this. Further steps to reduce inaccuracies were employed, including additional checking of the transcript against the recording and asking the participants to validate the transcript. This latter yielded no changes, a fact which in itself is not evidence of the accuracy of the transcripts but perhaps an acceptance that they are close enough. As I listened to the teachers' voices and re-read their words I found I was constantly sent back to the literature to explore context or concept, beginning to build the background knowledge needed for the contextual layer. The initial transcript was completed verbatim with an anonymized copy made afterwards; a list detailing the changes was stored securely in accordance with ethical guidelines. Names of people, schools, organisations and places have been changed or removed.

Making progress with analysis necessitated decisions regarding transcription. Common changes in transcriptions include the omission of frequent interviewer responses (for example my 'yes' which punctuates recordings), and hesitations (including 'you know', 'er') and the 'repair' of false-starts and self-corrections

(Finnegan, 1992, p.196-7 in Plummer, 2001, p.150). Following these guidelines, I developed and employed a consistent approach to transcription (Gibbs, 2007) and punctuation (see Appendix V, p.225). From here, the process became more difficult: I had the recorded conversations, the stories that four women had shared with me and now the responsibility I felt for the research process intensified. Throughout the planning of the research, outlining procedures and developing interview prompts ethical issues had been at the fore but it was at this stage, once I had the data that progress slowed as I struggled to see how I could do justice to the stories. Transcription was crucial in this as a misplaced comma, a misheard word or a missing pause could fundamentally alter the meaning of the text.

Immersion phase

As I began to develop my approach to data analysis, scouring research accounts to see what others had done, I found that detail was often lacking. One account of data analysis (Nardi and Steward, 2003) revealed the benefit of detailed coding, however, this was a very different type of study to my own. Others utilise a multi-level analysis, proceeding from first readings which may lead to an individual's portrait, through to closer, more detailed reading and coding, noting themes and developing a fuller picture (Cole and Knowles, 2001). This has some similarities to case and category-centred approaches in narrative research (Riessman, 2011). My intention was that themes would arise from the data rather than being pre-determined, thus helping to avoid the loss of valuable data simply

because it did not fit pre-determined categories. In reality, some themes were essentially pre-determined, arising naturally from my interview prompts.

Initial coding proved useful in helping me to know the data on a deeper level.

Intensive reading of the transcripts aided the move from descriptive coding through to categorization and then to a more theoretical analytical coding (Gibbs, 2007). Progress was slow as I worked to clarify my understanding of the terminology and processes commonly adopted, as it was only after familiarity that I felt able to begin to work more creatively within (or without) the rules of others. The range and apparent prescription of these rules was daunting and at times overwhelming; one account details 29 different coding methods, divided into first cycle (more straightforward, often descriptive) and second cycle (more analytical) (Saldaña, 2009). Trying to find my own way in the face of all this direction was difficult and yet I found it difficult to ignore this advice from more experienced others.

It is difficult to find researchers engaged in life history studies who have profited from the use of computer-assisted qualitative data analysis (CAQDAS) and some oppose them: 'Reductionist, positivist assumptions underlying process [of computer assisted analysis] are antithetical to the perspective we portray' (Cole and Knowles 2001, p.100). Software developments over the last ten years may have shifted this view and it appeared to me that software packages such as NVivo could offer support in storing, coding, sorting and structuring data, thus

aiding analysis (Cohen et al., 2007). It was just as clear, however, that these tools were no substitute for 'mental readiness' (Cole and Knowles, 2001, p.99).

Alongside this, I often preferred to work from either the paper copies of transcripts and a highlighter or the original audio recording and a notepad. Having categorised the data, I focused on a particular category and a particular participant, reading and rereading sections, looking for striking or interesting sections (Rapley, 2011). These reconstructed initial categories were biography, teaching, learning mathematics, identity, and attitude and emotions. These were further sub-divided; extending at one point to 65 categories (Appendix VI, p.226). I found it helpful to see how others have managed the process, for example, Burton's (2004) tree diagram of the NUD*IST (an earlier version of the CAQDAS software NVivo) categories used in her study of mathematicians. I worked with my research questions beside me, amending and re-drawing my conceptual framework (Appendix VII, p.227). Unsure where to focus my attention, the data, the literature, the methodology; I kept spiralling round, often grasping at ideas or finding new links between them.

The idea is to discover essences and then to reveal those essences with sufficient context, yet not become mired by trying to include everything that might possibly be described. (Wolcott, 2009, p.39)

For a time, I was mired, though optimistic of finding a way out. The coding process supported my immersion in the data, helping me to know the stories.

Continuing to grapple with the mechanics of analysis, coming to know the women who had shared their stories, I inched towards a way of presenting the narratives that I could justify. I found more scraps of useful discussion of analysis by other researchers, though the under-reporting of this in a chasm is qualitative research. Echoes of my struggle were found in one account of analysis, the author noting that she began using a thematic approach but then 'abandoned this approach in favour of a more holistic one that involved writing a story for each interview. Using stories rather than codes better captured the distinctiveness of each account...' (Mendick, 2006, p.38). Once she had written the stories she began to explore the connections between them, looking at patterns and categories. Premature identification of themes can be problematic, risking 'stifling or failing to listen to narrators' voices and missing valuable data' (Smith, 2012, p.492). The meandering route I was taking was legitimised as I continued to explore different approaches, unsure of what worked but slowly, inexorably, getting closer to the women and the stories they told.

If engaging in data analysis 'usually involves fitting the evidence and information into a framework of some kind [...] classification, categories, models, typologies or concepts', (Goodson and Sikes, 2001, p.34) then the challenge lay in balancing the need for a systematic approach with the desire to preserve a life whole (Cole and Knowles, 2001). To represent these lives respectfully is a challenge:

We do so not by taking information and slicing it into discrete bits and sorting the pieces in separate containers, but by trying to understand, in

a holistic way, the connectedness and interrelatedness of human
experience within complex social systems

(Cole and Knowles, 2001, p.101)

This holistic approach is taken up by Chase (2008), who notes that narrative researchers begin by listening to the narrator's stories rather than looking at themes drawn from across a collection of interviews. Riessman (2011, p.311) refers to this as case-centred rather than category-centred research, preserving human agency, coherence, sequential and structural features. Form, in narrative inquiry, focuses attention on the story as told by the narrator, in this case the interviewee. The narrative is examined in order to consider the way the story is told and how the teller is positioned (Riessman, 2011).

It became clear that a narrative approach was an appropriate way to examine the stories generated in the Initial Study; in places the narrator dramatizes her accounts, using direct speech, repetition and asides, creating commonality between the narrator and the listener (Riessman, 2008, p.112). An approach to structuring a personal experience narrative by linking interpretive stories ultimately yielded an appropriate form, further enhancing my understanding of the stories told (McCormack, 2004). This approach involved identifying the stories in the interview transcripts and reconstructing them (see example, Appendix VIII, p.228), locating the key parts as identified by Labov (1972 in Riessmann, 1993): an abstract (summarizes the content of the narrative), orientation (sets the scene), action (sequences of events), evaluation, resolution and a coda (closing the story) (Riessman, 1993). Drawing on the narrative processes of theorizing,

augmentation, argumentation and description (Rosenthal, 1993 in McCormack, 2004) I structured the stories, adding further detail for clarification (see extract, Appendix IX, p.231). This analytic process resulted in more concise and coherent stories that best represented the women's stories as constructed in the interview conversation. The interpretive stories were combined into one personal experience narrative for each participant and returned to participants, with a request for them to check the stories against their experience, making any necessary changes or additions. Feedback from one participant alerted me to her concerns regarding the depth of data that might be published; subsequently I contacted all participants with a more detailed account of the research process. This contact with participants was always a delicate balance: I wanted them to be informed and involved but did not want to overburden them with, what was after all, my research project.

Earlier I discussed the construction of biographical time-lines; these aided the development of the interpretive stories and my understanding of the women's lives (see Figure 3, p.108). Nicole drew her own during our first meeting; Marta and I worked on hers together during the second meeting and it proved a useful stimulus tool, drawing out further biographical details; I drafted the others following our first conversations, requesting verification in the second meeting. Alongside this I worked on a time-lines charting education policy developments and focussing specifically on mathematics education (see Figure 1, p.12). The interpretive stories and the construction of time-lines mark the transition to the representation phase of analysis.

Re-presentation

What would these life histories look like? This question occupied much of my time for I was aware that 'Decisions about how to introduce, present, depict or describe the participants are crucial' (Cole and Knowles, 2001, p.117). I considered creative forms; poetic transcription in particular offered a useful tool for analysis and is one I intend to explore further. A degree of experimentation with presentation is encouraged in narrative analysis in the interests of accessibility (Kvale and Brinkmann, 2009) though further support for a cautious approach comes from Marvasti (2011) who warns of the dangers of more creative forms, advising the researcher to adapt the form according to the audience. Ultimately my goal is for the participants to be able to recognise their own stories and for others to find them engaging, troubling, powerful and inspiring. Feedback from participants indicated that the personal experience narratives were recognisable as their stories.

The personal experience narratives form the basis of chapters 4 – 7. Taking each story separately I endeavoured to present the women's voices together with my own commentary, adding context and interpretation. I chose to organise the findings by individual to allow a picture of a teacher's learning experience throughout their career to be presented. Analysis by theme formed a second level of analysis (Cohen et al., p.467), enabling comparison and a search for shared or divergent experiences, the result of this analysis is reported in Chapter 8. This work built on the categories, time-lines and narratives developed in the immersion phase of analysis. Whilst I accepted that all 'our analytic

interpretations are partial, alternative truths...' (Riessman, 1993, p.22) I was aware of the responsibility I had to participants when interpreting their experiences. In order to meet this responsibility I borrowed the tool of discourse analysis to use alongside the development of the personal experience narratives. This enabled me to think more deeply about the women's experiences, to try to interpret them from the perspective of their worlds rather than mine (Gee, 2010). In particular I focussed on the situated meaning of language or the way in which language takes on different meanings in different contexts (Gee, 2011).

In Chapter 2 I discussed how Boaler and Greeno (2000) typified mathematics classrooms as 'figured worlds'. A 'figured world' is a 'socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others' (Holland et al., 2001, p.52). These imagined worlds or models locate the actions of individuals within broader institutional and social practices and are maintained through simulations (Gee, 2011). According to Gee, these simulations are generally constructed from and supported by typical situations which are themselves located within particular cultural practices and discourses, though this particularity is often rendered invisible due to the pervasiveness of local practices. Noticing and asking questions about the figured worlds in operation, the way in which they shape judgements, the interests that are served and the influences upon them can contribute to a more robust analysis (Gee, 2011).

One check on the validity of analysis involves a re-examination of context, broadening the scope by filling in relevant detail in an effort to 'keep us honest' (Gee, 2011, p.37). This formed an important aspect of the analysis. I drew on both the time-lines, interpretive stories and original recordings, reconsidering my initial interpretations and seeking further contextual information. Much of this work centred on a history of mathematics education and teacher learning. It pushed me beyond my own biographical and professional knowledge to look more closely at policy and practice from 1960 to the present.

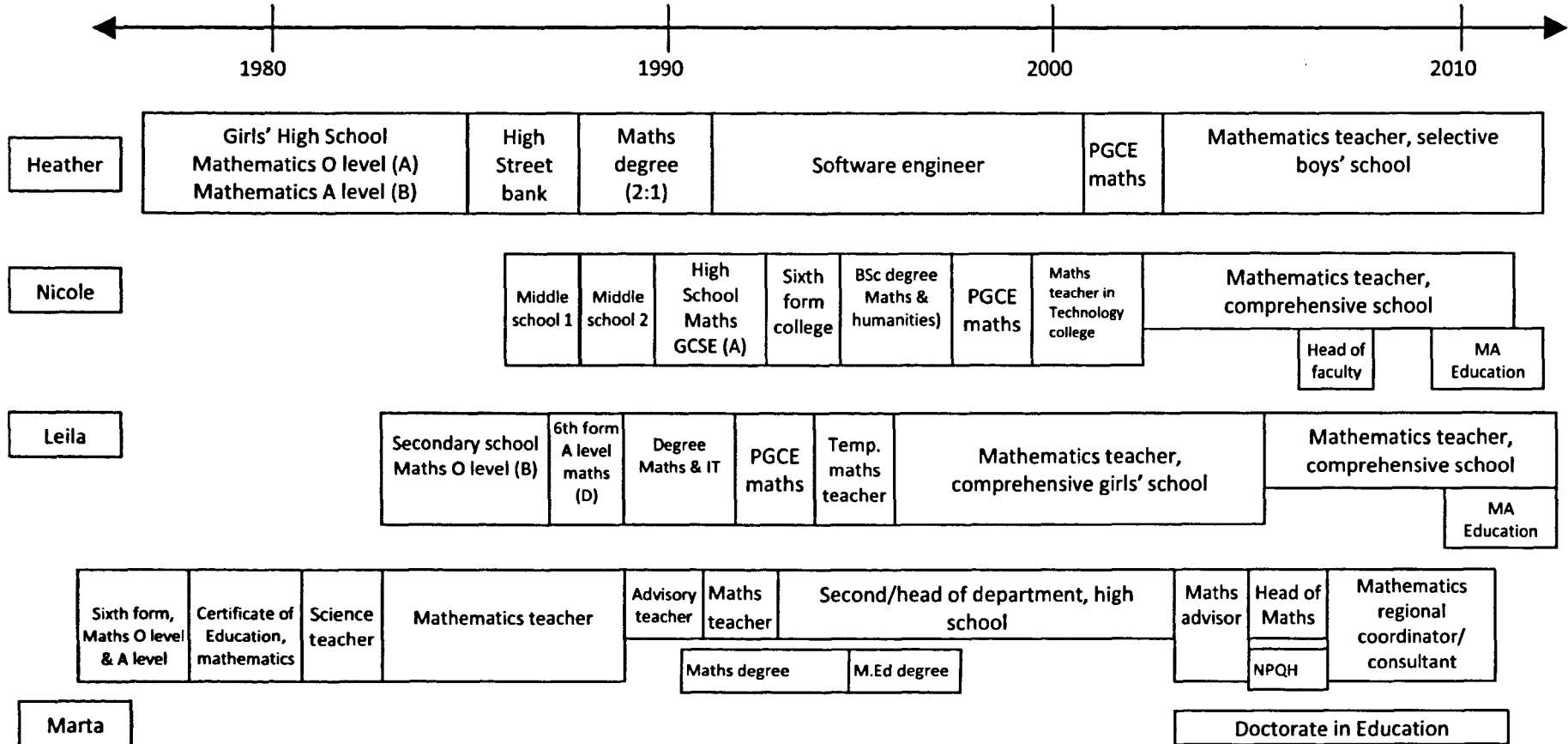
Grammatical discourse tools were used to further my understanding. The way that language was structured helped me reconsider the meaning I had ascribed to sections of narrative. By playing with the text, reforming the script into lines, each representing one relevant piece of new information, and stanzas, groups of lines on a theme, (Gee, 2010) my attention was drawn to the way language was used to mark tensions (see Appendix X, p.232). In addition to revealing an alternative mode of presentation, this process focussed my attention on the grammatical structure of the narratives and the way in which this might illuminate meaning.

Novice researchers often engage in a fruitless quest for a set of tools or methods for data analysis, though the reality of analysis of life history data is a creative and 'a sometimes convoluted and chaotic process' (Cole and Knowles 2001, p.99). My original conception of a series of neat approaches to data analysis was undermined as I worked, transformed into a myriad of approaches. It became

clear that it was possible to use several of these simultaneously or at least sequentially (Burck, 2005; Simons et al, 2008; Ackerly and True, 2010). In this multiplicity of approaches, or call to find your own way, the guiding principle is to ensure that the approaches are appropriate for the purpose (Cohen et al., 2007, p.461). My own approach can best be described as 'bricolage', the adoption of a variety of strategies in the search for significance (Kvale and Brinkmann, 2009, p.233).

