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Early career primary teachers' perceptions of the influences on their teaching of mathematics – a longitudinal study

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Abstract

Newly qualified primary teachers in England enter a varied environment in terms of schools' approaches to the learning and teaching of mathematics and provision for their ongoing learning and development as teachers of the subject. Previous research suggests that in addition to factors related to their school context, potential influences on their evolving practice relate to their beliefs about the learning and teaching of mathematics; their subject knowledge, emotions and attitudes towards mathematics, and their self-efficacy as teachers of the subject; and their proactivity in response to their own reflection on practice.

This qualitative longitudinal study extends the existing literature by exploring these influences from the perspectives of teachers themselves. Eight pre-service primary teachers, with a range of mathematical backgrounds, are followed from the end of their teaching course through their first two years as qualified teachers, with detailed evidence gained from five interviews with each teacher. Key features of the methodology are the creative use of participant generated visual data collection techniques, including 'influence maps' which enabled participants to describe and present the interacting influences on them, and the innovative use of mind mapping to reduce and analyse the data whilst retaining its cohesiveness.

Through their narratives, teachers' perspectives on the personal and complex nature of these influences are highlighted and deeper insights are provided into how these interrelate, enabling an extended theoretical model to be presented.

The research findings have implications for providers of initial teacher education as they seek to effectively prepare teachers of mathematics, for early career teachers and those seeking to support their further development, and for national policy makers as they consider future policy related to primary mathematics. It will also be of interest to the mathematics education research community in their continuing focus on teacher learning and development and other researchers using qualitative longitudinal approaches.

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Abbreviations and glossary

Abbreviations

ACME	Advisory Committee on Mathematics Education
A Level	Advanced Level – qualification usually gained at aged 18
CoP	Community of practice (Lave and Wenger, 1991)
CPD	Continuing professional development
EAL	English as an additional language
GCSE	General Certificate of Secondary Education – qualification usually gained at aged 16
ITE	Initial Teacher Education
LPP	Legitimate peripheral participation (Lave and Wenger, 1991)
LSA	Learning support assistant
NCETM	National Centre for Excellence in the Teaching of Mathematics
NNS	National Numeracy Strategy
NQT	Newly Qualified Teacher
Ofsted	Office for Standards in Education, Children's Services and Skills – government inspectorate
PGCE	Postgraduate Certificate of Education
SATs	Standard Assessment Tests - tests taken in English and Mathematics towards the end of the academic year by Year 6 and Year 2 children

TA	Teaching assistant
ZoE	Zone of Enactment (Millett and Bibby, 2004)
ZFM	Zone of free movement (Valsiner, 1987)
ZPA	Zone of promoted action (Valsiner, 1987)
ZPD	Zone of proximal development (Vygotsky, 1978)

Shulman's (1987) categories of subject specific knowledge:

SMCK	Subject Matter Content knowledge
PCK	Pedagogical content knowledge
CurCK	Curricular content knowledge

Ball, Thames and Phelp's (2008) categories of mathematics subject knowledge:

ComCK	Common content knowledge
SCK	Specialised content knowledge
KCS	Knowledge of contents and students
KCT	Knowledge of contents and teaching
HCK	Horizon content knowledge
KCC	Knowledge of content and curriculum

Glossary

Mathematics subject leader/coordinator: The teacher responsible for leading mathematics in a primary school.

Pre-service teachers: Those studying to become qualified teachers.

Primary school: In England children attend primary school between the ages of 4-11. Within an English primary school, Key Stages and Year names are allocated as follows:

Key Stage	Year	Age of children
Foundation	Reception	4-5
Key Stage 1	Year 1	5-6
Key Stage 1	Year 2	6-7
Key Stage 2	Year 3	7-8
Key Stage 2	Year 4	8-9
Key Stage 2	Year 5	9-10
Key Stage 2	Year 6	10-11

Postgraduate Certificate of Education: A one year course for graduates leading to qualified teacher status.

Primary with Mathematics PGCE: A generalist PGCE course for those with a particular interest and strength in mathematics.

Professional development: The in-service learning and development of the teacher - in this context, as a teacher of mathematics.

Pupil and **Student**: Words used interchangeably in the thesis for a learner at school.

School Direct PGCE: A PGCE course which is run by a school, or group of schools, working closely with a university.

1 Introduction

There is widespread acknowledgement of the fundamental importance of mathematics for the functioning and development of society and for the individual. A high quality mathematics education not only equips a person for everyday life and participation in society, but enhances the capabilities of their mind with problem solving and reasoning skills and enables them to appreciate the beauty, creativity and value of mathematics (Kilpatrick, Swafford and Findell, 2001; Department for Education, 2014). The responsibility for providing such a mathematics education rests upon the teaching profession and is dependent on teachers who enter the profession with a range of mathematical backgrounds, qualifications, beliefs and attitudes to the subject (Rowland *et al*., 2008; Brown, 2005).

In the twenty-first century, the learning and development of teachers of mathematics has been a particularly active field of interest for the mathematics education research community, with studies usually focusing on one of three specific areas: teachers' subject knowledge, teachers' beliefs and teacher identity (Skott, Van Zoest and Gellert, 2013). Such studies regard learning by teachers as an ongoing process, starting from their own experiences of mathematics as a child, through their pre-service teacher education and into learning and development as a qualified teacher (Llinares and Krainer, 2006). This study contributes to the research literature by exploring the interacting influences on the evolving practice of eight primary teachers of mathematics as they leave pre-service teacher education and complete their first two years as qualified teachers.

1.1 Researcher background

To enable me to understand their background as mathematicians, the teachers participating in this research related the story of their relationship with mathematics from as far back as they could remember. Similarly, to enable the reader to understand my background and perspective as a researcher, it is important to tell my story.

I have always enjoyed mathematics. At primary school in the 1970s, I learnt using a textbook approach, silently working on my own through questions which drilled me in mathematical knowledge and procedures. I picked up procedures quickly, had a good memory for learning facts and moved through school mathematics with relative ease, finishing aged 18 with the most advanced school mathematics qualifications, A levels in Mathematics and Further Mathematics, at the highest grade. At university I studied geography, my favourite subject at school, applying some of my numerical and statistical skills as I increasingly specialised in physical geography. After then completing a one year teaching course, which in retrospect gave me limited understanding of how to effectively teach mathematics, I taught for 14 years as a generalist primary school teacher. Although I loved mathematics myself and believe that I taught it enthusiastically, teaching the subject required a steep learning curve. I found that many children did not just pick up procedures and facts as I had and this made me question how mathematics should be taught. I reflected on the approaches, strategies and questions I used and sought to continually adapt my teaching to enable children to not only 'do' mathematics but to deeply understand it, essentially a shift from Skemp's (1976) instrumental to relational approaches.

Whilst continuing with full time teaching responsibilities, my interest in primary mathematics was further strengthened by taking on the mathematics coordinator role in my school in the mid-1990s, giving me responsibility for the mathematics teaching of eleven other teachers, and the opportunity for part-time university based postgraduate study in teaching primary mathematics.

In the late 1990s I attended extensive mathematics coordinator training as the UK government sought to roll out considerable changes to the pedagogical approaches used by primary teachers in mathematics with the introduction of the National Numeracy Strategy (Department for Education and Employment, 1999). Leading these developments at my school was effectively the start of my work as a teacher educator.

After then becoming a mathematics consultant, employed by a local authority, I gained a master's degree in the learning and teaching of mathematics which facilitated my entry into initial teacher education (ITE) as a lecturer in primary mathematics. Having also worked with primary education undergraduates, I currently lead the mathematics strand of the one year Primary PGCE (Postgraduate Certificate of Education) ITE course at the University of Leicester. I chose an area of research for this thesis that would further inform my work in ITE as well as contribute more widely to knowledge related to teacher learning and development in mathematics.

1.2 Current practice in teaching mathematics in England

Newly qualified primary teachers in England enter a national context where mathematics is recognised by the government as a 'core' subject, alongside English and science. Mathematics is generally taught daily, with teachers in state schools following the programmes of study within the statutory National Curriculum for Mathematics, first introduced in 1988 and revised several times since, most recently in 2013-14 (Department for Education, 2014). Formal testing of primary aged children in mathematics takes place at the end of Key Stage 1, when children are aged 7, and at the end of Key Stage 2, when children are aged 11, using Standard Assessment Tests (SATs) and teacher assessment against set criteria (Standards and Testing Agency, 2019).

Since the implementation of the latest National Curriculum in 2014, the government has been promoting, through the National Centre for Excellence in the Teaching of Mathematics (NCETM), the development of east and south-east Asian mastery principles for teaching mathematics in primary schools (NCETM, 2014). However, in practice, approaches to teaching mathematics vary considerably and a variety of mastery initiatives, resources and textbooks, introduced by different organisations and publishers, have become available to schools. Whilst there is some agreement as to pedagogies that support children's mathematical understanding, such as the greater use of representations and interactive dialogue between teachers and children, different features of east and south-east Asian teaching of mathematics have been advocated by different organisations (Boylan, 2019). There therefore remains some confusion for teachers and a range of views as to what mastery actually involves.

From 1997 – 2011 various non-statutory ‘National Strategies’ provided very detailed pedagogical and planning guidance and documentation for teachers of primary mathematics, and local authority consultants provided support for schools and courses for individual teachers. The ending of the Strategies initiated the current complex and changing situation in schools in terms of the provision for individual teachers’ ongoing professional development as teachers of mathematics (Advisory Committee on Mathematics Education, ACME, 2013). Although the mastery agenda has led to a range of commercial organisations and the NCETM running professional development events for teachers and schools on the theme of mastery, there is currently no national guidance on mathematics specific knowledge that should be focused on for ongoing teacher learning and development (ACME, 2016).

Whilst this research investigates the experiences of pre-service teachers from the University of Leicester PGCE course, all ITE providers in England operate within this national context. In line with the government inspectorate, Ofsted’s (2014), criteria used to assess providers, they seek to ensure that pre-service teachers are achieving as highly as possible against the National Teaching Standards (Department for Education, 2011), successfully gain employment as teachers and continue to develop as newly qualified teachers (NQTs).

1.3 Background to the study

As an academic involved in teaching the next generation of primary mathematics teachers, I decided to focus my research on understanding more about how early career primary teachers develop as teachers of mathematics, recognising that this would provide useful understanding to inform my own practice of preparing pre-service teachers within this variable national context, and enable me to contribute more widely to research knowledge related to teacher learning and development in mathematics.

Pre-service teachers taking the University of Leicester PGCE course start their ITE course with a range of academic qualifications in mathematics and related subjects, sometimes achieved over 30 years earlier, a range of experience of working with children in school with mathematics and a range of attitudes and beliefs about the subject. During the course they develop their subject and pedagogical knowledge and gain experience in mathematics teaching; their progress is closely monitored, with additional support given to the less confident and competent. Although the PGCE is a generalist route into teaching, equipping pre-service teachers to teach across the curriculum, at the University of Leicester there is also a specialism element to the course with mathematics being one of a number of specialist options. In addition, since September 2015, a specific Primary with Mathematics PGCE course has run, providing some further time for studying wider subject knowledge, leadership and management of primary mathematics for generalist pre-service teachers with a pre-existing demonstrable strength in mathematics. The value of potentially having a mathematics specialist in each primary school was recognised by Williams (2008) in his review of primary mathematics in England, which subsequently influenced government policy to actively recruit mathematicians into primary teaching through such courses.

Mathematics specialists on University of Leicester PGCE courses, both those who opt for the mathematics specialism on the main course and those on the Primary with Mathematics course, generally have a stronger mathematics background than grade C in Mathematics at GCSE (General Certificate of Secondary Education), the minimum qualification required for all primary teachers in England. They will usually have formally studied mathematics to a higher level and have a particular interest in the subject.

I was keen that my research enabled me to explore the early-career experiences of teachers with a range of mathematical backgrounds and consider any differences in the evolving practice of specialists and non-specialists.

1.4 Focusing the research questions

Based on the background outlined above, the initial aim for my research was to carry out a study that explored in depth how the effectiveness of the mathematics teaching of early career primary teachers develops and the nature of influences on this. Over the initial year of the data collection, particularly useful and interesting evidence was gathered about the factors influencing the evolving practice of the early career teachers, whilst it became apparent that the notion of effectiveness was rather broad and subjective for a small-scale study of this nature. My focus narrowed to specifically exploring the interaction of factors influencing early career primary teachers' teaching of mathematics.

When initially reading and setting up a pilot study for this research in 2014-15, the background to the current context in primary mathematics in England suggested that opportunities for ongoing learning and development for early career teachers, and therefore the nature of their evolving practice, was likely to be highly dependent on their individual school context. However, the literature suggested that characteristics relating to the teachers themselves also influence their evolving practice. As I will be exploring in the literature review, these include their mathematical proficiency and subject knowledge for teaching (Kilpatrick, Swafford and Findell, 2001; Shulman, 1986, 1987; Ball, Thames and Phelps, 2008; Rowland *et al.*, 2008), their attitudes and emotions towards mathematics (DeBellis and Goldin, 2006; Di Martino and Zan, 2010), their beliefs about learning and teaching mathematics (Askew *et al.,* 1999; Ernest, 1989), their confidence and self-efficacy as teachers of mathematics (Bandura, 1997; Eraut, 2004) and their proactivity in learning and developing through reflection on practice (Schön, 1983; Schön, 1995; Korthagen, 2010; Turner, 2008). A range of literature related to each of these factors is explored in Chapter 2, after the initial presentation of three theoretical frameworks for discussing teacher learning and development which begin to explore the links between these influences (Millett and Bibby, 2004; Lave and Wenger, 1991; Goos, 2013). This study contributes to the current research literature by investigating the nature of these influences on the evolving practice of early career teachers of primary mathematics, and particularly how these influences interact, from the perspectives of both mathematics specialists and non-specialists.

This thesis therefore addresses the following research questions.

Main research question:

How do factors related to the teacher themselves and factors related to the school context combine to influence the evolving practice of early career primary teachers' teaching of mathematics?

Sub-questions:

- How do early career primary teachers perceive the influences on them as teachers of mathematics?
- How does the evolving practice of mathematics specialists compare with non-specialists?
- Does my data align with the views expressed in existing literature? Where does my analysis extend understanding and have any contradictions emerged?
- What implications do the findings of my research have for ITE providers, policy makers and advisory bodies, and the research community?

1.5 Methodological overview

Chapter 3 sets out the methodology that enabled me to gather and analyse data related to the research questions. In summary, using a longitudinal qualitative research design within an interpretivist paradigm, I followed eight early career primary teachers with a range of mathematical backgrounds through their first two years of teaching, meeting five times with each. Data from semi-structured interviews, including participant generated visual data and other documents provided by the participants, was analysed using narrative analysis. To support the analysis an innovative mind mapping approach was developed.

1.6 Overview of the thesis

In order to address the research questions, the thesis is structured in the following chapters:

Chapter 2 provides a literature review for my research. This includes literature relating to existing theoretical frameworks for discussing teacher learning and development; literature relating to the characteristics of teachers that influence their evolving practice as teachers of mathematics including their own reflection on practice; and literature related to their learning and development through the influence of the school context. A theoretical framework from the literature is presented which informs the study.