In what follows I present the edited and interpreted personal experience narratives for each woman. The stories are presented chronologically, starting with those teachers who are newest to the profession. First is Heather, telling the story of one teacher's professional learning in a grammar school, followed by Nicole, the youngest participant, who started teaching in the late 1990s. Going further back, Leila began teaching in inner city schools in the early 1990s. The final story is Marta's, looking back over a teaching career which began in the 1980s. In a later chapter I draw on the four narratives as I return to address my original research questions.

Figure 3 Biographical time-lines



4. Heather: 'I'd never have thought of doing maths as a degree'

From school, gosh I didn't perform very..., well, I'm saying I didn't perform very well at maths, the maths teacher at school, I went to [Girls' High] School which was quite an academic school and I always remember my mum saying that we went to a parents' evening when I was about 14 and the teacher said 'Well, she'll never be any good at maths, so you know she might just about scrape through her O levels and that's it'. And then once I heard that it made me think 'Well actually am going to do something about it', [...] did my O-levels then and did fine, got an A, then I did my A-levels and didn't work very hard really for my A-levels so that was a shame but I got a B for my maths A-level. Then I went to work for [High Street] bank for three years and then decided that I wasn't really going to get anywhere just with A-levels working in the bank so I decided to leave when I was 21 and went and did my maths degree. And then because I went when I was 21 I think I just really worked at it and you know just, if I'd have gone at 18 I don't think I'd have worked as hard as I did when I went when I was 21 and I ended up getting it a 2:1 [...].

I'd never have thought of doing maths as a degree and I think even when I was thinking of where to go when I was 18, I was looking for things like environmental science and food science and things like that,

not maths at all and it was only just giving it more thought and deciding what degree would benefit me and what I was interested in and that's when I decided to do maths. So yes, I went to [University], did my degree and then I went to work for [company] and I worked there for, I think on and off about 10 years I think, because I had my son along the way and then I ended up working part-time and while I was there I started tutoring at night, maths, because I had the, you know, maths background and so I thought, well, I'll give it a try and I think in the back of my mind I'd always thought I might go into teaching eventually and then [company] had redundancies and I decided to take a redundancy and got the payment and it paid for me to do my PGCE. And that was 10 years ago now so I did my PGCE at [university] and then came here and I been here ever since.

Learning mathematics

As Heather introduces herself with this biographical account, I am struck initially by her response to her teacher's prediction, by her determination to act. Her narrative of self is one who succeeds through hard work and determination, challenging expectations. She repeatedly positions herself as underperforming, echoing her teacher's belief that she will never be any good at mathematics, then challenging this by presenting her achievements. This reification of her success in mathematics is an attempt to capture her fluid identity in the form of solid accomplishments, giving her a foundation for imagining who she can be (Sfard and Prusak, 2005). Repeated stories can evolve into a 'designated identity',

often of talent or inability (ibid, p.18); Heather appears to oscillate between these, as though she remains unconvinced by the evidence that she is a successful mathematician.

Heather's comment echoes a prevalent discourse in school mathematics: that ability is fixed, you are good at mathematics or you are not (Dweck, 2000).

Teachers contribute to limiting students' potential, for example by telling them that a grade B at GCSE is not good enough for them to continue to study mathematics to A-level (Brown et al., 2008). Receiving such a message has the potential to affect a student's image of self, damage often fragile self-esteem and lead to lower attainment. However, rather than accepting her teacher's view, Heather determines to act to alter her predicted future.

Heather's response to her teacher's feedback is to work harder. Despite recalling that the teacher had said that Heather would 'never be any good at maths' Heather responds with a determination that she can, with effort, achieve success. This mastery-oriented response (Dweck, 2000) is evident elsewhere in Heather's narrative as she confronts challenges positively. She seeks understanding, not content until she has fully grasped a concept. The need of girls to understand mathematics has been noted elsewhere (Boaler, 1997). The quest for understanding is characteristic of the practices of real mathematicians (Burton, 1999) but at odds with students' views of a successful school mathematician as one who can follow procedures rather than one who seeks deep understanding (Boaler et al., 2000). At A-level and at university Heather develops strategies to

support her learning, working with small groups of her peers and on her own to understand the mathematics as these extracts illustrate:

having a team of us working together as students helped and that was like that when I went to uni really, there was a good group of us and we all helped each other to try and understand, to get to grips with a lot of it.

Oh, gosh, I just remember, at University, I just remember sitting, taking notes, writing everything down and then going away and trying to understand what was said. But at the time not really understanding what I'm writing. Well, sort of understanding it to a point...

Heather's attitude towards learning mathematics demonstrates 'mathematical resilience' as she exhibits a positive attitude and perseverance, collaborating with others in a belief that with work will come success (Johnston-Wilder & Lee, 2010). The construct of mathematical resilience focuses attention on the attitudes and behaviours needed to counter a prevailing discourse of fixed ability in mathematics; these attitudes can be actively fostered in students though they often appear to develop in the face of opposition rather than with support.

Identity

Heather strongly identifies herself as a teacher but presents herself modestly, feeling uncomfortable introducing herself as a Head of Year as 'it sounds a bit pompous'. She describes herself as lacking confidence and is more ambivalent about her mathematical identity:

GILL: ...Do you see yourself as a mathematician?

HEATHER: ...[6 secs pause]

GILL: Or did you? When you were in your other job?

HEATHER: ... I don't know. I suppose I do, yes, I do. ... I do really.
Yes, well, yes I do. It doesn't come as naturally to me I think as it might do to other people but, yes, yes, I probably would do. Yes. ... But I wouldn't say 'I'm a mathematician'. [laughter]. You know, I wouldn't tend to say that.

GILL: Why not?

HEATHER: Because maybe I don't feel I'm as natural, working things out the same. I mean my husband and my son, they are very quick with mental arithmetic and that sort of thing and I'm not really.

Again, though, Heather has surmounted this issue, rationalising her perceived lack of speed by noting that she was never taught strategies for mental calculation herself:

...going back to when we were at primary school and high school, calculators were just starting to be used so then we were starting to use

calculators instead of mental calculations so my, I often blame that, the fact that I haven't got those basics of working things out mentally which a lot of the lads have got. And certainly when I started here they were working things out very quickly in their heads that I wasn't able to and its only through practice and you know, learning different strategies and I was thinking 'I've never been taught to do that'.

Heather resists the prevailing discourse of what it means to be successful in school mathematics, a resistance that is further evident when she talks about her dissatisfaction over early entry at GCSE. She describes a significant learning experience when she had to prepare a Year 10 class for GCSE, how she was 'rushing through everything' questioning whether they were settling for second best when boys who get a grade A in Year 10 could have got an A* in Year 11:

...is it a disservice to those who would benefit from having extra time to just have a better understanding of what we are doing rather than just learning to get through the exam at the end of Year 10?..

As she talks she contextualises this further, noting that other students may be restricted by exams in Year 11, feeling she is pushing them towards surface rather than deep learning (Marton and Saljo cited in Biggs and Tang, 2007). This early experience of teaching is significant in that it brings her into confrontation with a reality of school mathematics, namely the pressure on results.

Learning to teach

Beyond her PGCE year, much of Heather's professional learning is informal, with learning from teaching and from colleagues playing significant roles. This learning from teaching comprises planning, preparation and reflection, often followed by further opportunities to refine approaches in the classroom. For Heather, much of this is individual work, with lack of time and pressure of workload cited as reasons for limited collaboration with colleagues. This learning began prior to her qualifying as a teacher when she was tutoring mathematics, with A-level mathematics and Further mathematics teaching continuing to demand considerable individual mathematics work:

Must've been maybe the third year I was here, I started teaching further maths and that was a **big** jump because it was really the first year of your degree, part of it, you know.

[...] But that was sort of like me learning at the same time as them as well really, which was difficult, and it still is [...] But good, but yes, it is, it's good.

Teaching Further Mathematics only once in every three years means that Heather has to review it in depth prior to teaching. Her strategies for learning appear to follow those learnt in her student days, working alone to develop a proficiency before teaching. The emphasis appears to be on the mathematical content knowledge rather than on pedagogical content knowledge (Shulman, 1987); her goal to stay one step ahead.

Informal conversations within the mathematics department serve as opportunities to reflect on practice, providing examples of the different approaches adopted by colleagues:

...there are certain things that Owen's told me that I have just thought you know actually, that's really useful and you know that's something that I'll definitely use. You know, and Sarah's brilliant in the department because she's got really good ideas and stuff and we just you know, take on some of the things

She is an advocate for student teachers in the department, seeing them as a support for learning:

I mean I know [the head of department] is not always so keen on having students coming in and that sort of thing but I really like continuing that because we don't change otherwise, and it's really important to have new faces coming in and new ideas because whenever we have students come in I **always** learn something from them

More formal learning opportunities have been limited and Heather struggles to identify further professional learning experiences during her career. In an effort to prompt a response I note that we tend to think of professional learning as courses but that it is not restricted to these. Heather admits that she has not participated

in mathematics specific professional development for some time, indicating that she believes she ought to. Despite this, she does manage to access new learning through her colleagues:

HEATHER: Do you know, I rarely go on courses, I'm terrible, I just don't. I haven't been on a course for ages (...) and when I have been on recently I think it was more head of year courses, not maths. I haven't really been on maths courses for a long time. Some members of the department did go on, oh gosh, what was it? Oh, using Autograph, that sort of thing, so I sort of learnt from them what to do.

Earlier, in Chapter 2, evidence was presented demonstrating how when offered a choice to study mathematics or not, girls and women were disproportionately lost to mathematics. Here Heather appears to be opting out of formal mathematics professional learning, choosing her pastoral role as Head of Year over her role as mathematics teacher, though an alternative interpretation is that she is acknowledging that courses do not work for her as a form of professional learning. Heather's engagement with the wider mathematics community appears to be limited to her colleagues in the department and, through the Initial Teacher Education students she mentors, to the local university. She makes no mention of professional subject associations, external sources of professional development or networks.

Heather casts herself as responsible for her professional learning history, noting that her workload constrains her choices. She acknowledges that the enthusiasm she feels at the end of a course gets lost when she returns to work as she says

she lacks the time to implement new ideas. And yet it is clear that she does engage with new ideas, as this example of her practice developing through the use of the interactive whiteboard illustrates:

My teaching changed quite a bit when I started using [the interactive whiteboard], because I use a tablet as well, [...] and that's, that is good and it has definitely moved my teaching on I think

A short inset session on cooperative learning, run by a teacher in the school, supported Heather to develop her practice. Initially sceptical that cooperative learning had a place in mathematics, Heather was excited by the potential a circus activity¹ offered, citing it as a critical event in her professional learning and describing her subsequent experimentation with this activity at some length.

Despite these experiences, Heather feels that teachers have limited time to direct their own learning, noting that the five professional learning days that schools have are exchanged for a shortened school year in her school with the time taken as twilight sessions. Although this has been lauded as a successful strategy (Ofsted, 2006) it is clear that it can have a detrimental effect:

We don't get inset days any more [...] now we have these twilights which is like an hour and a quarter after school every couple of weeks [...], our term is two days shorter I think it is, but really we all end up doing this stuff, sometimes it just feels like for the sake of it, so. And we are thinking well actually we could spend that time thinking about

¹ Group work where students move to different activity stations, usually at timed intervals

how we could do outstanding lessons, for example, you know, getting ideas in that way, but instead [...] someone will stand up and talk about, I don't know, I mean it could be something useful and I've done some on Asperger's and stuff so useful sessions but after work, after a day at work, then to sit and do an hour and a quarter of that it's, I just don't think that people take it in, the way that they should do and I think – and then everybody moans and they say they don't think our views are taken into account the same as they used to be, I think, you are not listened to.

Although she acknowledges that there can be useful whole staff inset sessions, Heather does not feel that she has a voice in deciding their direction; rather than a source of support they appear to have become a source of discontent. She does not perceive any improvement in her working conditions over her teaching career, reporting reduced autonomy and ever increasing demands on her time. Efforts to improve teachers' conditions through workforce reform (DfES, 2002) appear to have made little difference to her, with Heather saying she is considering monitoring her working hours to demonstrate how much she is working. Heather is resentful of the 'audit culture' and the way she sees it restricting teachers' freedom:

...it just seems to be more targets...

...whatever we do, we always need to do more and it is encroaching on your time and...

Much of this pressure is attributed to the school's most recent Ofsted inspection, when Heather notes that despite the school being graded outstanding overall, teaching and learning were judged good. The responsibility of individual teachers for their own professional learning appears to have been curtailed as the school react to external demands in an endeavour to bring about improvements. Heather is not resistant to improvement per se, rather it is the perceived lack of autonomy, the denial of a voice in determining the direction of such improvements that she objects to.

Mathematics focussed professional learning opportunities within school appear to be limited:

GILL: Do you get time as a department to think about mathematics and teaching mathematics?

HEATHER: Not really, no. No. And we said, we had a twilight last week, we had to fill in a form saying about the good practice that we do, so it was literally just listing what we already do, we weren't thinking of new ideas and stuff...

Other opportunities to collaborate within the department are under-utilised:

...but observing each other, no we don't do that, in the department. We have been encouraged to do it in the past and, but no, we just haven't. I'd like to. We always say we would like to do it but it's somebody actually saying 'I've got this really good lesson, if you want to come in and watch' or you know. And I do, you just know how much pressure

everyone is up against, if I was to, you know say that you can go in and watch one of their lessons

Although Heather is busy she would like the opportunity to observe colleagues, to have feedback on her own teaching, to discuss mathematics, share ideas and gain support.

Supporting learning

When asked who or what had supported her learning to be a mathematics teacher Heather responds that the most significant source of support has been from someone who helps her to believe in herself:

I think, the main support, one of the main supports is my husband actually who is brilliant, [...] because I'm not confident at all, he would probably say I am one of the least confident, but I always say I can't do things and all this sort of thing so just having somebody to give you a boost and to give you confidence [...] I just think I must be putting myself down all the time [...]. Because you can never do everything, and you are trying to and then its, it sort of somebody realistically saying to you 'Actually, you are doing absolutely fine and [...] some things just have to go' and, but I do think that is something particularly with teaching isn't it, do you think?

Feedback on her practice is limited:

GILL: Do you have people, do you observe each other or have people observe you teach here, apart from the students?

HEATHER: I do have. I had the Head observe me, we had, I should have had somebody observe me a couple of weeks ago but it was cancelled, so we have senior management come in and observe once a year. Well, supposed to be once every two years possibly...

Heather says she would value affirmation:

I think maybe I need validation to know that it is right. I don't tend to think what I am doing is good until somebody tells me it is

She notes that people do not have time for this support. Heather's story underlines the isolation teachers can experience. She expresses a willingness to engage more deeply with issues of mathematics teaching and learning but the scope for this appears to be constrained.

5. Nicole: 'Is it always going to be this crazy?'

In her early thirties, Nicole had been teaching for twelve years at the time of our first meeting. She had held posts of responsibility for more than half of this time, including two years as Head of Faculty.

Learning mathematics

Looking back on her early years as a mathematics learner, Nicole describes a fluency with number and an enjoyment of mathematics which appears almost irrepressible. She recalls playing with hymn numbers in bored moments in church and completing 'reams and reams of sums' in primary and in her first middle school. In these formative years there appears to be little to trouble her emerging identity as a mathematician.