Chapter 3 sets out the methodology employed, providing the researcher worldview and theoretical perspectives on which the study is based alongside details of the research design and ethical framework.

In Chapters 4 to 8 findings from the study are presented. In Chapter 4 each of the participants is introduced and the rationale for the choice of three of these as detailed narratives is set out. These narratives are presented in Chapters 5, 6 and 7. Chapter 8 highlights distinctive themes from the narratives of the other five participants.

In Chapter 9 the findings are discussed in relation to the literature reviewed and an extended theoretical model of the interacting influences on early career primary teachers' teaching of mathematics is presented based on the findings of this study.

Finally, there is a short concluding chapter summarising how the research questions have been addressed and how the study has provided contributions to knowledge. Implications from the research are discussed, limitations of the study acknowledged and potential areas of future research outlined, before the thesis ends with a reflection on my role as a researcher.

2 Literature Review

2.1 Approach

There are many influences on early career primary teachers' teaching of mathematics and therefore of necessity this literature review has broad coverage. With such a wide coverage a fully comprehensive review of the literature has not been attempted; this is a review *for* my research, rather than a review *of* all the related research (Maxwell, 2006). Whilst I have read widely, I have not attempted to read all the available research on each aspect of the subject area. Rather, I have sought to become well informed by looking for and carefully reading key texts and then following these up, for example, by reading references that appear in several papers and in library and online searches. I have particularly looked for examples where theoretical ideas have been used in mathematics teacher education research.

As Boote and Beile (2005) recommend, I have read throughout the years of undertaking this study. At the outset this informed my initial proposal and pilot study. Later reading during stages of analysis, when interpreting my findings and when reviewing the thesis in its entirety, enabled me to develop a wider and deeper understanding of relevant theoretical concepts and empirical research. This literature review has therefore evolved as a "dynamic, integral part of the research process" (Boote and Beile, 2005, p.11). At various stages, I have found storyboarding points from the literature to be a useful way of mapping, comparing and contrasting points before attempting to write (Thomas, 2009).

Noting O'Leary's (2017) distinction between "self-educative reasons for reviewing the literature" (p.108) and the purpose of the literature review as written in a thesis, and in line with Maxwell's (2006) suggestion, I have aimed here to present evidence that is relevant for informing and justifying the research questions, and for forming the theoretical framework for the interpretation of my research; a review *for* my research.

2.2 Introduction

The literature review centres around the overarching theme of teachers' learning and development. Synthesis of research on this area from the PME (Psychology of Mathematics Education) community, an international group of mathematics educators and researchers, shows this to be a "complex process" because of the interconnections between a number of influencing factors related to "the individual, the social and the organisational" (Llinares and Krainer, 2006, p.445). Specific themes identified by Llinares and Krainer in recent mathematical research in this area are: reflection as a mechanism of change; the social dimension of teacher change; and the organisational context within which teachers work, including the extent to which this provides resources to support any change.

To explore these interactions and inform my research, I searched for literature from researchers looking at the impact of a broad range of factors influencing teacher practice and development. I found particularly useful research from three contrasting groups of studies seeking to understand why and how some teachers/professionals change their practice to a greater extent than others. The literature review starts with a review of these studies and some of the subsequent research informed by them: firstly Millett and Bibby's (2004) model for discussing teacher change in the context of national reform in the teaching of mathematics; secondly the concept of learning and development of professionals within Communities of Practice developed by Wenger (1998) and Lave and Wenger (1991) and thirdly the Zone Theory of change developed by Goos (2013, 2014) within the context of mathematics education. Whilst these theoretical frameworks have been formed in different contexts and for different purposes, their contrasting perspectives provide a rich conceptual background for discussing teacher change and together highlight the social context within which teachers work, learn and develop their practice.

These researchers use specific language to describe the outcomes of their work, with considerable overlap in the meaning they ascribe to 'model', 'theory' and 'theoretical framework'. When describing each, I use the vocabulary of the original literature, but when bringing ideas together to compare and contrast them the overall term 'theoretical framework' seems appropriate, defined as "any empirical or quasi-empirical theory of social and/or psychological processes that can be applied to the understanding of phenomena" in the SAGE Encyclopaedia of Qualitative Research Methods (Anfara, 2008, p.870).

These studies present theoretical frameworks to begin to understand how factors related to the individual, the social and the organisational interact. Although teacher learning includes not merely individual learning, but also elements of learning with and alongside others, the practice of individual teachers in similar contextual situations may differ because of personal factors (Millett and Johnson, 2004). For a collection of individual teachers in different school contexts such as in my research, both their varying personal factors and differences in the social and organisational situations of their school contexts are likely to lead to differences in their evolving practice, despite all having taken the same ITE course.

Whilst the three theoretical frameworks pay particular attention to the social and organisational contexts within which teachers carry out and develop their practice, there is a considerable depth of literature describing research that is more specific to the personal factors influencing teachers' evolving practice. Given that my research is based on individual early career teachers' perspectives on their practice and my interest in the mathematical background of these participants, a substantial portion of the literature review is devoted to these personal factors. Literature from research relating to reflection as a mechanism of change is then reviewed separately, using evidence from the three theoretical frameworks and a wider range of literature. It is suggested that whilst the quality and impact of reflection depends on personal factors, it can be facilitated by social factors.

Evidence relating to the influence of the social and organisational context within which teachers work is then drawn together from earlier parts of the review and extended with some additional literature. Then literature around the practice and policy in

England related to teacher development is presented to provide the national context within which the teachers in the study are situated. The final part of the literature review includes a summary, the presentation of an overall theoretical framework from the reviewed and synthesised literature, and a justification of the research questions in relation to this.

2.3 Three theoretical frameworks for discussing teacher learning and development

2.3.1 *Millett and Bibby's model*

In order to discuss and analyse data collected during a range of research projects in England in the late 1990s and early 2000s, Millett and Bibby (2004) drew on and extended an explanatory model previously developed in the United States by Spillane (1999). Both Spillane's and Millett and Bibby's models were formed to understand teacher change at a time of national reform in the teaching of mathematics where significant changes in practice for all teachers were expected by reformers, but where the research indicated that in reality the extent to which teachers changed the "core of their practice" (Spillane, 1999, p.154) varied. Millett and Bibby's model is shown in Figure 2-1.

The 'person', the individual teacher, is shown at the centre of the model, surrounded by their 'situation'. Including both the pupils and colleagues in the school community, the situation represents the "intimate and day to day influences" mediating the impact of external factors, such as government policy, which might be driven by external consultants, commercial and other public factors (Millett and Bibby, 2004, p.3). The Zone of Enactment (ZoE), explained by Spillane (1999, p.144) as "that space where reform initiatives are encountered by the practitioner", is considered the key to the nature of teacher change; it is where the interactions between personal factors related to the teacher combine with the external and school based influences including "rich deliberations" with others in the professional community (Millett and Bibby, 2004, p.4).

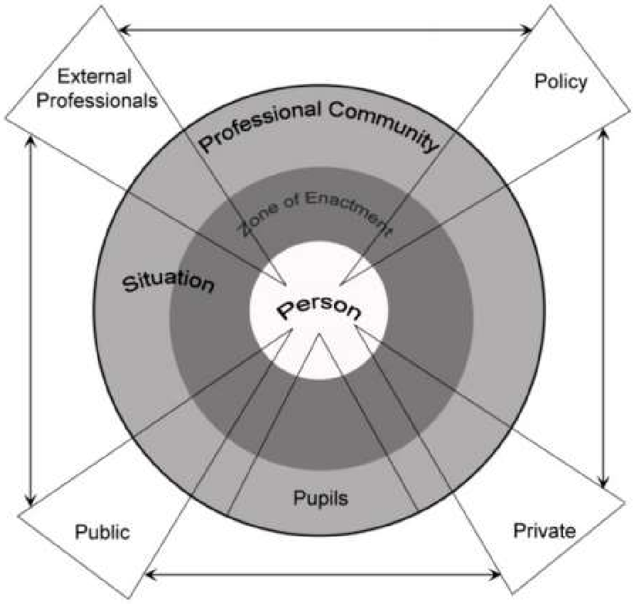


Figure 2-1 Millett and Bibby's model for discussing teacher change (Millett and Bibby, 2004, p.3)

This professional community is recognised as including: both pressure and support from colleagues, subject experts and the headteacher; the extent of coherence and consistency of views amongst the community; and the nature of the culture of collaboration within the school. Personal factors are considered likely to include both the motivation to change practice and various cognitive and affective aspects related to the learning and teaching of mathematics.

In a number of related studies using this model, the impact of the large-scale reform, the National Numeracy Strategy (NNS) (Department for Education and Employment, 1999), on individual teachers' practice was found by researchers to be dependent on the "richness" of the ZoE and situation of the individual. Four key conditions were identified through which deep, as opposed to superficial, change in practice can be realised: time, talk/collaboration, readily available expertise and motivation to change (Millett, Brown and Askew, 2004). These researchers found that time to engage in professional development events was essential, with time for discussion, trial and reflection needed as changes were implemented. Talk between teachers, particularly within a culture of collaboration where individual contributions were valued, led to coherence and consistency of views within the school community and a positive climate for change. This included both talk within formal learning and development experiences such as training sessions and observations of each other's teaching, and informal talk through, for example, collaborative planning with a subject leader or colleague teaching a similar class. Thus, it was noted that while personal factors impact on teacher change, collaborative factors such as these are particularly important. In their study, expertise often came from external consultants, but was also available from experts within the school, offering peer coaching and sharing of expertise. Individual teachers' motivation to change and develop their practice was seen as having both internal and external elements, such as a desire to improve and pressure or encouragement from colleagues.

Millett and Johnson (2004) found great variation between schools in both the nature of the school community and the internal and external factors that impact change within the school as a whole. A 'rich' situation within a school might derive from drawing on contributions from different members of the school community, clarity of vision for change and strong leadership. Disequilibrium might stimulate change, for example through a negative inspection report, a new headteacher with a change of leadership style, or a mathematics subject leader with a new vision for change in the teaching of mathematics; school complacency about existing pupil attainment might mitigate against change. Thus, schools vary in their collective capacity and infrastructure for supporting teacher change.

Millett and Bibby's model therefore recognises strong connections between factors related to the teacher themselves and factors related to their context in driving teacher change. In addition to its use in analysing the impact of change on teacher practice as a result of the NNS initiative, this model has been adopted by other researchers, such as Lamb (2010) and Valentin (2012) whose research confirms the complexity and range of influencing factors on teachers of mathematics in reform contexts. Although the current context of change in England does not bear the same weight of wholescale national reform as the NNS, there were initiatives in several of the schools of my participants in line with national policy and aimed at further developing the teaching of mathematics. It is of relevance to my research that this model usefully highlights how individual teacher change in the teaching of mathematics is situated within the wider professional community which is itself subject to external influences.

2.3.2 *Wenger's Communities of Practice*

Researchers using Millett and Bibby's model (e.g. Millett and Johnson, 2004; Hodgen and Johnson, 2004) also draw on some of the elements considered by Wenger (1998) and Lave and Wenger (1991) in their theorising of learning and development within Communities of Practice (CoPs). Although conceived within an apprenticeship context, the notion of learning within CoP has been applied widely within educational contexts in relation to teacher change and development. As in Millett and Bibby's model, learning is seen to be situated within the context of a community, through social participation.

Defined by Wenger-Trayner and Wenger-Trayner (2015) as: "Groups of people who share a concern or passion for something they do and learn how to do it better as they interact regularly" (p.1), the purpose of CoPs is "to create, expand and exchange knowledge and to develop individual capabilities" (Wenger, McDermott and Snyder, 2002, p.36) with the focus on the learning of its members rather than the teaching of others (Krainer, 2003). Lave and Wenger (1991) developed the concept of 'legitimate peripheral participation' (LPP) as the "central defining characteristic" of such situated learning (p.29). The LPP concerns and conceptualises how newcomers take an increasingly sophisticated part in an established CoP, developing their identity as they learn and moving over time from entering the 'periphery' of the community as a 'newcomer' to becoming an 'old-timer' with 'full participation' in the community. In order to do this, newcomers need to be "granted enough legitimacy to be treated as potential members" (Wenger, 1998, p.101), such that any shortcomings are seen as opportunities for learning rather than cause for rejection.

CoPs have three essential elements (Wenger, McDermott and Snyder, 2002, p.27). Firstly, the 'domain' of interest provides the identity of the group. The domain "inspires members to contribute and participate, guides their learning and gives meaning to their actions". Secondly, the 'community' "creates the social fabric of learning", building mutual respect and trust, and encouraging willingness to contribute, ask questions and learn from others. Thirdly, the 'practice' is the actual knowledge the community "develops, shares and maintains". Together these domains not only help to define CoPs, but also provide the motivation to become part of one. Applied by Hodgen and Johnson (2004, p.227) to the "multiplicity of social spaces" within a teachers' Zone of Enactment, an individual might belong to a number of CoPs at the same time on their 'landscape of practice'; these might connect and overlap, with shared practices and members (Wenger, 1998, p.118). A CoP evolves over time as the members negotiate the meanings of their 'shared repertoire' of elements such as actions, concepts, language and routines (Wenger, 1998, p.83). On an individual level, newcomers can gain access to the "competence", or expertise, available within the community or gained from 'visitors' to the CoP (p.112); engagement with this and the use of imagination to consider future possibilities are considered to be the ingredients of reflective practice.

With my research, analysing the experiences of, and influences on, newcomers to the teaching profession, the concept of LPP seems highly applicable, with novice teachers entering a CoP of experienced teachers (Cuddapah and Clayton, 2011). However, the notion of becoming an 'old timer' with 'full participation' in a CoP for a teacher, contrasts markedly with those entering a CoP as an apprentice in Lave and Wenger's original conception. Teachers come into the school context with at least a year's specific training and are immediately given responsibility for a class of children. Lave and Wenger's (1991) description of participating productively at the periphery of a CoP seems questionable in this context:

> “Productive periphery requires less demands on time, effort and responsibility for work than full participants. A newcomer’s tasks are short and simple, the costs of errors are small, the apprentice has little responsibility for the activity as a whole.” (p.110)

Adler (1998), however, believes that LPP can “illuminate how teachers learn about teaching” (p.3) because as they carry out the full duties of a teacher, newcomers are at the same time developing their knowledge about teaching. Adler points out that, “In Lave and Wenger’s terms, knowledge about teaching is fundamentally tied to the context of teaching” (p.4), so it is within the school context that teachers evolve.

Lave and Wenger (1991) suggest that full participation in a CoP involves gaining knowledgeable skills, having greater responsibility and carrying out riskier and more difficult tasks than are carried out at the periphery and, most significantly, having a sense of identity as a “master practitioner” (p.111). However, as Adler (1998) points out, periphery verses full participation does not equate simply to newer and older teachers. Learning trajectories within CoPs vary (Wenger, 1998); whilst some trajectories remain peripheral, newcomers join a community “with the prospect of becoming full participants in its practice” (p.154) hence aiming for an ‘inbound trajectory’. Even full members of a community continue their learning; their ‘insider trajectories’ relate to their ongoing evolution of practice. Hence full participation is not simply about knowing all there is to know about their practice, but about fully engaging with the resources of the community alongside participating in its social practices (Adler, 1998). Lave and Wenger (1991) sum up the conditions necessary to become a full member of a CoP as “access to a wide range of ongoing activity, old timers and other members of the community and to information, resources and opportunities for participation” (p.100). Access to resources through their use and understanding of their significance is crucial.