At age 11 the family moved across the country and Nicole started a new middle school. This was the beginning of a somewhat uncomfortable five years for her mathematically.

see before that we'd done an awful lot of y'know, the basics really, what I remember of my primary and my first middle school was very much reams and reams and reams of sums, [...] nothing else really, so yeah, it was quite weird to suddenly be told at another school that there is actually, tasks, problem solving, but you can't get the answer wrong, you know was a bit like being thrown quite a lot actually so yes, that phrase 'no right answer'.

Here Nicole is discussing the open-ended tasks, or investigations, which she experienced periodically throughout her late middle and early secondary schooling though the bulk of her mathematics learning at this time followed the SMP² mathematics scheme.

when I was at school, we did SMP maths which meant you went and got a booklet and you did what it said. You got the answer sheet and you marked it and then you carried on. So in terms of whole class teaching, from the age of eleven onwards, it didn't happen. And obviously that is now regarded as about the worst way possible to teach maths so what I think of as an horrendous maths lesson so [...] I'm probably the opposite now because I don't do a lot of extended pieces of work because I think, well actually we remember our teacher just sitting there.

[...]

...we actually just sat there, almost like machines churning out these booklets

Nicole describes learning through the School Mathematics Project (SMP) scheme continuing from middle school through the transfer to a local secondary school. The underlying philosophy of the scheme was to move from rote learning, drill and practice to using mathematics with understanding '...thoughtful working rather than routinely churning out answers' (Cutler, 1966, p.117). For Nicole,

² School Mathematics Project, initially conceived as a research project based at the University of Southampton in the early 1960s, driven by economic demand for a workforce with mathematical skills.

working with this scheme, learning and doing mathematics became an individual process, conducted mainly in silence and with little teacher involvement. Rather than 'routinely churning out answers' she sees herself churning out booklets; the philosophy of the SMP scheme appears to have been lost in its enactment. She begins to question this experience through our conversations.

In her final year at the school, a parents' evening allowed Nicole's mother the opportunity to discuss A-level choices:

my mum had said to my high school maths teacher 'Nicole really wants to do maths and further maths' and the teacher had gone 'What you?' [incredulous tone] sort of attitude. 'Ah that's funny' she said 'cause I thought my daughter was in set one' and she went 'Oh no, its only for people in the top end of set one' [...] so it became quite clear even then that there was stuff that they just, you know, some had seen because they were being directed in a certain way and some hadn't

Nicole sees a family move, when she was 16, as freeing her, allowing her to choose mathematics, rejecting her Year 11 teacher's scepticism of her aptitude for A level mathematics: 'if I'd stayed put, I wouldn't have got to do the A levels I wanted'. Her experience of A level mathematics was markedly different.

A level was different because I moved schools and I went to a sixth form college 'cause my family moved as well and I had this lovely lady who could just explain anything in the most simplest ways.

[...]

so I did A-level maths and I did Further maths with this lady so I had her for half my timetable for Lower and Upper Sixth and she was someone that we actually got to know 'cause we had her so often [...], she was really, really lovely and she could just, you'd look at the board at the end of the lesson and you'd think, 'oh my God, look at all that' but actually, she'd guided, she'd carefully led you through, so carefully and so gently that you'd got from start to finish with no problem at all

These accounts of school mathematics provide evidence of the confusion Nicole experienced when her conception of mathematics as certain and incontestable, built up during her primary years, was shaken on hearing that there were aspects of mathematics with 'no right answer'. With her A level teaching apparently founded upon a transmission pedagogy (Pampaka et al., 2012) Nicole returned to safety and security once more. Following A levels, Nicole went on to study mathematics and humanities before doing a PGCE in mathematics.

Learning to teach

Nicole describes two difficult placements on her PGCE mathematics course. The first was a city centre school 'where there were often drug dealers etcetera trying to get onto the yard at break time', but where, despite the challenges, Nicole felt well-supported by her mentor (see Appendix X, p.232). She describes this mentor as a popular, caring teacher whose active teaching methods inspired Nicole's own approach to teaching.

'We were like rabbits in headlights...'

Despite her positive experiences with this teacher, Nicole's stay at the school was short-lived, truncated by a visit from Ofsted which resulted in the school being placed in 'special measures'³. This presented a challenge to her developing understanding of teaching:

we were like rabbits in headlights, the group of us, 'cause we couldn't believe, so on the one hand we were being guided by somebody who said you should teach in this way and this way and this way and my mentor didn't get slated by Ofsted so clearly she did know her stuff but the rest of that maths faculty and the rest of that school were given a grade 4, notice to improve and all the rest of it. So it was the worst and the best really [...], it also meant that I learnt early on that actually just because a school is labelled whatever doesn't mean that every teacher in there is and she was like a little star, she really was, like a twinkling star amongst all the other things that were going on.

Despite the challenges these schools posed a beginning teacher, her mentor provided Nicole with a new perspective on mathematics teaching and learning, one that had been absent in her own school days; perhaps this is why Nicole sees her as a 'twinkling star'. Trying to follow the uninspiring, fixed approach dictated by her mentor in the second school was challenging, with Nicole working to two different standards (see Appendix XI, p.234). This school was also

³ schools 'failing or likely to fail to provide an acceptable standard of education' (Ofsted, 1999, p. 1)

inspected by Ofsted during her placement, and deemed to have 'serious weaknesses'⁴. These two mentors provided Nicole with two very different models of mathematics teaching.

Early teaching experiences

Of her first teaching job Nicole notes that she was in the first cohort of teachers to follow the new induction process for newly qualified teachers (NQTs), supported by a 'brilliant' assistant head and by the head of mathematics, a teacher who Nicole describes as having little interest in students' mathematics learning as long as they were on task.

...we were always aware that he would tick every box, just for the fact that the children were sat down and on task, regardless of what that might be.

After several years Nicole moved to a school nearer home, taking on additional responsibility. The mathematics results were below those for other subjects in the school but this brought significant learning opportunities for Nicole.

...we had a truck load of local authority support and there were two people, one was the lead inspector for maths and one was a consultant who, we were her designated, one of her designated schools and she

⁴ schools which, though generally providing an acceptable standard of education, are deemed to have significant weaknesses in one or more areas (Great Britain, Schools Standards and Framework Act, 1998, Part 1, Ch.IV, p.14).

was extremely supportive but also her job was kind of to open your minds about how you would go about teaching

The Key Stage 3 National Strategy was in its infancy as Nicole started in this school. One feature was the deployment of mathematics consultants to work alongside teachers in under-performing schools, supporting planning and teaching; this support was positively received by teachers (Ofsted, 2003).

Another key support for learning was a senior teacher who offered Nicole encouragement in the face of the diffident voices of colleagues.

...there's a member of staff here as well, who , he's on SLT but teaches some maths, and when I first came here I said 'well I'm going to teach such and such in this way' and the other staff were saying to me 'God, you're not are you? That's a lot of hassle' you know and put me down for everything. He's one of those people who would go, 'D'you know what Nicole, have a go and tell us how you get on', do you know what I mean? 'Just try it, just try anything' and actually, if you take risks and it doesn't pay off, it doesn't matter because you'll do it differently next time and you'll learn from that

Both this senior teacher and the mathematics consultant were important figures for Nicole in her development as a mathematics teacher, encouraging her to try new approaches and deepen her understanding.

Nicole's reflections on her secondary school days expose questions which still remain regarding the nature of teaching. She discusses her experience of

individual work coupled with occasional investigations with little interaction with the teacher, struggling to make sense of it.

NICOLE Occasionally, we did an investigation, very occasionally, maybe two or three in a year, where we would be in a huge masterclass where three classes of ninety kids were put together and we would work at tables, and write it up, but I don't ever, we used to be told that there was no right or wrong answer and then we wouldn't get our work back so we didn't really know what the point was. So in retrospect, that was pretty dire as maths teaching goes, isn't it? 'Cause there wasn't any what you would actually call teaching going on.

[...]

NICOLE but really occasionally, maybe have a conversation with your teacher maybe once in a term really. It was really, really just that they were, almost like what you would imagine a cover supervisor doing now, which is dire, isn't it? Isn't that a really bad way of teaching maths?

She uses these memories as justification for her avoidance of planning for extended tasks in her own mathematics teaching as she sets herself up in opposition to the disengaged teacher of her memories.

The Ofsted lesson

A significant memory from Nicole's teaching experience is her last Ofsted lesson. She describes this in some detail as she constructs a time-line of her experience:

...everyone thought I was mad 'cause I decided I was going to do algebra for Ofsted and the rest of my faculty thought I was insane, absolutely insane , but I got a got a one for my lesson so [laughter] which was all that anybody really minded. So it was algebra, what were we doing, substitution? [Nicole writes this on her time-line] And it was year 9 set 1 and I got observed. And I did, a card sort and I had differentiation by colour and because Ofsted were in the room the weaker ones in the group, when I said right, ok the orange cards, or whatever it was, are for the most able in the room so you know, aim for it, aspire to it or something like that I worded it as, and because the Ofsted guy was in the room every one of the 35 students crammed in this little classroom felt obliged to do it

[...]

And I used the interactive whiteboard to recap the card sort, extend the knowledge and then, the pupils, they wrote their own card sort

Nicole refers to this lesson when talking about one of her mentors in her initial teacher education (Appendix X, p.232) and the similarities between the two pedagogic approaches are apparent. This lesson provided valuable learning regarding what constitutes good teaching, as Nicole challenged her class with a more open-ended task and had this approach validated by both the students' response and by Ofsted:

The other thing was when, they were writing their own cards, they had little laminated cards to write on and wipe off, and I said 'Come on, we're set one, let's not make it too easy. But you've got to be able to

explain, if someone gets stuck after I've sorted these and passed them on, your name is on the back. It's your job to go and explain if someone gets stuck'. And you've never seen so many indices and brackets and nasty fractions and all the rest thrown in and I thought, oh, this could go either way, but to their credit they could explain everything they'd done. And I think, from my point of view, we would get quite obsessed, especially with the Ofsted agenda that actually that every bit of evidence has got to be in their book and it's got to be marked and up-to-date and all the rest of it and actually the freedom that they had brought out so much higher level thinking that it was actually, and the guy from Ofsted, you know he was not bothered that none of that, none of that was recorded in their exercise books.[...] after all that paranoia and stress actually just having an open-ended task that the children were enjoying and the Ofsted guy was enjoying and the level of mathematics was far higher than anything I probably would have risked doing with them, so I do more of that now, that's what I've learnt, because they enjoy it.

Returning to this lesson several times in our conversations, Nicole appears to use it as the enactment of her espoused philosophy of mathematics. There is evidence of Nicole operating in the role of facilitator, with students confidently posing and solving problems (Ernest, 1994). There are elements of a connectionist orientation (Askew et al., 1997) of teaching here and elsewhere in Nicole's accounts of her practice, of a desire to support students to be able to use and apply mathematics flexibly rather than just apply rules without understanding.

She acknowledges here that the students have increased the challenge in the mathematics beyond the level she would have felt comfortable with, using the validation of the Ofsted inspector to support the shift in practice which follows.

Ofsted again: 'it's when you're absolutely at your best, isn't it?'

Ofsted appear to play an important role throughout Nicole's teaching career, providing validation, an external perspective on how she, and others, are performing. We discuss this at the start of our second meeting, reflecting on the transcript of our earlier conversation.

GILL ...they feature quite large in that account don't they, Ofsted?

NICOLE They do actually.

GILL Why do you think that is?

NICOLE Probably because, its when you're absolutely at your best isn't it? And its probably the points in my teaching career that filled me with the most fear and therefore you remember the most. [...] it doesn't matter how well trained you are or how well you know your job until you've actually been through an inspection I don't think you ever believe any of the feedback you get from people that you work with.

[...]its always been quite interesting because I'm not like the loudest member of staff here but I know I do alright at my job so it kind of gets verified, that you are allowed to think that you are good at your job.

Then it makes you feel a bit more safe about things

Support for teaching

For Nicole, further support for her development as a mathematics teacher is derived from the informal support of colleagues, with whom problems and resources are shared.

...I actually think that the informal stuff is something that I value far more than, yeah the formal stuff happens, it happens every term and you get your feedback and you tick a few boxes and its lovely and supportive and stuff but actually personally, I think its more the support and the pooling of ideas and the moral support and the camaraderie, working together as a team I find is more important to me.

Beyond this, she searches out resources herself but notes that networking beyond the department is more limited than hitherto:

I think I do that [networking outside the department] a lot less now than what we used to. Because we used to have quite strong links with the local authority and stuff like that but, rightly or wrongly, that's felt more like a stick we got beaten with than an actual support, I don't know whether its the kind of competitive nature of inter-school stuff or, or what, but there isn't much...'cause I've always kind of been taught that if something is troubling you then you wouldn't take it outside of school, outside sources don't tend to be something that I would view as support, so I might go on NRICH site or National Centre for Excellence in Teaching Mathematics and stuff like that for myself because I want to plan x for next week or something like that but it wasn't something that I would have associated with the word support.

As the most experienced mathematics teacher in her department, Nicole takes responsibility for her own continuing development, saying she is studying for a generic Masters in Education to support her career progression. Drawing on the conversations she has with student teachers to support their reflection on practice Nicole expresses a need for similar opportunities herself.

I miss somebody actually keeping me on my toes and pointing, you know just sometimes when you going through your career there are those people who kind of signpost you to 'I think you'd be really good at such and such next' and I kind of miss that now.

Nicole acknowledges that she has little engagement, or encouragement to engage, with mathematics specific opportunities:

I mean I know that there are various organisations and associations that you go to for resourcing and things like that and I do, so I'm aware of ATM and things like that and I will regularly retrieve stuff and you know, do a google search 'cause I want a new resource for something because I'm not happy with how it, that lesson went last time I taught that topic[...] but it does tend to be something that I kind of do off my own back rather than through school or something that we are encouraged to do

In the days of the National Strategies Nicole felt she had more opportunity to network with mathematics teachers from local schools, working collaboratively on developing materials for numeracy across the curriculum. In part, she sees this

as less essential now that the department is fully staffed and she herself has more experience, remarking on the importance of learning through teaching.

I probably understand maths far better now because I've **taught** it than what I ever did to pass any of the qualifications to become a teacher, so I think, although I understood individual topics and I passed the exams and all the rest of it, its only when you come to explain them and then explain it again in a different way and then explain it again in a different way, and a different and a different, until you've gradually worked through all thirty pupils to make sure everyone understands, its probably that that makes me understand maths the way I do much more than ... what I ever did when I was learning it.

6. Leila: 'No-one really supported me in my teaching'⁵

Biographical commentary

Leila was born and brought up in a city in the north-west of England. One of twins, Leila was known as the more outgoing one of the two; her twin sister was a quiet, studious student. Leila describes how she and her sisters followed their mother's example in establishing themselves, opposing the prevailing cultural expectations regarding women's roles:

You know, that we weren't going to be messed around with and we are quite headstrong, like my mum I suppose in that way. The biggest person, I suppose, has been my motivation has been my mum, in all of it you know. Just do it, just do it. You know. She's quite good in that way.

Her schooldays were, according to Leila, fairly uneventful.

... the type of education I had was very girls' school based because my parents wanted that on religious grounds. So they were adamant that it wasn't going to be mixed schools or anything like that so. [...] The schools were fine, never had problems with school.

⁵ I met Leila only once as part of this research; despite several attempts I did not get a response to my request for a further meeting. Subsequently Leila has been back in contact and has read the interpretive story I sent her.

Leila notes her progress in mathematics in the years prior to national examinations at age 16.