Resources, including artifacts and technologies, are used by full participants with high ‘transparency’ in terms of both full use and full understanding of their significance (Lave and Wenger, 1991). This transparency involves both visibility and invisibility. A full participant, teaching using a mathematics textbook, will do so with knowledge of the significance, limitations and possibilities of the use of the textbook (visibility), but in a sense will also use it with invisibility in that it makes the mathematics itself visible (Adler, 1998).

The notion of CoPs has been applied within mathematics education by a number of researchers, including Adler, whose research in the context of the teaching of mathematics in multilingual classrooms confirmed that teachers' knowledge about teaching was "tied to their identities", evolving through participation in the practices of their teaching community (Adler, 1998, p.8). She found that the extent of teachers' knowledge about teaching depended on their access to resources, particularly activities related to talk within and about the practice of the community which facilitated reflection and memory, and the transparency of this practice.

Gómez (2002) also used the framework, in his case to analyse the progress over time of a mathematics professional development programme within a high school. He considered what activities the participants engaged in, the goals they negotiated and the resources they produced to support the achievement of their goals. Within the focus group in Gómez's study, a range of depths of participation was evident, but it seemed that the most and least experienced of the four teachers engaged and benefitted most from the community. The other two teachers found the new ideas "difficult and even threatening" (p.15). In line with the importance of motivation highlighted by Millett, Brown and Askew (2014), Gómez argues that attitude to change is significant; some will attempt to make changes despite difficulties, but others might decide not to implement changes. This suggests that in practice there is added complexity to the workings of a CoP as compared to the original concept

Cuddapah and Clayton (2011) applied the notion of CoP to a study of a cohort of newly qualified teachers on a cross-school induction programme, finding that within this community teachers shared problems and successes related to various aspects of their practice, engaged in resource exchange and used each other as sounding boards. They also supported each other in making meaning of their experiences and discussed their identities as teachers. Meaning, practice and identity, three components of Wenger's (1998) CoP were therefore evident as focuses within the overarching context of this community. Thus, despite the whole community being made up of newcomers, it nevertheless seemed to function as an effective CoP, with teachers extending their practice by "taking pedagogical and expressive risks" within this group context (p.73). Cuddapah and Clayton suggest that such a non-hierarchical community might be particularly beneficial for a group of novices.

Application of the notion of LPP within CoP to the teaching context implies that the main 'object' of the attention and intentions of the participants is the learners being taught (Adler, 1998). Adler recognises that this object differs from the object of attention in Lave and Wenger's (1991) apprenticeship settings because of the additional factor of the relationship between the teacher and those they teach. Discussion of the influence on a teacher's practice of the children being taught seems to be limited in mathematics education literature, although a teacher's perceptions of those they teach are recognised as a significant element of the teacher's environment by Goos (2013).

Although recognised as a useful framework, critique of the CoP is focused on assumptions surrounding its use. Researchers using the theory have tended to assume that participation within such communities is a positive influence on teacher development and that such communities improve the quality of teaching (Llinares and Krainer, 2006). In practice, it was recognised by Wenger (1998) that this might not be the case – a CoP can reject or stifle innovations and renegotiations of the meanings and practices of the community. Levine (2010) considers the definitive view of learning within a CoP to be "a provocative image" (p.119) suggesting that teacher learning is more complex in practice. The studies above provide some evidence of this. Nevertheless, thinking in terms of the CoP can be a useful way of conceptualising the learning of early career teachers and can be applied to the "multiple and evolving forms of collaborative activity" they might be engaged in (Levine, 2010, p.124).

2.3.3 ***Goos' Zone theory***

A third complementary theoretical perspective comes from the zone theory developed over several years by Goos and Geiger (2010) and Goos (2013, 2014) and who, whilst acknowledging that teacher change is situated within the school context, focus more specifically on the learning and development of the teacher as an individual in response to specific 'promoted actions'. In that my participants are developing as individual teachers of mathematics within their school context and are likely to experience individualised learning opportunities as early career teachers, zone theory seems appropriate to consider alongside the more community focused theoretical frameworks outlined above. Goos and Geiger (2010) Goos (2013, 2014) and have taken the 'practice' perspective of Wenger's (1998) CoP, i.e. the knowledge the community "develops, shares and maintains", and linked this to the 'change' perspective of Valsiner's 'zone theory' of child development to create a zone theory for the context of learning within mathematics education. This section outlines how this theory was created and how it can be applied to analyse teacher learning and development.

Vygotsky (1978) introduced the term zone of proximal development (ZPD) to explain a child's use, with the guidance of an adult or more capable peer, of mental functions that are still maturing. This concept and his focus on development and change rather than product and outcome, were taken by Valsiner (1987) and extended into considerations of the relationship between a child's learning, their social setting and actions of participants within that setting. Valsiner (1987) presented a theoretical framework with three zone concepts – Zone of Free Movement (ZFM), Zone of Promoted Action (ZPA) and an adaptation of Vygotsky's ZPD. The ZFM is the whole environment of the child - their access to different areas of their environment, the availability of objects within these and the ways they might interact with these. The ZPA comprises the activities, objects or areas of the environment that are promoted to the individual by an adult or more capable peer – these might overlap with the ZFM but might also include currently unattainable aspects. Valsiner's ZPD consists of the possible next stages of development for the individual that are currently being actualised. He argues that if this exactly matches the ZPA, the conditions are set for the maximum possible effect on learning. On the other hand, if the ZPA has no overlap with the ZPD, efforts to promote the child's learning at that time will fail.

Taking this theory into the context of the professional development of a teacher of mathematics, Goos (2014) explains how the teacher's ZPD becomes the "set of possibilities" for their development in terms of subject knowledge, beliefs, goals and practices, and is created by the teacher's interaction with their environment, its resources and the people within it (p.444). The teacher's ZFM which "structures" their environment or professional context includes factors related to the particular school such as the organisational structure of the school, its ethos, curriculum and assessment requirements, and resources within this (p.444). It also includes teacher's perceptions of the students they teach – "their social background, motivation, beliefs and attitudes, mathematics achievement and behaviour" (Goos, 2013, p.523). The ZFM therefore suggests which teaching actions are "permitted".

In Goos' model, the ZPA comprises the activities which are offered to the teacher which promote certain teaching approaches through professional development events ranging from formal programmes to informal interactions with colleagues. These may be outside the ZFM and therefore seem currently forbidden (Goos, 2013). Hence the environment within which a teacher works is not "simply the backdrop for practice" (p.531) and the ZFM/ZPA complex may hinder or support the learning of the teacher (Goos, 2014).

Goos (2013) suggests that commonly professional development programmes and interventions address only one of the three zones, for example focusing in isolation on improving teachers' subject knowledge, seeking to change their beliefs or providing funding for new resources. She argues that such initiatives will have limited impact because teacher learning and development is more complex, being influenced by factors within all three zones interacting together. A teacher might gain new knowledge and change their beliefs, but may consider it impossible to make changes to their practice because of the restrictions within their environment. Goos and Geiger

(2010) suggest therefore that these perceptions of what is permitted within their school context "can promote or limit opportunities for teachers to change themselves" (p.503). Thus, tension arises when their ZPD does not align with the ZFM/ZPA complex.