...I was in set 3 in year 9, moved up to set 2 in year 10, moved up to set 1 in year 11 so obviously that gave me motivation to want to do really well in my maths.

In the final cohort to sit O levels, she gained a Grade B, using this as evidence that she is not 'the most academic person'. She did not feel she did herself justice in her A-levels, retaking them at a later date.

Sixth form was...sixth form I was quite lazy. Didn't do as well in the A levels as I should have done. I've gone back and done A levels now, got A's and stuff like that, I got D's then. And I was one of those slobbish students, anything to have an easy life.

Following sixth form she went to a local university to study for her degree, following this with a one-year PGCE course.

Leila says one of her secondary mathematics teachers inspired her decision to go into teaching, though there was also an element of pragmatism in her choice, with job security a factor. Her parents placed a high value on education for all, challenging more traditional cultural views. Choice of career for her siblings was influenced by cultural norms which valued the sciences and medicine and Leila faced some opposition when she started to study a mathematics degree.

That was just – [my mother] couldn't [accept teaching as a career for me] – because in that day, those days it wasn't the norm. Everyone

was into medics and pharmacists and dentists and this and that – you know, teaching wasn't – in the Asian culture I'm talking about, wasn't seen as a profession. But she realised it was a profession, it was a salary, it was you know, a good job to have.

Several of the stories that Leila tells underscore the barriers that she and her sisters faced in their quest for education and the criticism her parents faced for advocating this.

...a lot of Asian girls had that high expectation they were going to get married at 16 or 18 and that's it you know. You can do your degree, you can do your studies but you are getting married and that's it and my mum had made that stipulation to my dad that [...] she was going to let her daughters educate themselves first and then get married ...

Today, Leila sees that she plays a role in supporting others to challenge traditional patterns, recounting the chance meeting of an ex-student in the local supermarket to illustrate this. This young woman told Leila how, in the early 1990s, she had been inspired to study law by Leila's example. Leila reports her saying that '... in [secondary] school, I didn't know any Muslims that worked and you were the first one that I could see that wore a scarf and actually worked. No one worked'.

Learning to teach

Leila's second placement on her PGCE course was positive, with a supportive mentor.

LEILA: He was very hands on. Would discuss everything. Would go through the planning with you. He was very creative in terms of like he was a very visual person. He knew what he wanted. And I think he helped me with – he was very – he was obviously somebody that was important in my training time because he, yes, without him I don't think I would have had a clue really. I think the, there was elements of the first placement where you just did what you were told and stuff like that but he was definitely hands on, 'Have you thought about this, have you done this?' and we would discuss a lot. So he was quite important.

In her first job, the situation was quite different, as Leila was just left to get on by herself:

... I was just left of my own accord. **No-one** mentored me, even in my NQT year. Left in the mobile⁶, just got on with it and literally learnt the hard way, through text books, so that's how my learning took place.

[...]

No-one really supported me in my teaching. Once I got into teaching there was no-one. Just got on with it and do as you are told kind of thing.

In her second teaching post she had her own classroom and she gained more support from other teachers in the department.

⁶ Mobile or temporary classroom

I think that helps me because I am quite creative, I've got different ideas and want to learn but no-one, I don't remember being supported in any way in the first two years. [...] I think talking to other staff was important and we all got on and that was really important and we helped each other and we worked as a team.

[...] I suppose that is where my learning came from, I would ask advice, can I do this, can I do that. I'm trying to think where else, 'cause there was nowhere else. Nobody was like monitoring me as such, or assessing me as such. But I think through informal chat in the staffroom or within department meetings or just in the maths office...

Leila believes that much of her learning has been through teaching; here she describes how important she feels it is to teach different sets:

And having taught set 1 and set 7 helps you realise that you have got to teach at that level or you've got to teach at that level and that's an important thing having different set levels. You can't always have like all the top sets. I think that by having that mix of sets, that communication, that understanding varies and makes you realise that you have got to talk down there and you have got to talk up there.

She notes too, how she learns through her work with students on placement from initial teacher education courses. Both her discussions with these students and her reflections on her own teaching support her developing practice, though she says that after a time, she does tend to revert to her old ways:

GILL:...you talked earlier about learning from the students as well when they come in.

LEILA: No I think that is quite- that is definitely...important for me I think because I can get too set in my ways and when you have seen a student doing that standard lesson that everyone does, there is the title, there's an example, copy it down, here's the textbook or a worksheet, copy that. Like I was taught in school, which I accept as being normal, then again maybe not, and then I realise how rubbish it is and how you can, you need to have variation, a variety. And once the student goes I go back to my old ways again. It has got to be balanced, it has to be balanced. So, yes, I do learn a lot and I like getting ideas off them as well.

Traditional and modern

There is a significant, lengthy passage in Leila's account which connects her own mathematics learning with her teaching, her learning through her MA study and her support of beginning teachers. She appears to articulate a struggle; one that calls into question the certainty she had about mathematics. She oscillates between justifying her own, more traditional approach and a tentative acceptance that there may be something in this 'pupil led learning' after all. Leila begins this story telling me about Miss Hunter, her own teacher in secondary school.

...she was a classic deputy head where she was constantly in meetings and she'd have a clear example on the board and one of these like

sheets with 50 questions and you would just sit there and you did,
'cause the door was wide open, and you sat in silence and you just got
on with it.

This 'old style teaching' followed a set pattern of teacher modelling preceding student practice, 'you just plod along and you just accept it'. She remembers the methods she was taught and maintains that Miss Hunter was a very good teacher. Today, in her own teaching, Leila employs the same methods, eschewing alternative approaches:

you know like the smiley face,
the multiplying brackets,
classic example.
I look at text books
and they have the grid method⁷
and I go 'Kids,
forget the text books.

You will do my style of teaching'.
And I get my coloured eyebrows
and get the coloured nose
and stuff like that
and they go 'Oh yes, I can see the face now'.

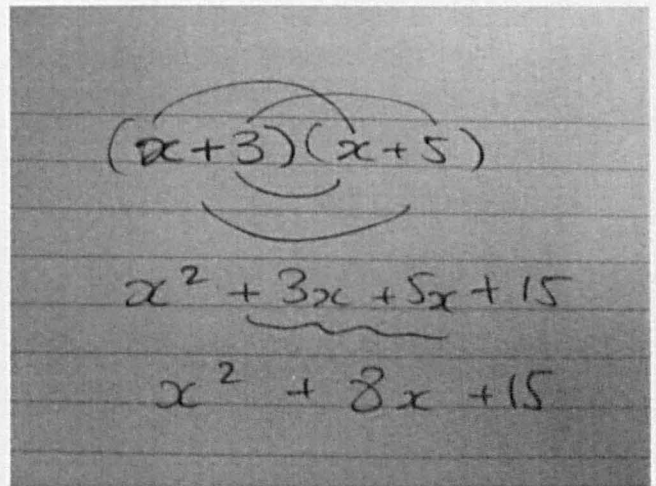


Figure 4 Smiley face multiplication

⁷ Method for multiplication

'I told you.

I can see the face, you can see the face'.

[...]

'there was nothing wrong with what I learnt and you'll learn my way.'

As Leila concludes this story she appears to be struggling towards a view of teaching and learning that feels right to her.

I mean I will show kids three methods

and I'll say 'Right

this is the way I was taught

and you are all doing that one'.

And one or two will pick up the grid

but that's it.

Yet people think that

'Oh the new method is the grid multiplication'

I think well

not really.

Though she shows her students a variety of methods for multiplication she is clear which they ought to adopt and yet she remarks, with reference to her Master's degree, that she is still learning, saying 'I think I have started to break

the mould a little bit but I think it will take me a little bit more time [laughter]'. I wonder which mould she is trying to break, the mould cast back in Miss Hunter's class or one rooted in her history and culture? Examining this passage closely, working with lines and stanzas, I note that the statements about the traditional approach are much shorter and more definite than those about more modern approaches. It is almost as though Leila refuses to open the traditional approaches up to discussion, needing to hold on to them as they are. Much of her past is invested in these approaches. They represent her own mathematics learning, rejecting them would challenge her identity and her view of mathematics. Challenging them involves a shift into a less certain world.

7. Marta: 'You don't need to teach it like that, you can teach it this way'

Marta had worked for around thirty years in mathematics education as teacher, head of department and advisor. At the time of this research her job was to support and coordinate mathematics teacher professional learning. Part of her role was to bring those involved in mathematics education together, facilitating network meetings.

Biographical commentary

Marta was committed to mathematics at primary school and felt able to do it, her success here serving to highlight her capability in mathematics when her performance slipped in secondary school.

I remember winning a prize for maths in primary, so I obviously had quite a good feeling about it at that stage and I think that I could do stuff and [...] I suppose I was really quite pleased with myself, quite proud of myself and I'm glad that I did because at least I know that I could do maths when I was in primary [...]. I think it's a mark, a reminder that, that it wasn't all bad, that there was a time in my life when I could do it and then it seemed to dip down and I don't think my intelligence dipped, I don't think, I think it was just my understanding of the subject dipped, my wish to engage with it just...

Secondary schooling was more difficult, Marta remembers that her mathematics lessons were characterised by poor teaching and she soon became disaffected.

I just remember being bored and not engaging and then amusing myself and amusing other people by being troublesome in class. I just had **very** weak teachers, **very** weak teachers who just did not know how to a) teach, who didn't have a content knowledge that was sufficient for the level that they were teaching at, and couldn't control the class and we were like grammar school girls so it wasn't as if we were hard line tough kids or city kids or anything like that, we were pretty much sensible schoolgirls but mischievous and some of these teachers just couldn't hack it.

Despite this period of disaffection Marta chose to study A level mathematics. She vividly describes the stark contrast between her sixth form mathematics and those earlier years, using the metaphor of a light being switched on, illuminating mathematics.

GILL: And those teachers, those two teachers in sixth form, what were they like?

MARTA: I don't really remember them that well except that I was thinking '**wow**'. They just taught **well**, they were **fast-paced**, they must've been well-organised, they just made it interesting, they made it accessible. I just think of them as fast-paced, interesting lessons and I'd never had that before so I sort of see a before and an after and, and they were just like a revolution to me. '**Gosh**, this is what good teaching looks like' because I hadn't had that. I don't think I'd had that in **any** subject. I don't remember being particularly well taught in any

subject at grammar school. I think, because we were a girls' grammar we were just, it was quite allowed to coast

[...]

I've just got this general feeling of thinking 'wow, is this what maths is about?' And I had had that in the primary school I think and it had been so far in the past I had forgotten about it and I'd spent so many years at grammar just coasting and not engaging and then to have this like, it was almost like this switch on and off, light, that was on, off and back on again [...]

In accounting for her experiences of mathematics at secondary school, Marta focuses on the teachers, on the difference between good teachers and weak teachers. However she is not merely a passive participant, in taking on the role of entertainer for her peers she is calling for action from her teachers; later she expresses regret at not having engaged positively sooner. In a subsequent conversation Marta added more detail to this story, recounting that she had 'only got 3 O levels' at the grammar school and had moved schools to re-sit them. This fragment had not been revealed initially and served as a reminder that other fragments of the story may be missing. Hearing this additional information altered my own picture of Marta's schooldays but, more importantly, made me question the image I had formed of her, the conclusions I had jumped to.

After completing her A levels, Marta went on to do a three year Certificate in Education course in mathematics, gaining 'a really good grounding' in psychology, child development and sociology amongst other subjects, with

teaching placements in primary and secondary schools. Her teaching career spans more than 30 years and a variety of roles, including that of advisory teacher, head of department and work on a curriculum project (see Figure 3, p.108).

As the final part of Marta's biography what follows are details of her formal, accredited learning experiences beyond her initial teaching qualification. These more formal experiences were uncovered during the construction of a time-line of professional learning during our second meeting (reconstructed in figure 3, p.108), hitherto playing an insignificant role in Marta's account of her learning to be a mathematics teacher, perhaps in part as she elected to tell me only of her experience directly related to mathematics.

Accredited learning

Several years into her teaching career there was a push towards an all-graduate teaching profession (DES, 1979) and Marta undertook a mathematics degree via distance learning, following it with a Masters degree in Educational Management, all while she was working full-time and bringing up a family. 'I didn't really stop, did Masters, I did diplomas and things in between'.

Throughout her career Marta has exploited opportunities for professional learning, undertaking the National Professional Qualification for Headship (NPQH) in addition to her degree and a Masters in Education. Most recently, Marta has been working on her doctoral thesis. As she finishes recounting this

academic history Marta expresses a desire to engage in further mathematics study.

I think I am going to stop. No actually I think what I would like to do is actually go back and do some more maths again because I have gone into education so deeply I think I would like to start looking at some further maths or go back and do an A-level again or refresh bits of maths that I haven't done for a while, just for the fun of it really. You know, I think part of me, when I was doing it, I was always worrying about the qualification and failing and I think now I could go back and just do it because I want to.

[...]

I'd like to now go back and have another go at because, I think the fear factor has gone and if I don't have to prove myself in examinations I can just go back and do it and enjoy it.

Marta remains dissatisfied despite the raft of qualifications she has achieved, wanting to go back and explore neglected areas of mathematics. The account of her experience of professional learning, related in the next section, points to an alternative to the accredited qualification as a route towards knowing: her reflective account illustrates a view that learning is professional life, a part of everyday lives (Wenger, 1998).

Learning to teach mathematics

Informal learning is important in Marta's account of her development as a teacher. She draws heavily on her own experience as a learner, exposing her difficulties with fundamental concepts in mathematics, recounting how she worked to understand them and how this influenced her teaching:

I remember probability, the teacher coming in and saying 'We have to teach probability, this new thing, I don't like it' and throwing some dice at us and telling us to roll the dice and I had a big block with probability for a long time until I actually understood it. And when I understood it I thought 'gosh'. But when I teach probability I always teach it in the way I had to re-teach it to myself so I could understand it and quite a lot of what I learnt in [grammar] school, I re-taught myself it in my own way. As a teacher I had to re-figure it out and then whenever I teach the kids I teach it to them as I had to figure it out. Something like ratio for example, I couldn't do ratio at all as a teenager, didn't understand what it was about. When I'm teaching it, I teach the kids as I learnt it and quite often the children say 'Oh, is that what it's all about? Oh wow' and, and I just think, well yeah, because that's how I understand it.

[...]

And I think that sometimes if you struggle with something, and you have to unpick it right back and build it back up again, then it makes you better in teaching it. I think you get an understanding of where the children are sticking at and you help them get round that.

This emphasis on unpicking topics recurs, beginning to create a rich picture which involves more than Marta merely working on the mathematics, though this is itself an important dimension, and points towards a framework or 'structure of a topic' (Mason and Johnston-Wilder, 2006, p.19) that she has built up over time. A key aspect of her learning is the focus on her own mathematics; exploring new approaches to understanding concepts.

I've [...] built up my repertoire of different ways of teaching something and [...] this morning I was teaching quadratics, solving quadratics with the coefficient more than one so I gave the children one way and some of them just weren't getting it so I said 'Look ok, here's an alternative way, which way do you want?' And some of them wanted to stick to the first way because they've got it and others wanted a second way and they preferred that because they found that easier and I think that that's part and parcel of becoming a teacher is developing, not just the way that you understand it but also other ways that the children might understand it (...).

This deconstructing mathematics as a prelude to teaching is a theme throughout Marta's account of her experience of learning to teach, a clear articulation of the necessity of a focus on learning mathematics content and pedagogic content knowledge (Shulman, 1987; Ball, 1990; McNamara et al., 2002).

Doors opening

A critical person in Marta's development as a mathematics teacher was originally her mentor when she was training to be a teacher, later becoming her head of

department. He led an innovative department, coming in with 'breath of fresh air ideas', talking about mathematics and encouraging risk taking. The contrast between him and her previous head of department was stark:

I think I remember as a newly qualified maths teacher that we taught maths from the chapter heading, you know the first term was chapter one, the second term was chapter two. You know, we taught from the book headings and it was very, very dry and very, very boring and then I got another head of department that made it more interesting and I think he guided me quite a lot in developing a philosophy in how maths should be taught.

[...]

I think that was a very subtle formation of my ideas and having a head of department who, one first of all that did it just by the book and it was just really dry maths and then another one that came in with a much more practical attitude [...] and also a bit of a risk taker, to try things, be part of projects, to go to meetings, to discuss things, I think that is all part of generating into a much more reflective type of practitioner really, somebody who would think about what they were doing and try to make it better.

[...]

GILL: What was that like, having to teach from chapter headings, that dry maths?

MARTA: Oh, it was just awful. Absolutely awful. (...) And you tried to do it your best that you can but if you, if you are in a classroom and you have to stay in the classroom and the door is shut, and you've got thirty something kids there and a textbook each and no equipment and even if you had you probably wouldn't really know what to do with it. You're quite isolated really aren't you? And then, to have that changed to someone who comes in and then opens a door and says 'Oh, hang on, you don't need to teach it like that, you can teach it this way, and do it this way' to have that was quite powerful really. So I think I'd probably underestimated that period really because it was a long time ago

Marta describes extremes, emphasising the contrast between the classroom with the doors shut and the lights out to a mathematics learning environment which extends beyond the classroom walls: the doors have been thrown open in an invitation to use the space beyond, to construct and connect learning. She articulates her development, noting the role of others in supporting her to take a more critical stance, becoming a reflective practitioner. The change in pronoun in the latter interview extract creates a distance between Marta and the younger Marta as beginning teacher, who is ascribed more limited agency.

These early years of Marta's teaching career spanned the 1980s. She notes that the publication of the Cockcroft Report was around this time and the developments of the period impacted on her own teaching.

...Calculators were starting to come in then, there was the Calculators Awareness programme⁸, there was RAMP Raising Achievement in Maths programme⁹, and there was Mechanics in Action¹⁰ and there was a lot of lovely things going on around that time and I think that all those had a moulding effect, a subtle effect on my teaching that I probably haven't given fair (...) discussion really.

Reflecting on these early teaching days, Marta recognises their influence on her; pointing to a knowledge of developments in mathematics education beyond the immediate sphere of her own classroom and school setting, to participation in a wider community, facilitated by her head of department. Marta drew additionally on published materials to support her development, citing the non-statutory guidance for the mathematics National Curriculum (National Curriculum Council, 1989) and the Cockcroft Report (Cockcroft, 1982) as influential supports to her planning.

I do remember the non-statutory guidance though of the National Curriculum, whenever that came out and the Cockcroft Report obviously that had some nice stuff in it as well, the two things are of the same sort of ilk aren't they? So it was quite nice to have a theoretical

⁸ The Calculator-Aware Number project, based in Cambridge in the second half of the 1990s, focussed on developing a calculator-aware curriculum for the primary phase (Shuard et al., 1991)

⁹ A curriculum development research project running from 1986 - 89 (Ahmed and Williams, 1992)

¹⁰ Mechanics in Action project supported a practical and investigative approach to solving problems in mechanics at A level (Savage and Williams, 1990)

background that underpinned what you felt as a maths teacher, that was similar to where you were coming from.

A key tenet of the Cockcroft report was the encouragement of a range of teaching approaches including exposition, discussion, practical work, consolidation and practice, problem solving and investigational work (Cockcroft, 1982, 243). This pedagogy appears to suffuse her practice, forming part of her own philosophy of mathematics education.

And also, whenever you were planning schemes of work that you made sure that you got the different sort of investigations, problem solving, different dimensions. In my head, whenever I plan schemes of work I would have the children's learning styles in my head, I'd be thinking of the different types of learning styles, but also I'd be thinking of the different Cockcroft activities and if I'm covering all those, not all in equal, by any means, but if I'm covering all those within a scheme of work then I think we've got a pretty balanced diet and I think that some of that stuff has gone by the wayside.

Around the same time Marta had another formative experience, working to facilitate the development of good practice as an advisory teacher. These advisors, often appointed by local authorities, were known as Cockcroft 'missionaries' (Royal Society, 1997).

And then I was an advisory teacher for a year and that was quite fundamental as well because I was out at the university quite often, getting in contact with people who had got really out there ideas and

GCSE was just starting to come in and the, the you know the tasks that we used to do and I think all that was sort of just at the right time for me because I think I was just developing into a, you know, a pretty good teacher probably at the time and 'cause I'd seen sort of the dry old boring bit and then how it was so much better and I think I'm probably not giving that fair hearing really to be honest.

This experience as an advisory teacher is significant, exposing Marta to new ideas and providing her with the opportunity to articulate her experiences, shape a philosophy and share these with other teachers. The interview conversation appears to play a role in supporting Marta's own reconstruction of her experience; as she talks and remembers she appears to realise, with surprise, the influence various episodes had on her practice. Figure 5 (p.159) shows this set in the context of selected developments in secondary school mathematics at the time.

Marta describes her attendance at a one-day course as a defining moment, this at a time when she had been teaching over ten years and was a Head of Mathematics. The light metaphor is used again here; the course is one of many that Marta has attended but unlike the others, this one marked a turning point in her teaching.

I remember going along to an MEP¹¹ maths enhancement programme day that was being run in [a large city in the north of England] and having like sort of a light switched on moment whenever David Burghes

¹¹ Mathematics Enhancement Programme

was talking about the MEP philosophy and not having this tail of children with special needs you know, dragging away behind, pulling them up and keeping the class together with this whole class interactive type of teaching and I remember feeling, you know, really enthusiastic about what he was talking about and taking it into my classroom and it changed my practice, not entirely, but certainly for aspects of, that we took that on board and I think it had a big impact on you know, using the maths language more precisely, using the equals sign more precisely, including units and being much more rigorous in the use of the equals sign you know in everything that you do, being much more precise about it. I think I got a precision there that lifted my level and that was through an outside speaker not an internal sort of CPD experience and that was quite profound with me. It caused quite a dramatic shift in how I taught. For the better I think. I think it just added an extra dimension to the teaching that I had, the teaching experiences that I was giving before that.

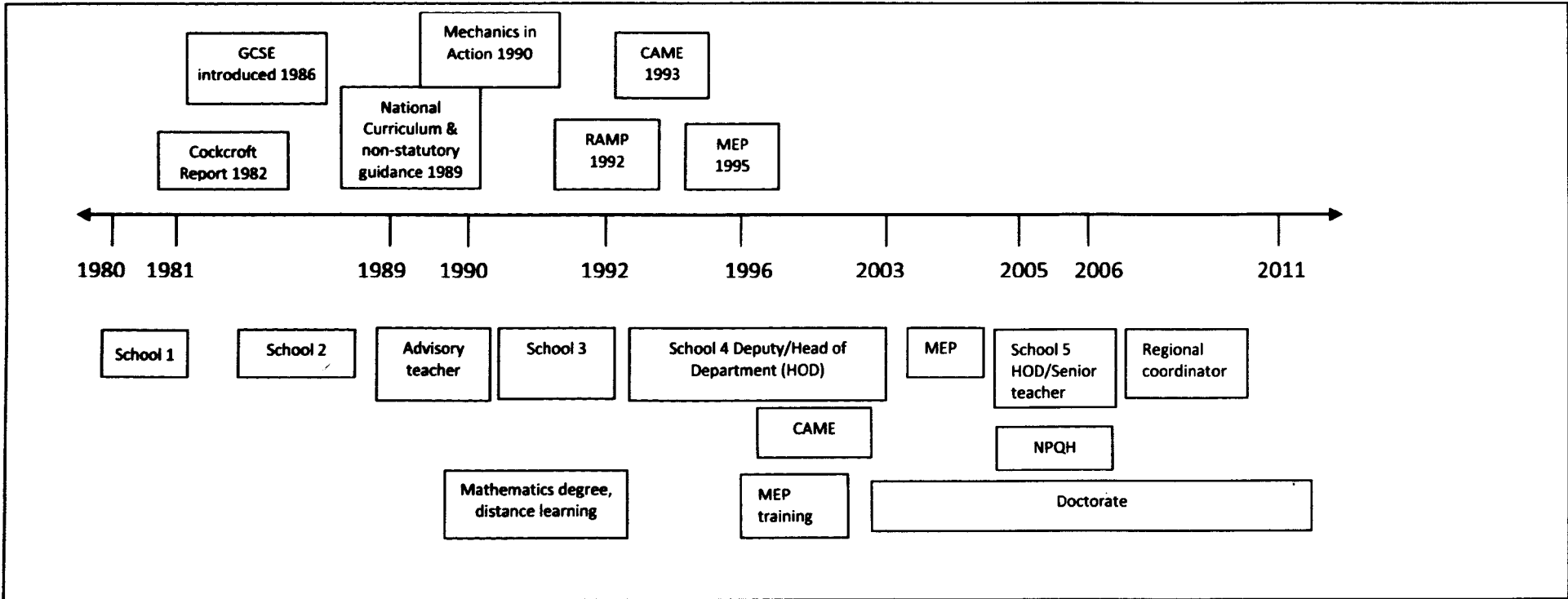


Figure 5 Time-line of Marta's professional experience

In addition to this one-day session, Marta participated in other initiatives in mathematics education including leading her department in trialling the CAME (Cognitive Acceleration in Mathematics Education) project developed at Kings University. This programme was founded on principles derived from the work of both Piaget and Vygotsky (Shayer, 2003) and Marta acknowledges the importance of Vygotsky's theory of learning, stressing the importance of collaborative learning, both for students and for teachers in their own professional learning.

But I think, you know the Vygotskian type idea of people working together at a similar level and learning from each other, I think it is something that teachers should or could do and do do but also the children.

[...]

I think that that that's important what the, within MEP and CAME and stuff like that, there's quite a lot of discussion about Piaget and Vygotsky and people like that but Vygotsky would stand out a mile in my mind because of the importance of people learning from each other.

Marta situates her own experience, locating it theoretically and in terms of developments in mathematics education at the time. The door was thrown open for her at a time when she was able to take advantage and step out, though she notes, ruefully, that not everyone is so fortunate.

I think there's an ambience of, that sets the tone, about whether you have to be in the classroom with the door shut and you are chalking

and talking or whether you are allowed doors opened and you've got measuring tapes out and you've got trundle wheels and you are out round the playground doing activities or trigonometry or you've got your clinometers and you are out measuring heights of buildings. [...] I think our young teachers coming through, not necessarily young, but I mean, inexperienced, newly qualified, are coming out of universities where they're coming out with all these ideas and things they want to try and then they meet that barrier and they've got enough to do without having to try and unpick a barrier, just surviving. And I think some of them just fall by the wayside and they don't have this enlightenment as it were, of somebody coming in and saying 'It doesn't have to be like this, the barrier is now gone, it can be like this', [...] too many teachers are met with that barrier, where they are in the classroom, the door is shut.

Marta acknowledges the importance of individual role models in teacher professional learning but is forceful in her view that support so vital to mathematics education should not be a matter of individuals triumphing against the odds, what she describes elsewhere as the barriers created by the 'pressure to perform'.

Coda

Right at the end of our conversations, as I ask Marta if there was anything that she wanted to add, I get back more than I had bargained for: information that

forced me to revise my interpretation of her story. There is a long pause before she starts.

MARTA: 'No, I think, I had to do my, I don't know if I said, I did my final year in primary, I had to do it twice. Did I say that?'

GILL: No, no

MARTA: That was quite a learning curve for me. They realised I'd gone to school a year too soon and so I was too young, I had to wait to get into the grammar so they made me repeat that year and that was awful, that was absolutely awful.

She describes the experience of a student who was well-regarded at primary school suddenly being held back, apart from her friends, kept back with the year below her as 'absolute cruelty'. Academically, she felt like she was marking time, repeating work. She sees that her disenchantment with school began during this year, sowing the seeds for the difficult time she had at secondary school. Again, this serves as a reminder that there is not one story of Marta's learning but many; stories which are constantly evolving and being reconstructed: by Marta as she lives and tells them, in my reconstruction and in your reading of them.

8. Discussion

In this section I consider how the four women's stories, taken together, address my research questions. Examination of these four different stories illuminates what participants learnt and how they learnt it, exposing the key sites of their learning and the ways in which this learning is supported or constrained. I begin by exploring the substance of teachers' learning, addressing the first broad research question focussed on teachers' experiences.

Professional learning - learning what?

Marta, Heather and Nicole all emphasise (re)learning mathematics as an important part of their professional learning. This mathematical work is frequently a solitary endeavour and one which is undertaken to serve their teaching; appearing functional rather than pleasurable. The sharing that does take place at departmental level is frequently a seemingly superficial sharing of strategies and resources rather than in-depth collaborative engagement or enquiry into practice. Although Leila notes 'we helped each other and we worked as a team' and Nicole remarks that 'we bounce things off each other and it's a nice environment to work in' she is also aware that 'we teach everything in a totally different way'; there is little sense of the development of a departmental approach or philosophy of mathematics education. This has echoes of the women's experiences of learning mathematics themselves, a subdued and tentative collaboration with peers that was not explicitly valued or encouraged by their teachers. Heather longs for more; she noted the value of working with a group of peers at school and

university, aiming to facilitate a collaborative environment in her classroom whilst wishing she had the opportunity for deeper collaboration in her department.

Marta's experience is an exception to this individual work on mathematics.

Encouraged by her head of department 'to try things, be part of projects, to go to meetings, to discuss things' she continues to work with her own department to develop collaborative approaches to mathematics:

it is quite an intriguing subject and you want to try it and chew it over and chat it through. And that is what I've been doing with some of the teachers at the school I'm at now is, we you know, put stuff up and somebody will put that way and I'll say 'Oh, I think it is that way, turn it around, upside down and I've never thought of it like that. Let's chat that one through, see what you think'. To me that's important, I love that sort of mathematical dialogue between maths teachers

This glimpse of Marta encouraging teachers to explore mathematics problems is the only explicit reference in the four teachers' stories to teachers working on mathematics together. Marta expresses a longing to go back and do more mathematics now 'just for the fun of it'.

Each woman learnt early on in her career about prevailing discourses in mathematics education. The pervasiveness of the ability discourse in mathematics is evident throughout the narratives, the gendered nature of this discourse highlights the challenge the women faced in choosing mathematics (Mendick, 2006). In England setting or grouping pupils by prior attainment is widespread, despite questions regarding the efficacy of this practice (e.g. Boaler

et al., 2000). Most recently the iniquities promoted by this system have been highlighted by Ofsted who note that students in the lowest sets receive the weakest teaching, with higher attaining students also failing to fulfil their potential (Ofsted, 2012). The teachers in my research recall their own experience of schooling, remarking on their positions in the hierarchy. Leila 'in set 3 in year 9, moved up to set 2 in year 10, moved up to set 1 in year 11' sees this as encouragement, motivating her to succeed. Nicole's attainment risked being limited by her teachers' view of her; although in the top set for mathematics she is denied access to key topics as she is not in the top end of the set. Nicole rejected her teacher's view of her, seizing the opportunity offered by a change of schools. Heather's teacher prescribed a limited future for her too, which Heather also resisted. This early resistance is significant, alerting the teachers to the dangers of low expectations. Their experiences within these sets have been influential on their developing identities as mathematicians: these environments appear to emphasise speed and procedural fluency over understanding, features which are seen as particularly disadvantaging girls (e.g. Boaler et al., 2000). Although all of the women have succeeded at mathematics, the restricted participation of three of the women in the mathematics education community echoes the marginalised identities found amongst top set girls of secondary school age (Solomon, 2007b).