A key aspect of Valsiner's theory, though, is that of canalisation, the process whereby the child actively participates in their own development "by altering its constraining structure" (Valsiner, 1987 p.85) in order to achieve their goals. Similarly, a teacher can actively change their environment and hence their ZFM/ZPA complex to more closely align with changing beliefs or new knowledge (Goos, 2013).

Whilst Goos and Geiger (2010) suggest this process may be challenging for early career teachers, this tension can actually be productive for teacher development, with the teacher then seeking to modify their environment or seeking out further learning opportunities. Empirical research from Goos (2013) provides examples of this. In one case study, changes in a teacher's beliefs about mathematical learning through technology (ZPD) were brought about through both formal professional development and informal interactions with his former mathematics lecturer (external sources of ZPA). These changes in beliefs prompted the teacher to make self-initiated changes to the organisational culture of his environment (ZFM) in order to achieve the newly developed learning goals he held for his students. In a second case study set within the context of a research project to support teachers' implementation of a new mathematics syllabus (external ZPA), tensions existed between the beliefs about student centred learning held by the two teachers in the study (ZPD) and the traditional teaching and rigid assessment regime in place in their school (ZFM/school promoted ZPA). In seeking to resolve the tension, the teachers created "rich and authentic" assessment tasks that fitted the investigative approach of the new syllabus (p.532) and were also acceptable in their school context.

Goos (2013) suggests that zone theory can help in understanding the links between the different influences on a teacher's evolving practice. A teacher who is undertaking a learning and development process that impacts on their knowledge or beliefs about learning and teaching mathematics may or may not make changes to their practice. It is important to understand the contexts within which they are working and how these might constrain or permit changes, whilst also acknowledging the individual's capacity to proactively seek to change themselves.

Goos' zone theory is positively critiqued by Lerman (2013) and Skott, Van Zoest and Gellert (2013). Lerman suggests it usefully enables conversations regarding teachers' choices and actions within an assumption that teacher learning is about "changing participation in social practices". Skott, Van Zoest and Gellert consider Goos' theory to usefully provide a framework for understanding the relationship between a teacher and their environment alongside identifying opportunities for teacher learning and development. They point out the importance of understanding how teachers' development can be constrained by factors related to both the environment and the teacher themselves.

2.3.4 ***Summary – three theoretical frameworks for discussing teacher learning and development***

The three theoretical frameworks outlined above provide complementary and contrasting perspectives on how and why teachers' practice in teaching mathematics might evolve. Millett and Bibby provide a detailed model emphasising the 'situation', made up of the professional community and the ZoE within which the teacher makes sense of external influences, supported by rich deliberations with other professionals. Goos' theory is less explicit about the nature of collaboration but recognises the importance of the organisational structure of the school context, the personal elements of the teacher's ZPD and the perspectives of the individual teacher on what is permitted within their environment. The particular relevance of these two theoretical frameworks lies in their development from research related to the learning of teachers of mathematics. Wenger's CoP framework, developed from a wider research base, gives a more general theoretical background on which to explore the notion of the newcomer and the integration and learning of a newcomer into the CoP of which they are seeking to become a legitimate member.

2.4 The individual – the influence of personal factors

2.4.1 *Introduction*

The influence of factors related to the teacher themselves, highlighted most specifically in Goos' Zone Theory, is embedded in each of the three theoretical frameworks outlined earlier in this chapter. Together, they recognise a range of personal factors influencing an individual teachers' practice, their ongoing learning and their response to external reform initiatives. The ZPD of the teacher (Goos, 2014), their set of possibilities for development, is based on the professional identity of the teacher of mathematics. This would include their subject knowledge for teaching mathematics, both their proficiency in mathematics and their wider subject knowledge, and various affecting aspects (Millett and Bibby, 2004). There is evidence that these factors, together with the promoted actions or opportunities for learning and development within their school context, might influence a teacher's willingness or motivation to change their practice, their ability or capacity to do so and their proactivity in terms of seeking opportunities to learn from others (Goos, 2014, Spillane, 1999, Millett and Bibby, 2004).

Specific individual influencing factors on a teachers' practice are discussed in more detail below in relation to additional research. Teachers are in the dual position of being mathematicians, with their own unique background in the subject, and being teachers of mathematics. They need to be proficient in mathematics, at least in terms of the mathematics they teach, and to develop an understanding of and beliefs about what proficiency in mathematics means. This section therefore starts with a discussion of literature around the nature of proficiency in mathematics. Wider subject knowledge is then explored, outlining why proficiency in mathematics is a crucial but, on its own, insufficient aspect of subject knowledge for teaching mathematics. Literature suggesting that beliefs, attitudes and emotions about mathematics impact on the learning and teaching of the subject is then reviewed. With evidence that personal factors connected to subject knowledge, attitudes and emotions combine to impact teachers' confidence or self-efficacy as teachers of mathematics and their motivation to develop their practice, a review of literature relating to these notions concludes this section.

2.4.2 *Proficiency in mathematics*

2.4.2.1 *Introduction*

Whilst all teachers in England have a qualification in mathematics of at least a GCSE Grade C, each comes into the profession with their own unique background in terms of proficiency as a mathematician and each continues as a learner of mathematics during their pre-service course and beyond. This section explores what the literature suggests proficiency in mathematics involves. This mathematics content knowledge feeds into the wider subject knowledge for teaching mathematics discussed in 2.2.2.

Kilpatrick, Swafford and Findell's (2001) model of "mathematical proficiency" is a useful starting point for discussions around what characterises proficiency in mathematics. Their model draws on research in cognitive psychology and mathematics education and presents a summary of their thinking about what factors are necessary for successful learning of mathematics.

The model of mathematical proficiency consists of five distinct strands (p.116):

- Conceptual understanding – "comprehension of mathematical concepts, operations and relations"

- Procedural Fluency – "skill in carrying out procedures flexibly, accurately, efficiently and appropriately"

- Strategic competence – "ability to formulate, represent and solve mathematical problems"

- Adaptive reasoning – "capacity for logical thought, reflection, explanation and justification"

• Productive disposition – “habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one’s own efficacy”

Kilpatrick *et al.* (2001) emphasise that these strands are interrelated and form different but intertwined aspects of “a complex whole” (p.116). Indeed, their representation of strands of a rope reinforces the idea of five equally significant elements (Figure 2-2).

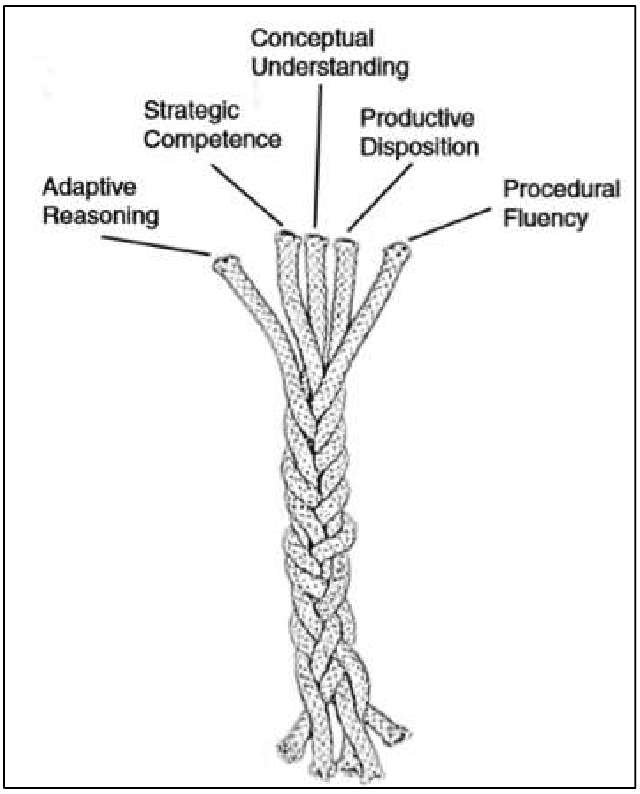


Figure 2-2 Model of mathematical proficiency (Kilpatrick, Swafford and Findell, 2001, p.117)

Each of these concepts is discussed below in relation to further literature and the model is compared to the ‘mastery’ approach of current policy in England.