The more 'fragile identities' of women mathematics students, which are evident in compulsory and post-compulsory mathematics education, have been ascribed to discourses which restrict the choice of identities available to learners (Solomon et

al., 2011). In Heather's story there is evidence that these discourses are sustained in the professional world of teachers. At school, being good at mathematics is equated with being quick; top set girls in particular are likely to report anxiety due to the fast pace of lessons (Boaler, 1997). However, being quick at mathematics is only one dimension of a successful mathematical identity: problem solving, for example, frequently necessitates a more considered, often slower, pace (Horn, 2012) and teachers that recognise this may nurture girls' mathematical ability more effectively (Boaler, 1997). Heather does not see herself as quick, therefore she does not see herself as a 'natural' mathematician (see p.113). The 'lads' (including her husband and son) are 'bright' and 'quick': for them mathematics appears almost effortless. For Heather it is hard work and takes time; her success is attributed to her hard work but in terms of school mathematics this appears to be regarded with less esteem than speed.

The teachers have also learnt about their own agency as they struggle with policy and practice that is at odds with their beliefs. Heather recounts a significant phase in learning to teach when she had to prepare a Year 10 group for early entry at GCSE:

for the set one it seemed a bit unfair really because you [...] seemed to be rushing through everything with them and a lot of them would get it but there's inevitably going to be some who start to fall by the wayside but [...] you've just got to race through everything. And then they take the GCSE a year early and sometimes you think [...] has it actually made maths a little bit of a, a rush for them [...] is it a disservice to

those who would benefit from having extra time to just, have a better understanding of what we are doing rather than just learning in to get through the exam at the end of year 10

This policy of early entry was widespread at the time of our interviews in 2012 and was criticised by Ofsted later in the same year (Ofsted, 2012). As I write, steps have been taken to limit the practice (DfE, 2013). Both the decision to enter students early and the subsequent curtailment of this practice demonstrate the restricted agency of teachers. This practice appears to exemplify that 'one of the devastating legacies of high stakes testing is nothing short of a brutal act of sabotage on teachers' intellect and ability to make autonomous informed decisions about what is in their students' best interests' (Miletta, 2010, p.149)

The support that Marta and Nicole experienced early in their careers appeared to have enhanced their self-efficacy, increasing agency as they imagined alternatives and made plans. These two express a self-direction in their professional learning. They were supported to achieve this direction by more experienced others, who flung doors open, encouraging them to improvise and take risks.

Mode of learning

The short courses that I had anticipated would make up much of the landscape of teachers' professional learning demonstrate their potential in Marta's story. A one-day course proved the catalyst for a transformative experience, changing the way Marta was to view mathematics teaching and learning. Heather found a session at an in-school inset day provided her with a model that she could use in

the classroom, expanding her understanding of what was possible. This experience stands in contrast to her view of the whole-school inset days, squashed in to after-school twilights with centrally determined agendas which Heather feels little ownership of. Such short courses are not reported as significant by Leila or Nicole.

The literature review indicates that effective professional learning typically involves sustained and intense engagement, with accredited courses offering considerable potential (Turner and Simon, 2013). Three of the participants had undertaken study at Master's degree level. These longer, accredited courses were focussed on coaching and mentoring, leadership and management or more broadly on educational practice. For each participant their study supported critical reflection on practice but lacked a specific focus on mathematics learning and teaching. Marta, having completed her Masters study and a doctorate, expresses a desire to return to study mathematics, perhaps in acknowledgement that this focus has been lacking in her formal learning.

Mentoring and coaching has played a role in the teachers' learning, though not always as a result of formal relationships. Teachers draw heavily on the early models and 'anti-models' (Williams, 2011, p.140) provided by their mentors during initial teacher education as they began to construct their professional identities. This experience helped to clarify the kind of teacher they wanted to be, often in opposition to these models. Nicole's experience of coaching was significant in her development. The support of a consultant allowed her to

experiment and to question existing practice. She gave Nicole permission to make changes and to work her way closer to a vision of mathematics teaching that worked for her. Crucially, this support came from someone with an explicit focus to help the school to raise attainment, and yet this consultant's message was that to do so involved a degree of risk, as fundamental changes were needed.

Reflection on practice and on experience, particularly on the teachers' own experience of school mathematics is an important, if underexploited theme. This often surfaces through questions as the teachers work to make sense of their experience. Nicole grapples with her experience of school mathematics, struggling to reconcile her experience as a school student with the knowledge and understanding she has gained as a teacher; here the complexity of learning and teaching are revealed. Teachers' colleagues are important in supporting their learning though this is frequently through informal networks and appears to be superficial.

Significant figures

One of the original research questions centred on uncovering critical incidents, phases or people in teachers' professional learning. The stories reveal the significance of individuals in teachers' learning and the impact these have on their 'identity work' (Williams, 2011, p.132); leadership emerges as a factor in teachers' professional learning. The power of the four stories considered together enable me to make comparisons, noting the absence of critical people in

addition to their presence, questioning the difference support may have made. It is clear that both the vicarious experiences and verbal persuasions of significant others have been influential in the women's development. Given the gender differences seen in mathematics self-efficacy (Pampaka et al., 2012; Zeldin and Pajares, 2000; see also p.37), the role of these figures in the professional lives of women warrants further study; in this study their impact is often dramatic. Critical persons in the teachers' learning come from within and without the school environment. Early support and encouragement from parents, particularly mothers, appears important in sustaining engagement in school mathematics. The teachers' own secondary school teachers remain important reference points in their shifting identities. Some of these teachers provide examples of 'the worst way possible to teach maths' (Nicole), others 'explained things [...] step by step' (Heather) or 'wanted you to do the best' (Leila). Marta maintains that the experience of extremes, from very weak teachers to those in a 'different league' that made her think '**wow, is this** what maths is about?', was influential in the development of her own approach to teaching. The models were not exclusively mathematics teachers, as Nicole recounts:

that history teacher had such a brilliant way of explaining, he made us do debates and made us do these activities and stuff and I thought well, how come our maths is just really, really dull and boring?

[...]

I never thought about that, how our history teacher taught us probably is a lot of what I do, yeah.

Reconciling these early models with what they now understand as good teaching may prove a useful context for the development of personal philosophies of teaching mathematics. Nicole raises several questions about the approaches she experienced when learning mathematics at secondary school, reflecting questions she has regarding her own teaching.

For Marta, a head of department early in her career proves to be an important informal mentor, encouraging her to participate in the wider mathematics community, modelling an approach to practice that supported active experimentation. He stood in stark contrast to the period under her first head of department when she felt 'you have to stay in the classroom and the door is shut, and you've got thirty something kids there and a textbook each and no equipment'. This new head of department opened the door to alternative approaches to teaching. Another significant person is a mathematics educator who leads a short course that Marta attends; he provoked her to think critically about her practice in a way that had far-reaching implications. These figures show her alternative approaches to teaching and provide ongoing support for her learning.

Nicole lacked strong role models early in her career, progressing quickly to the role of head of department in the absence of other specialist teachers and at the expense of support and the opportunity to develop her understanding of the nature of mathematics teaching. In her second teaching post, work with a local authority mathematics consultant and informal support from a school leader

encouraged her to experiment and it is this stance towards her practice which has given the greatest learning gains:

...if it weren't for people like that and the lady who came in from the authority who'd say 'Well, well, that went pear shaped so what are you going to do differently tomorrow?' sort of thing and still had a big grin on her face and still said 'You're doing well' and still encouraged, so those are people who **probably** I attribute getting outstanding off Ofsted to because they taught me to be an individual rather than worrying about what the rest of people around me thought...

Here Nicole speaks authoritatively, gaining confidence from the support she has been given to find her own way, to create an identity as a 'risk taker'. For both Marta and Nicole other professionals have simultaneously provided models of alternative practice and the affirmation they needed in order to experiment and learn from practice, this encouragement echoing the experiences of women mathematicians (Case and Leggett, 2005). Leila and Heather have yet to find support in the school environment; neither of them report significant people in their professional lives. Leila remarks that her mother has been an important source of support; for Heather her husband fulfils that role.

I set out to establish whether the teachers saw their learning supported and found that even when support is provided, for example Leila's school supporting her MA in Education, it may not be perceived as such. This may be a result of the teachers' restricted agency, as in Leila's case where the school leadership

decided on a choice of routes for the MA (Leadership and management or mentoring and coaching).

I don't feel supported in school [...]. You know, there is nothing going on. There is no professional development, there is no professional support at all

Leila, Heather and Nicole identify occasions where their learning is supported yet do not see these as part of a coherent, supportive environment. Instead, it falls to them to direct their own learning, yet the degree to which they feel empowered to do so varies. The models that were available to them as mathematics learners and as beginning teachers (through their mentors) have disappeared into the shadows as they take the stage themselves. Although there is an acknowledgement in the literature that career-long professional learning is important (Schleicher, 2011) the evidence suggests that little attention is paid to the significance and availability of these models for experienced teachers. Nicole notes that competition between schools results in her being less likely to seek support from outside her own school. The stories of Leila and Heather appear to sustain this view of isolated school communities rather than supportive local networks. Again, Marta's account stands out, a rich network of significant figures and experiences as she began teaching in an era when teacher involvement in curriculum development was encouraged, sometimes funded, often supported by universities (McLaughlin, 2013).

Identity and community

These significant others provide access to a wider mathematics education community, one that extends beyond the school. Without these introductions, teachers may remain ignorant of the existence of supportive networks and organisations. Heather and Leila reveal little evidence of an awareness of the existence of a mathematics education community beyond the immediate school environment. Nicole knows of some groups and draws on their resources, sharing them with her colleagues; participating on the periphery. Earlier collaborative work within her local authority proved useful but increasing competition between schools, together with the curtailing of funding for the National Strategies meant that this stopped. The mathematics community for Nicole, Leila and Heather in an operational sense has become their own departments. Each appears to garner informal support from colleagues but this stops short of in-depth enquiry or collaborative learning. These three women appear isolated, their schools/departments cut-off. They appear to be 'in the classroom with the door shut' (Marta), indicating, perhaps, a feeling of 'not belonging' similar to that found amongst some female mathematics undergraduates (Solomon, 2007a). As these communities of practice offer potential to support women mathematics teachers in developing their self-efficacy beliefs this evidence of such restricted community is concerning.

Marta's experience is different. This difference may be partly attributable to length and breadth of experience; Marta has been teaching much longer than the other three teachers in the study and has held a variety of roles. She began

teaching in a different era, one where teachers had responsibility for curriculum developments, in contrast to increasing emphasis today on competencies and standards (Hargreaves and Goodson, 1996). Her community incorporates a mathematics department that work together to develop practice and extends to regional and national networks and projects. Earlier in her teaching career she encouraged her department to engage with initiatives, building on the example set by her own head of department. She is aware however that there is an element of fortuity in her learning, that opportunities may have passed by without her noticing.

Epistemology of mathematics education

My early engagement with existing research led to an interest in exploring the extent to which professional learning might support women mathematics teachers in developing an epistemology of mathematics education. I specifically set out to discover whether, through their professional learning, women were helped to become 'constructed knowers and connected teachers' (Becker, 1995, p.172). Linked to this is the question of whether the teachers supported their students to become constructed knowers, participants in a community working together to explore mathematics. Reviewing the stories I find evidence of a range of epistemological perspectives and data which supports a connected view of mathematics learning and teaching. Nicole explores the difference between an instrumental approach designed to foster success in examinations and her own

philosophy with her aim to build connections. She describes how she has come to this understanding through teaching and how it is enacted in practice as she unpicks topics as part of her planning.

And one of the things that I don't agree with is just teaching 'to do this you do this, this, this and this' and you don't need to know why because in my experience,[...] well you might have trained a pupil well enough to pass the exam the next day but you haven't enabled them to be able to stand on their own two feet when they finish school [...] I've seen that sort of maths teaching and I've always thought, I hope I never end up like that as a teacher...

Elsewhere, evidence in the women's stories of connected teaching takes the form of seeking out students' views and explanations, supporting them to engage in processes, working on problems and encouraging reasoning. Heather articulates this clearly: her own experience of learning mathematics at school and university was founded upon working collaboratively with her peers to make sense of mathematics and this mathematics talk remains important

one teacher in our department [...] likes the class in silence, absolute silence, but I don't [...]. I quite like them to talk about it and explain it to each other and that and to learn from explaining to others as well...

Heather expresses a longing for this approach to learning for herself as a teacher, feeling constrained by pressures on time, the accountability agenda and the lack of a collaborative culture. She has forged her epistemological position in opposition, beginning in her school days when she rejected her teacher's view of

her capability. In rejecting the view that ability in mathematics was fixed, Heather argues that it is possible to succeed with effort, and both through her participation and engagement at school and university and later through her teaching, she challenges the view that mathematics is difficult and largely masculine (Ernest, 1995; Mendick et al., 2008). The limited support she receives from colleagues fails to deliver sufficient structured learning and collaborative opportunities to meet her needs and contributes to her tentative pronouncements and self-professed lack of confidence. Her questioning of common practices is evidence of a tentative position of author/ity (Povey, 1997), perhaps limited by the restricted opportunity for dialogue with colleagues.

For Leila, subjective knowing is evident as she views herself as the voice of truth (Belenky et al., 1986). In her own school days authority was external and knowledge received: '...you just got on with what you were told', '...you didn't sort of question it' and '...you sat in silence and you just got on with it'. Now, as a teacher herself, she has taken on the role of authority as these extracts from her description of teaching multiplying out brackets illustrates:

I look at text books and they have the grid method and I go 'Kids, **forget** the text books. You will do my style of teaching'.

[...]

I mean you always want to encourage to learn new styles and I think, well no, there was nothing wrong with what I learnt and you'll learn my way.

Leila's authority is predicated on her own teacher's authority as she perpetuates a form of received knowing in mathematics. Here and elsewhere in her narrative Leila apparently rejects alternative perspectives, drawing on her own experience to validate this stance. And yet there is doubt, as expressed here; after recounting a teaching episode where she set herself in opposition to her colleagues she finishes on an uncertain note:

So I don't know. You have got to find a balance when it comes to learning. I'm still learning. I still feel as though I'm learning all the time. I think I have started to break the mould a little bit but I think it will take me a little bit more time.

The uncertainty Leila expresses above indicates that these old models may be ready for revision. She sees her engagement with Master's level study facilitating reflection on practice.

Marta's narrative emphasises constructed knowing as she engages critically with sources of authority. She supports her students to engage deeply with mathematics, acknowledging that this 'takes guts, a bit of self-esteem, [...] a bit of willingness to [...] have a go, make mistakes', responding flexibly to their needs. Brought in to work with one group of students in the final weeks before their GCSE examinations she says

'we did some circle theorems with geoboards, because I thought, if they can't do these and they must've done them that many times and if they can't do them with diagrams then it ain't working and so I got out the

geoboards, the circular ones and they played with elastic bands and I felt like they knew some of the circle theorems by the time we had finished'

This is typical of the stories Marta tells, starting from the students' experience, unpicking their understanding and helping them to build their knowledge in the way she had learnt herself. As she supports teachers to develop their practice and their own philosophy she is careful to make spaces for them to find their own way, making them aware of alternatives whilst trying not to judge.

In all the stories there is evidence of the women's critical appraisal of their own views and of external authority. They justify their approaches to teaching in terms of their experience and with reference to sources of authority, often making tentative pronouncements in acknowledgement of the dynamic context of practice. Nicole confidently explores ideas in practice, often in the face of prevailing discourse, one that frequently leads to teachers playing safe, sticking with existing practice, the stakes too high to risk experimentation. She illustrates this exploration in the story of the Ofsted inspection of her teaching: despite the characterisation of Ofsted as constraining, looking to make sure 'that every bit of evidence has got to be in their book and it's got to be marked and up-to-date and all the rest of it' and in the face of incredulity from colleagues, Nicole plans carefully, following her own beliefs. By taking calculated risks, in the way that was encouraged by significant people in her development, Nicole learns much about herself, her students and her practice.

the constraint that you feel in the run up to Ofsted [...] after all that paranoia and stress actually just having an open-ended task that the children were enjoying and the Ofsted guy was enjoying and the level of mathematics was far higher than anything I probably would have risked doing with them, so I do more of that now

Her own experience of open-ended tasks at school was not a positive one but she examines it critically, envisaging new ways of working. Nicole articulates her doubts, questioning her experience and the views of others, developing her understanding of a view of mathematics that allows all students to gain confidence, engage positively and achieve.

Both Nicole and Marta have experienced the support of 'experts' early in their careers: for Nicole, a Local Authority consultant played an important role in encouraging her to find her own way; for Marta, the head of department who led his staff in the development of new approaches had a huge impact of her philosophy of mathematics. These more experienced others led the way, serving also to validate the beliefs and practices of these two teachers. That Heather has had no such support may help to explain her more tentative approach. All three had their views of mathematics shaken early on in their school careers, this dissonance serving to provoke.

In summary

A picture emerges of the women's professional learning. They work on mathematics, alone in their classrooms. Their professional identities are constructed from aspects of practice modelled by teachers from their own

mathematics and professional learning. These others are hugely significant, though access to them is limited. The women learn from a variety of sometimes unpredictable events and circumstances, although the encouragement and example of mentors and models is important. Community is restricted, pressure on results acting to close doors. Limited dialogue about mathematics learning appears to result in teachers' epistemological views largely founded upon their own school experience.

Another picture emerges. Teachers are working together on mathematics, exploring ideas, testing conjectures. They collaborate on curriculum development projects, encouraged to participate by more experienced colleagues. The doors are flung open...

9. Conclusion and implications

This study has explored the experiences of professional learning of four women secondary mathematics teachers. By aiming for depth and seeking to understand the experience of individuals, the intention was not to make general claims regarding women mathematics teachers, rather, the detailed examination of the teachers' experience has served to illuminate alternative realities of the professional learning landscape. In this final chapter I evaluate the research and draw conclusions, noting the implications for professional practice and policy.

A starting point for my research was the attention focussed on uncovering what makes for effective mathematics CPD. Studies of mathematics teacher professional learning (e.g. De Geest, (2011), Back et al., (2009); Graven (2004); Adey et al., (2004)) have often focussed on the experiences of teachers engaged in some kind of formal learning experiences. There was a need for research designed to help us '...understand the multiple experiences which constitute a teacher's continuing professional development throughout their career as a teacher' (Back et al., 2009 p.29). The focus on learning rather than development in this study emphasises the importance of teacher agency. An exploration of the experiences of teachers serves to highlight the gaps in provision and expose common, everyday experiences, including the constant process of identity work in the context of school mathematics. Whilst there is much research considering the development of mathematics identities both at school and amongst university undergraduates (and to a lesser extent, postgraduates) (see for example Boaler

(2002a), Mendick (2006); Solomon (2009)), and research into the developing identities of beginning teachers and primary mathematics teachers (e.g. Brown and McNamara (2011)), there remains little exploring the development of secondary mathematics teachers' identities through their experiences of professional learning.

Each woman's story makes a unique contribution to knowledge about mathematics teacher professional learning. Taken together, despite the rich diversity of experience, it is possible to identify common themes, discussed in the previous chapter. Teacher professional learning is a complex interaction of individual and contextual factors (Hoban, 2002; Clarke and Hollingsworth, 2002; Opfer and Pedder, 2011); the focus in this research on the experience of individual teachers exposes this complexity.

In Chapter 2 I analysed models of teacher professional learning, finding considerable agreement on the conditions required for learning to take place. Many of the desirable characteristics appear lacking in the experiences of participants. Theoretical models to predict when teacher learning is likely to occur illustrate the complexity of the processes at work, drawing attention to the importance of intensity and scale, rather than merely to the presence or absence of characteristics, and to the multiple combinations of these characteristics for different individuals in different circumstances (Opfer and Pedder, 2011). This complexity is exposed both in the individual teachers' stories examined in my research and in the synthesis of the research findings. The women's stories

reveal teacher professional learning as a career-long project of sense-making, following a meandering route, punctuated by critical incidents which act as landmarks in this journey.

This meandering professional learning journey is disjointed, lacking a coherent thread to support teachers' sense-making. And yet the thread exists. It is the teachers' own lives, their life stories. The journey itself is the thread. It may only be that by understanding our own position and professional identity, by working on what we are doing and why, that we can begin to direct change. The data reveals that the process of reflecting on experience illuminates learning, shifting the teachers' images of themselves, bearing out research which shows importance of the role of biography (e.g. Day and Gu, 2007). Although there are restrictions on teacher professionalism, the development of reflective professional narratives, analysing the social and political contexts within which practice is situated, may, as Sachs (2001) proposed, help teachers to develop an activist identity.

Teachers' own experiences of learning mathematics provide a rich vein for exploration though it is clear that understanding this experience is challenging, involving the questioning of their existing beliefs. These early experiences of learning mathematics at school also provide a background tapestry of critical incidents and significant people, reminiscences revealing sometimes unresolved questions regarding the nature of mathematics and mathematics teaching.

Mathematics teachers, from school days and from initial teacher education school

placements, remain important reference points informing the participants construction of themselves as teachers. Leadership at all levels is an important factor in determining the direction and extent of professional learning, with subject leaders occupying a powerful role, shaping access and engagement. A leadership team supportive of professional learning appears not to be sufficient; what is significant is the model provided by individuals. Teachers draw on the models these significant others provide when fashioning their professional identity. The lack of such models inhibits teacher learning.

Traditional conceptualisations of professional learning, in the form of one-off or short courses, do feature in teachers' experiences of professional learning and occasionally have far-reaching implications on a teacher's career. Teachers reported noting the significance of these courses at the time and reappraise the impact as they look back over their careers. Where teachers reported this impact the course was followed by opportunities to engage in active experimentation in practice. The two courses of note in this study are just two of many courses that the teachers will have attended, other experiences proving unremarkable at best, at worst failing to engage teachers. Conceptualizing teacher learning as a complex system helps to explain this (Opfer and Pedder, 2011). Marta acknowledges one dimension of this complexity when she reflects on individual readiness for learning, as she wonders whether a factor in support for learning is teachers' receptiveness:

it doesn't matter whether it is a piece of literature that you have read or a person that you hear speaking who motivates you or whether it is

just an off-chance conversation with a colleague, or a family member [...]. I just think, sometimes, when you are ready to hear something, you hear it [...]. And I think that that's support and I'm sure that there must be so many incidents that I didn't hear [...] and I read and I[...] it didn't resonate.

Further support for this view recognises fortuity in unfolding lives, whilst acknowledging that individuals can increase the probability of fortuitous events through engaging proactively with new environments, activities and interests (Bandura, 2006). This 'agentic management of fortuity' (ibid, p.166) is one dimension of human agency. It is apparent from the teachers' stories that, despite our knowledge of the characteristics necessary for teacher professional learning to take place, conditions in schools do not consistently provide these. Those experiences that did have an impact were those that caused teachers to question their beliefs about mathematics learning and teaching. The significance of cognitive conflict has been noted elsewhere (Timperley et al., 2007), although there is evidence that if the new ideas presented are too challenging they are rejected (Opfer and Pedder, 2011). Leila appears to struggle with this, uncertain about new approaches to teaching, preferring to remain in the safety of her own experience.

The stories re-presented here inform the debate on teacher professional identity, focussing particularly on women mathematics teachers. Despite the prevalence of an instrumentalist discourse in teaching (Mockler, 2005) and the associated perceived reduction in teacher agency, teachers can and do 'climb up the house'

(Holland et al., 2001), finding the courage to push the boundaries. Each of the four women tell how they have found ways to resist the prevailing discourses of school mathematics. This resistance takes many forms, from Heather's attempts to sidestep the instrumental approach to mathematics that she feels is foisted upon her through the policy of early entry for GCSE, choosing instead, where possible, to encourage her students to talk about mathematics, to Nicole's active experimentation in the classroom and Marta's insistence that her department trial the CAME project. Support and encouragement from others appears to be an important factor in enabling women to imagine alternatives and experiment in practice.

Self-belief is an important strand in this learning journey. Constant reinvention takes place as the teachers re-fashion their views of themselves, drawing on the words of others (Sfard and Prusak, 2005). Nicole articulates this clearly when she recreates herself as a risk-taker, building on the views of significant others, eventually demonstrating how she enacts this role in her story of the Ofsted lesson. The stories expose this identity formation; indeed this is one of their strengths and an important way in which this research can contribute to practice. Sharing these stories, the women's recollections of the constant twists and turns of their professional learning journeys, can serve to inspire, to convince others that there is no limit on what they can do. The stories provide strong evidence to argue against the voices that attempt to restrict us. Even in difficult circumstances, teachers find room to grow, seek out opportunities to learn, to challenge themselves. Whether this is through mentoring teachers in initial

teacher education, studying for a Master's degree in Education, trying out new ideas in practice or leading a department in a new initiative, teachers find ways to push the boundaries. They push against a prevailing discourse of school mathematics which demands a focus on results at the expense of deep understanding, of performativity rather than pleasure. This focus on results and the fear of Ofsted are often viewed as inhibiting creativity and change.

Access to expertise appears important in stimulating and supporting learning. This is noteworthy as there appears to be a reduction in this access as funding to support professional learning is reduced and the role of local authorities, universities and other organisations sidelined. Opportunities to work outside the classroom may be invaluable in providing access to alternative models, with the accompanying opportunities to enter debates in the wider mathematics education community. This access does not necessarily mean changing jobs as new staff can serve to stimulate and provoke. By contrast, the very stability in one school, with little staff movement, compounded by a subject leader who appears reluctant to support change, results in unchanging practice.

Striking by its absence in the accounts is mathematics-specific professional learning. With the exception of Marta's narrative there is little discussion of mathematics learning other than individual work in preparation for teaching. What appears important is actual contact and relationships with others to support this; it remains to be seen whether the increasing support offered through virtual, online environments is able to meet teachers' needs. Teachers seem unaware of

their learning; there is limited attention given to discuss and analyse this learning both within school and in the wider mathematics community. They appear constrained by instrumentalist discourses and have not been supported to imagine what is possible. Where they have had this support, the difference is dramatic and manifests itself in a growing confidence to engage with developing practice.

The data reveals glimpses into the communities of practice that teachers belong to, with teachers appearing isolated within their departments and schools jealously guarding their secrets. In this era of increased competition and accountability there is some evidence of entrenchment, of teachers and departments unable to share with other schools due to real or perceived restrictions on their time, fear of censure and competition. This appears to be a recent development and warrants further investigation, exploring whether the focus on performance, as judged by examination and inspection outcomes, may be leading to an inward-facing, restricted agenda for professional 'development' at the expense of teachers owning and directing their professional learning. All the teachers in this study noted the focus on results and on doing well in Ofsted inspections, perceiving these as restricting their freedom to experiment with new practices or even to support students' in deep learning. Yet Nicole, supported to take risks, found that going beyond traditional practices was successful, as evidenced by feedback from students and the inspector. What is important here is that she has been encouraged to take ownership of pedagogic decisions.

This study focussed on women. Their stories reveal that support is required to induct them into the wider mathematics education community, support which appears limited in some settings. Subject leaders and more experienced teachers play a crucial role in this induction into the mathematics community. Further research is needed to explore the experiences of men as well as women, to develop additional stories which may be used to support increased dialogue about professional learning, to create opportunities and open doors.

Evaluation

In this section I examine what might have been done differently in this research. I am at once satisfied that I have done what I set out to do and at the same time left wanting more. Beginning this research troubled by my own experience of learning to teach, seeking to develop my own professional practice in support of teacher learning, I set out to see how others experienced this process, to explore whether the issues I grappled with were personal, individual to me, or political. As Heather, Leila, Nicole and Marta expose their own, very personal, experiences of education I am moved by their stories. Rather than merely feeling reassured that I am not alone, I feel galvanized into action, more certain of my own voice through hearing theirs.

In response to the question 'What might you have done differently in retrospect?' I hesitate. What mis-steps am I aware of? Is what is really being asked 'what now?', for surely it is obvious that knowing what I know now, and being the

person that I have become through this work, I would not conceive of this research in the same way. It is clear to me now that I am not alone, that my experience is mirrored elsewhere – I know this not just through the stories presented here but through the literature I have explored. I wonder why was this not clear to me before, why we do not discuss these ways of working. Why don't we talk? I feel a sense of déjà-vu as I recall just how it felt reading women's life stories back in the 1970s.

In terms of research design, overall I am satisfied that the methodology and methods were appropriate for the study. Though I regret that there was not greater collaboration with the participants, I now feel prepared to embark on further research of a collaborative nature. As for methods, I did not really know what methods I would use when I started. I remind myself that this is a kind of apprenticeship to research, my tutors, those who have gone before me, sharing their work in print and in process. I have heard these tutors' voices from apparently opposing positions: cast as separate or connected knowers (Belenky et al., 1986), on the one hand setting out step-by-step methods and on the other urging me to find my own way, work with what I know. Attuned, through my own education, to listen to rules, it was some time before the voices whispering 'find your own way' came together to shout loud enough for me to take notice. Finally, it seems, I reach a position of constructed knowing regarding research, posing questions and examining assumptions. Maybe, if I do have regrets, it is that I did not hear these voices sooner, could not throw off the restrictions I perceived. Still I worry that I am to be judged on whether or not I have adequately followed the

rules, met the criteria. Ultimately, however, I acknowledge that I had to know these detailed approaches in order to go beyond them, to create an approach appropriate for examining these research questions in this way. An illustration of this issue is my agonising over coding. Although this was time-consuming it allowed me to know my data better, to develop my own understanding of approaches to analysing qualitative data. I had to know about these approaches in order to reject them and to really know them I had to use them.

As I develop this research for publication I hope to involve the teachers further, seeking detailed responses from them as they read the stories constructed from their experiences. I would like to develop this study longitudinally, to explore experiences of professional learning with these women in two, five or ten years. I planned to bring the four women together and still intend to do this to share the thesis and seek their feedback.

My own practice continues to develop, invigorated by this research. I am convinced, now more than ever, that my day job, supporting teachers to enquire into their own practice, has an important role in the improvement of mathematics teaching. A critical exploration of autobiography frames and informs this enquiry.

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11. Appendices

Appendix I. Interview Prompts

Can you tell me about an early memory of learning mathematics (at school/university).

Can you draw a time-line, noting significant phases/events in your experience of learning mathematics?

In a professional gathering, how would you describe yourself to others?

How have you learnt how to be a mathematics teacher? Can you add significant phases/events to your time-line?

What is important in secondary school mathematics?

How did you come to know mathematics in the way that you do?

How does this influence you as a mathematics teacher?

What sources of support do you draw on as a (mathematics) teacher?

How do we learn mathematics? (want to elicit an account of the nature of mathematics, of what it means to know and do mathematics)

Is there anything you wish you had known/understood earlier in your career?