2.4.2.2 ***Conceptual understanding and procedural fluency***

The first two strands of the mathematical proficiency model are particularly related to the understanding of the mathematician and raise the question of what type of understanding is effective and desirable for the learner.

The notion of 'understanding' is complex but Skemp's (1976) seminal paper on understanding explores a useful distinction. He argued that much teaching in mathematics lessons is instrumental, putting forward "rules without reason" (p.20), and leading to pupils having the shallow understanding gained of simply knowing rules and procedures. This contrasts with learning mathematics relationally, "knowing both what to do and why" (p.20), thus enabling pupils to build conceptual schemas with the depth of understanding necessary to become flexible problem solvers. Most mathematics educators would agree with Skemp that relational understanding is the most desirable outcome for learning and Kilpatrick *et al.*'s (2001) conceptual understanding is based on a similar premise. They consider that such understanding consists of "an integrated and functional grasp of mathematical ideas" (p. 118), emphasising the connectedness of learning as opposed to simply knowing isolated facts and methods. Both Skemp and Kilpatrick *et al.* discuss the benefits of such understanding for knowledge retention and Kilpatrick *et al.* (2001) go on to suggest that a "significant indicator" (p.119) of conceptual understanding is being able to represent the mathematics in a variety of ways for different purposes.

The connected nature of mathematics is widely acknowledged, (e.g. Rowland *et al.,* 2008 and Shulman, 1987) and is consistent with the "Robust understanding of mathematics" put forward by Schoenfeld (2013) which is based on conceptual underpinning (p.616). Schoenfeld additionally identifies "cognitive demand" as a key aspect of robust understanding with the need for students not only to be gaining conceptual understanding, but to be appropriately challenged intellectually.

Relational and conceptual understanding seem essentially the same notion, but Kilpatrick *et al*.'s procedural fluency goes significantly beyond Skemp's instrumental understanding. It is a positive attribute involving knowledge of the procedures for computation, knowing when and how to use these, and having the skills to perform them with accuracy, flexibility and efficiency. Kilpatrick *et al.* consider that conceptual understanding and procedural fluency "are often seen as competing for attention in school mathematics" (p.122) but they stress the importance of the relationship between these. Having conceptual understanding helps learners to remember and more accurately apply procedures, while competency in the skills of procedural fluency can strengthen their conceptual understanding.

Askew *et al.*, (1997) also emphasise this link and consider effective teachers to be those who help pupils acquire factual and procedural understanding and the ability to apply their knowledge in a range of contexts, stressing the importance of pupils' understanding being based on "an integrated network of understanding, techniques, strategies and application skills" (p.10).

The concept of effective learning in mathematics being based on conceptual understanding and procedural fluency within the context of appropriate intellectual challenge is endorsed by current policy makers and teacher inspection systems in the UK. Ofsted (2012), in their report based on inspections 2008-11, state "The best teaching developed pupils' conceptual understanding alongside their fluent recall of knowledge, and confidence in problem solving" (p.9). This seems consistent too with the philosophy and aims of the current National Curriculum (Department for Education, 2014) which the teachers in my study have been teaching to (Appendix 1). Although conceptual understanding in the National Curriculum is not defined, it is reasonable to assume that this is in essence the understanding described above. In developing the National Curriculum, international comparison was carried out to attempt to locate the curriculum within challenging intellectual demands in the drive to raise standards of pupil attainment (National Centre for Excellence in the Teaching of Mathematics, 2014).

2.4.2.3 ***Strategic competence, adaptive reasoning and productive disposition***

Skemp (1976) concluded that having relational understanding enables a learner to adapt their understanding to new problem solving situations. He goes as far as suggesting that relational schemas are "organic in quality" (p.24) as learners seek out and explore new areas of learning. This proactivity and competence in application are recognised in the other three strands of Kilpatrick *et al.*'s (2001) model.

There is much literature surrounding the importance and nature of problem solving in mathematics and space permits only a brief overview here. McClure (2013) attests that "problem solving is the essence of being a mathematician" (p.3) and that being able to solve problems is "the whole point" of learning mathematics (p.1). She uses the analogy of a musician learning scales to enable them to play music fluently to a mathematician learning mathematical facts and rules as tools to enable them to carry out problem solving.

Kilpatrick *et al.* (2001) also recognise this importance and suggest that mathematical proficiency should equip learners to cope with the problem solving challenges of every-day life. Thus they take a similar stance to Pólya (1957) and Schoenfeld (1992) in suggesting that a learner of mathematics needs to go beyond just solving 'routine' problems of a type they have previously encountered and can solve based on past experience. Rather they need the 'strategic competence' to cope with both non-routine 'real life' problems and problems within mathematics itself (see also McClure, 2013), where "part of the difficulty is to figure out exactly what the problem is" (Kilpatrick *et al.*, 2001, p.124). Thus they suggest that problem formation is a key first step in strategic competence. Having formulated the problem it then needs to be accurately represented; whilst the learner needs a mental representation, this might be assisted by the use of words, symbols or pictures. These initial stages are summarised by Pólya (1957) as understanding the problem. Kilpatrick *et al.* argue that becoming a proficient problem solver also involves detecting mathematical relationships and devising solution methods. These are the types of activities necessary for Pólya's other three phases of solving mathematical problems: devise a plan, carry out the plan and look back. These simple headings summarise the application of a range of problem solving strategies which can be applied to non-routine problems.

Kilpatrick *et al.* (2001) suggest that "mutually supportive relations" exist between strategic competence and both conceptual understanding and procedural fluency (p.127). As McClure (2013) explains, throughout the solving of a non-routine problem learners are involved in “discovering and making sense of mathematics” (p.2).

A learner with strategic competence is likely to come up with a range of approaches to a particular problem (Kilpatrick *et al.,* 2001). Schoenfeld (2007) agrees that good mathematical problem solvers need to be flexible and resourceful, with a repertoire of ways to think about problems. Learners will use their adaptive reasoning skills as they navigate such thinking (Kilpatrick *et al.,* 2001).

Adaptive reasoning then, the fourth strand of the model of proficiency, is the “capacity to think logically about the relationships among concepts and situations”, the glue that holds mathematical learning together, guiding a learner as they seek to make sense of the various concepts and procedures in their mathematical landscape and apply these in problem solving (Kilpatrick *et al.,* 2001, p.129). In particular, adaptive reasoning leads a mathematician to adopt a specific strategy.

The second aim of the Mathematics National Curriculum in England (Department for Education, 2014), that all children should “reason mathematically by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language” seems to advocate this strand of mathematical proficiency, but Kilpatrick *et al.* stress further the connections with the other strands of mathematical proficiency as adaptive reasoning is used to determine whether procedures used in solving problems are appropriate, and uses conceptual understanding to decide whether solutions are justifiable. Finally, they state that adaptive reasoning “both depends on productive disposition and supports it” (p. 131).