Closing questions

Is there anything that you might not have thought of before that occurred to you during our conversation? (Question adapted from Charmaz, 2006, p.31)

Is there anything else that you would like to add?

Appendix II. Questions seeking affirmation and elaboration

MARTA: I enjoyed physics and I enjoyed English actually, when I'm saying that I don't think I was that well taught, I don't think I was particularly well taught in them but I actually quite enjoyed them as subjects and that was why I wanted to do the maths because mechanics, I enjoyed mechanics.

GILL: Yes. What was it about the physics and the English then in those secondary years, when the light was switched off that was different to the mathematics?

MARTA: I don't really know. I think physics, I just enjoyed mechanics, it seemed down to earth and practical, you could see the use for it and I think I could do it so it was enjoyable and English, well, you learn the language don't you? It's not like a big ask is it, to do well in English, English language?

GILL: That was something you took for granted?

MARTA: English language, not English literature because for English literature you had to read the books and that was something you had to make an effort for, so yeah, I quite enjoyed English and physics, yeah.

Extract from interview 1 with Marta, January 2012 (lines 229-246)

HEATHER: For my A-levels I had really, a couple of teachers, I remember my pure teacher, which is why I think I sort of went along

the line of pure when I came here, she was excellent. Really, really good, and just had lots of time to spend with you and you know, good explanations and that.

GILL: Can you say a bit more about that, that excellent teacher. What was she like?

HEATHER: Approachable, I think that was the thing, she was very approachable and she did explain things at our level so we could, you could understand it better, you know, and also there was one, I remember there was one girl in our class who was brilliant at maths so she was really good at explaining things, so, having a team of us working together as students helped and that was like that when I went to uni really, there was a good group of us and we all helped each other to try and understand, to get to grips with a lot of it.

GILL: So what was that like in practice, that helping each other in school and uni?

HEATHER: It was fine yes, yes. No, and it made it more enjoyable, really. And you sort of realise that there's other people, that it wasn't just me who didn't understand, there would be a few of us.

Extract from interview 1 with Heather, February 2012 (lines 166-191)

Appendix III. Pre-planned follow-up questions for second interview

I have a few questions about what prompted your career decisions:

- Besides mathematics, what other A levels did you do and why did you choose them?
- What prompted your joining the bank?
- Was there anything that precipitated your decision to go to university?
- You say 'I'd never have thought of doing maths as a degree' (lines 59-60). Why not? And what changed to make you do this?
- 'I'd always thought I'd go into teaching eventually' (lines 73-74). Why? What do you think influenced this?

The group of you at uni (lines 181-2), what was significant about that?

You say how strange and alien the initial experience of teaching was on your teaching practice (lines 638-9). You had 13 years work experience by this point, what was it like, starting again in a new profession?

You talked about understanding and doing – the time pressures on coverage for early entry GCSE. Can you tell me some more about your view of that?

Extract from notes in preparation for the second interview with Heather

May 2012

Appendix IV. Participants' reflections

GILL: So our first meeting was back in January, what was that like for you?

MARTA: It felt like I was sort of rustling through a lot of old territory that I couldn't quite remember. When I read the transcript I thought it was quite illuminating. I think I felt like 'oh, did I say that? type of thing'. I think it was a bit sort of... quite an eye opener to be quite honest, quite a nice capture of my story. So yes, it was quite pleasant.

Extract from Marta, second interview conversation, May 2012 (lines 6-13)

GILL [...]I have brought my transcript with me. [...] Did you have a chance to have a look at it?

NICOLE Yes, I read through it.

GILL Did anything strike you? [...]

NICOLE I think really, there was some periods of my life that I could talk about at such length and there were other periods of my life that when you asked me even something quite specific about it my answer was really, really short and it didn't really go with how long the time period had been, there's just certain parts of my past that I remember really, really well

GILL Yes

NICOLE and other bits are fairly insignificant and I talked some of them through with my mum afterwards. I said, do you know what, you know, there were certain yeah, it was quite strange to talk through with family as well but those are the points of my life that are kind of insignificant, that I just didn't remember much about.

GILL What periods were those then particularly that...

NICOLE an awful lot of school was so insignificant

Extract from second interview with Nicole, June 2011 (lines 76-97)

Appendix V. Transcription notes

For consistency and ease of analysis I have adopted the following practice (developed from Arksey and Knight, 1999) when transcribing interviews:

Abbreviations and contractions: transcribed verbatim

Verbal tics (e.g. er, um) ignore

(e.g. like, y'know, sort of) include (exclude repeats)

Pauses: represented by (...)

Repetitions: some removed for clarity

Yeah: transcribed as yes

Non-verbal communication: []

False starts: removed

Interruptions signified by –

Interviewer prompts: removed brief prompts/encouragement such as 'yes', 'right', 'ok'

Names: speakers name in capitals at the start of speech to facilitate electronic searching

Emphasis: bold font

Appendix VI. Coding

Nodes\professional learning

Nodes\professional learning\critical incident

Nodes\professional learning\formal learning

Nodes\professional learning\formal learning\going through the motions

Nodes\professional learning\informal learning

Nodes\professional learning\informal learning\beyond labelling

Nodes\professional learning\informal learning\from teaching & preparing to teach

Nodes\professional learning\informal learning\taking risks, developing practice and confidence

Nodes\professional learning\initial teacher education

Nodes\professional learning\initial teacher education\denied a voice

Nodes\professional learning\initial teacher education\making sense

Nodes\professional learning\initial teacher education\trying to deceive two people

Nodes\professional learning\initial teacher education\we were like rabbits in headlights

Nodes\professional learning\priorities

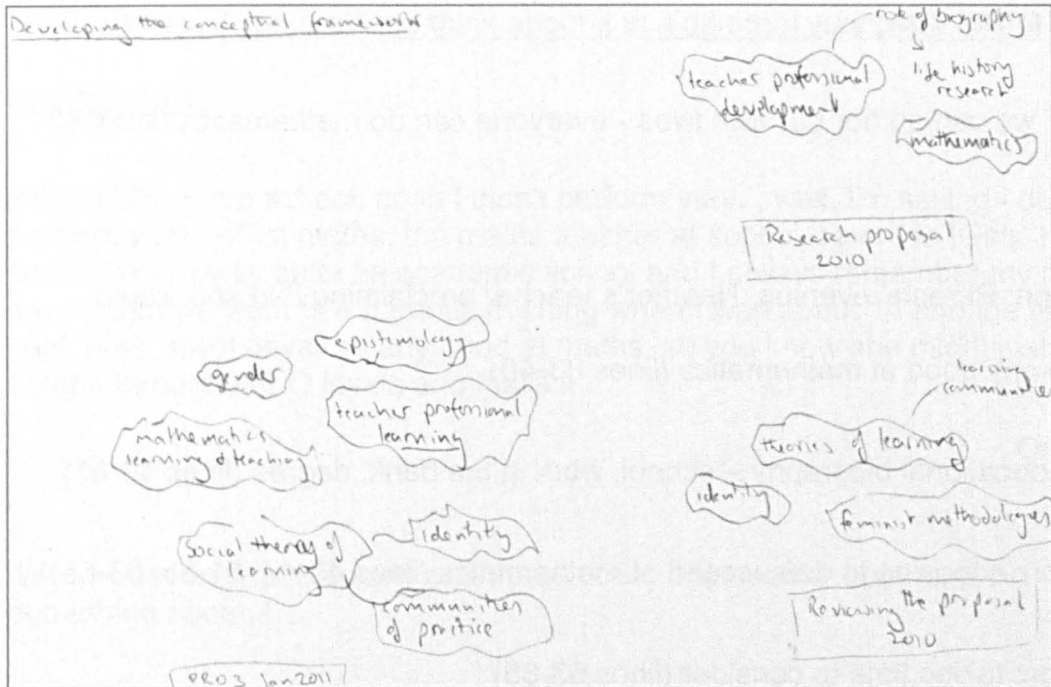
Nodes\professional learning\support

Nodes\professional learning\support\external validation of teaching

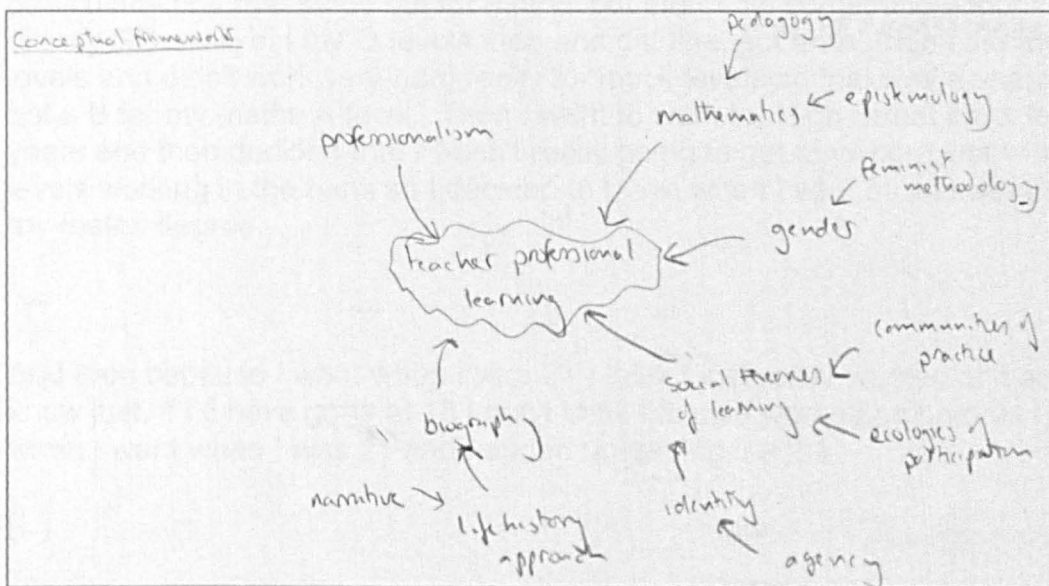
Extract from NVivo node structure report, professional learning

November 2012

Appendix VII. Conceptual framework



Extracts from research notebooks



Appendix VIII. Identifying and reconstructing stories

Heather's first story

Abstract: we can author our own lives - everyone can do mathematics (lines 43-44)

Orientation: Parents' evening, Heather's teacher proclaiming that she would never be any good at mathematics (lines 33-40)

Action: educational biography – school, work in the bank, degree (lines 40-51)

Evaluation: choosing to do/succeed at mathematics (lines 45-47, 51-55, 63-65)

Resolution: taking time to consider (lines 63-65)

Coda: starting teaching (lines 73-78)

Augmentation: (lines 133-145)

From Heather, first interview

'Well actually, if you really do think about it in a different way or do this or do that you can do it'.

HEATHER: From school, gosh I didn't perform very.., well, I'm saying I didn't perform very well at maths, the maths teacher at school, I went to [Girls' High] School which was quite an academic school and I always remember my mum saying that we went to a parents' evening when I was about 14 and the teacher said 'Well, she'll never be any good at maths, so you know she might just about scrape through her O levels and that's it'.

Orientation

'Well I was never particularly one that stood out for maths' but then I did something about it,

Abstract

And then once I heard that it made me think 'Well actually am going to do something about it' and I often say this to the lads, I say 'Well I was never particularly one that stood out for maths' but then I did something about it, well I did my GC, well, did my O-levels then and did fine, got an A, then I did my A-levels and didn't work very hard really for my A-levels so that was a shame but I got a B for my maths A-level. Then I went to work for High Street bank for three years and then decided that I wasn't really going to get anywhere just with A-levels working in the bank so I decided to leave when I was 21 and went and did my maths degree.

Action

And then because I went when I was 21 I think I just really worked at it and you know just, if I'd have gone at 18 I don't think I'd have worked as hard as I did when I went when I was 21 and I ended up getting it a 2:1

[...]

'Well actually, if you really do think about it in a different way or do this or do that you can do it'.

Evaluation

it was only just giving it more thought and deciding what degree would benefit me and what I was interested in and that's when I decided to do maths.

Resolution

in the back of my mind I'd always thought I might go into teaching eventually and then [company] had redundancies and I decided to take a redundancy and got the payment and it paid for me to do my PGCE. And that was 10 years ago now so I did my PGCE at [university] and then came here and I been here ever since.

Coda

HEATHER: Oh yes, I think it **did** back then. I always remember my mum telling me what she'd said. Unless my mum just did it to try and get me to work or something, but I just, whatever it was, it stuck, and ... then it did, yes, I did just start to try. Which is I why often say to the lads 'If you...'. They say 'Oh, I can't do it, I just can't do it'. I said 'Well actually, if you really do think about in a different way or do this or do that you **can** do it'. I think it is attainable for everybody, to a certain level, you know everybody should be able to do it to their own level but I think it's that putting down sometimes and they just say we can't do it it's like people, older people, people my age they say 'I've never been able to do maths' and whatever.

Augmentation

Appendix IX. Interpretive stories – extract from Heather’s stories of learning to teach

Further maths – a big step

Once in her current school, her first and only teaching post, Heather embraced the challenges of teaching, seeing them as opportunities for learning. She recalls a significant professional learning incident, representing this with a Further Mathematics textbook:

...when I came here, 'cause I'd not really taught A level before because I ... I'd only, in my teaching practice, I'd only gone up to GCSE. So that was a big step anyway [...], it was from, straight away from the first year. And then I think in the second or third year? Must've been maybe the third year I was here, I started teaching further maths and that was a **big jump** because it was really the first year of your degree, part of it, you know. [...] But that was sort of like me learning at the same time as them as well really, which was difficult, and it still is, it still is difficult, like I'm saying this year, it still is difficult. ... But good, but yes, it is, it's good.

The Further Mathematics textbook supported that learning, which Heather describes as an ongoing struggle to keep one step ahead of the students. Teaching Further Mathematics only once in every three years means that Heather has to review it in depth prior to teaching. Her strategies for learning appear to follow those learnt in her student days, she describes how she works alone to develop a proficiency before teaching.

Appendix X. **Actually that lady**

Actually, that lady

Actually, that lady

Who was our mentor

Would get her Year 11's into groups

And she would do a lot of like that

*Actually like that Ofsted lesson I've just
described*

That she would pair

Share

And you can take **your** answers to there

While they peer assess this

And all the rest of it

And her lessons were quite dynamic

And quite active

And the kids loved her

Absolutely **loved** her

And they knew that she did more **for** them

Than what a lot of the other maths staff would
have done

So they respected the fact

That she did her best for her students

And wanted to be in her lesson therefore

I probably did learn a lot from that actually

For how I do stuff now,

In retrospect.

Nicole

Appendix XI. Is it always going to be that crazy?

'Is it always going to be this crazy?'

At my second school

My mentor was very much

'You show 'em this,

And

If they don't get it the first time you show it them again

And then once you've done that

You give them a worksheet with three to five examples on

Or ten if its not going to take them long,

So that you fill your lesson,

And then

At the end you go over the answers'

But when your tutor came in

That was their idea of

A failing lesson

So we were all, again, very well aware

That we had to kind of

Tread this careful path,

Because you wanted your mentor

To make your week by week

Write up

Good

But you wanted your pupils to be prepared

For what you were going to **have** to do to get a good grade

Off the tutor when they visited.

I guess it was,

We were quite like,

'Oh my goodness,

Teaching must be a bit mad, you know

Because we already trying to deceive two people

And we are only on placement, you know,

What is it going to be like when we are actually fully fledged you know?

Is it always going to be this crazy?'

Because that's why it felt really crazy, trying to play

Two cards at the same time

And then Ofsted came in

And kind of said the same thing.

Nicole