Indeed, Kilpatrick *et al*. (2001) state that productive disposition, the “habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one’s own efficacy” (p.116), is essential for the development of the other strands of mathematical competence. This personal disposition comes about through frequent opportunities to explore and make sense of mathematics and appreciate the rewards of perseverance. In turn, as learners become more proficient in the other strands, their productive disposition is likely to increase. For example, they are likely to become more positive in their attitudes and beliefs about themselves as they develop their strategic competence in solving non-routine problems.

Kilpatrick *et al.* (2001) stress the importance of learners realising that with appropriate experience and effort that they *can* learn mathematics. This key attribute of having a growth mindset is needed to overcome any notions of mathematics being a gift that only some people have (Dweck, 2008; Boaler, 2016) and encourage learners to see a range of opportunities to improve, through a positive response to challenges, effort and setbacks (Yeager and Dweck, 2012). Further discussion about productive disposition in the form of attitudes to mathematics and emotional responses to the subject is included in 2.2.3.

The element of productive disposition that is particularly highlighted in the current policy in England is that of perceiving mathematics as “useful and worthwhile” (Kilpatrick *et al.,* 2001, p.131), with the purpose of study given in the mathematics National Curriculum (Appendix 1) including statements emphasising the value of mathematics to society as well as to the individual.

2.4.2.4 ***Current policy and practice in England***

The UK government is currently promoting through the National Centre of Teaching for Mathematics (NCETM) the adoption of east and south-east South Asian mastery principles (NCETM, 2014), defining “mastering” mathematics as “acquiring a deep, long-term, secure and adaptable understanding of the subject” (NCETM, 2018). There is an emphasis on procedural fluency and conceptual understanding being developed in tandem (NCETM, 2016), with further clarification that

> “Mastery is not just being able to memorise key facts and procedures and answer test questions accurately and quickly. It involves knowing ‘why’ as well as knowing ‘what’ and knowing ‘how’. It means being able to use one’s knowledge appropriately, flexibly and creatively and to apply it in new and unfamiliar situations” (NCETM, 2015, p.6).

These ideas on mastering mathematics seem to be in line with Kilpatrick *et al.*'s (2001) model of mathematical proficiency. However, they do not extend to the full scope of the model; the NRICH team at the University of Cambridge suggest specifically that the NCETM mastery approach does not sufficiently focus on the productive disposition strand of the model of mathematical proficiency (NRICH, 2015).

Although promoted nationally, implementation of mastery principles is varied and the government call for more schools to join a "Teaching for Mastery programme" through locally led 'Maths Hubs' is ongoing (Maths Hubs, 2018).

2.4.2.5 ***Summary – proficiency in mathematics***

Kilpatrick *et al.'*s (2001) model of mathematical proficiency unpacks a range of attributes that combine to characterise effective learning in mathematics. As Schoenfeld (2007) states, "there is much more to mathematical proficiency than being able to reproduce standard content on demand" (p.60) and the model illuminates some of the complexity involved. Proficiency is not simply present or absent; rather it grows over time, influenced by the mathematical environment and opportunities given to develop (Kilpatrick *et al.,* 2001). The teachers in my study will have had varying mathematical experiences as learners of the subject and are therefore likely to vary in the extent to which they have proficiency in each of the strands. Indeed, as Williams (2008) suggests, the current minimum requirement for admission to an undergraduate or postgraduate teaching course in England might demonstrate a basic understanding of the subject, but not necessarily the depth of subject knowledge needed for a "sound basis for the development of 'Mathematical Knowledge for Teaching'" (p.9).

2.4.3 ***Wider subject knowledge for teaching mathematics***

2.4.3.1 ***Introduction***

Whilst the mathematics subject knowledge discussed above seems crucial for teaching the subject, it is widely acknowledged that this in itself is insufficient i.e. teachers need subject knowledge beyond competence in the mathematics being taught. This section explores various elements of subject knowledge for teaching mathematics, concluding that it is not the qualifications in the subject that are of most significance in influencing practice, but rather the nature of the teacher's subject knowledge. Most recent research on teachers' subject knowledge for teaching mathematics uses Shulman's seminal papers as a starting point.

2.4.3.2 ***Lee Shulman's seminal papers***

Shulman (1987) proposed seven categories of subject knowledge for teaching, of which three are subject specific (Table 2-1).

Subject matter content knowledge (SMCK)	**Pedagogical content knowledge (PCK)**	**Curricular content knowledge (CurCK)**
"the amount and organisation of knowledge per se in the mind of the teacher" (Shulman, 1986, p.9)	"that special amalgam of content and pedagogy that is uniquely the province of teachers" (Shulman, 1987, p.8)	Knowledge of the curriculum

Table 2-1 Shulman's (1986, 1987) categories of subject specific knowledge

Subject matter content knowledge (SMCK) includes understanding the structures of the subject and how knowledge within the subject is developed. It thus includes both the "substantive" and "syntactic" structures of Schwab (1978) as cited in Shulman (1986). Substantive structures are the ways that the concepts and principles of the subject are organised and certainly would include, for mathematics, ideas around the connected nature of the subject. Syntactic structures determine how the subject evolves, for example, how truth and proof are established within that subject and how knowledge is constructed. Shulman (1987) considered that transformation needs to take place as a teacher reasons their way from their SMCK to how they might teach this.

Pedagogical content knowledge (PCK) then includes knowing what forms of representation, what analogies, examples and illustrations will most effectively support learning and knowing what difficulties and misconceptions children are likely to have. Curricular content knowledge (CurCK) includes knowledge of programmes and pupils' progression through the curriculum.

2.4.3.3 *Developing Shulman's ideas in mathematics teaching*

Others have applied these ideas to mathematics teaching, debated which aspects are most important and relevant, and sought to measure or evaluate them. Of the 'second generation' researchers the University of Michigan based team led by Ball have been recognised as the most influential (Barwell, 2013; Rowland and Turner, 2008). Their work is based on Shulman's categorisation but goes further and subdivides SMCK and PCK (see Figure 2).

Shulman	Subject matter content Knowledge (SMCK)		Pedagogical content knowledge (PCK)		Curricular content knowledge (CurCK)
Ball, Thames and Phelps	Common content knowledge (ComCK) – mathematical knowledge used in other settings	Specialised content knowledge (SCK) – mathematical knowledge specific to teachers	Knowledge of content and students (KCS)	Knowledge of content and teaching (KCT)	Horizon content knowledge (HCK) Knowledge of content and curriculum (KCC)

Table 2-2 Comparison of the categories of subject specific knowledge from Shulman (1987) and Ball, Thames and Phelps (2008).

Ball, Thames and Phelps (2008) argue that there is knowledge that is specific to teachers of mathematics and that might have an identifiable impact on the effectiveness of their teaching, for example the understanding needed to be able to explain procedures, to analyse errors and strategies, and to consider appropriate examples. This specialised content knowledge (SCK) thus goes beyond the common content knowledge (ComCK) that teachers need to know to be able to teach the curriculum, but which is also used in other settings. SCK seems to overlap with Shulman's PCK; indeed Ball, Thames and Phelps (2008) acknowledge that boundaries between their categories are blurred. However, they insist that "there are predictable and recurrent tasks that teachers face that are deeply entwined with mathematics and mathematical reasoning" (p.21), and that the mathematical understanding required of teachers goes beyond Shulman's PCK. Horizon content knowledge (HCK) overlaps some of Shulman's CurCK category and is essentially about having an awareness of how mathematical topics are related over the span of the mathematics curriculum.

Ball, Thames and Phelps (2008) argue that PCK should be subdivided; knowledge of content and students (KCS) includes knowledge of student conceptions and likely misconceptions, and anticipating what students might find hard and easy. Knowledge of content and teaching (KCT) includes, for example, sequencing teaching content, using representations and choosing methods. Knowledge of content and curriculum (KCC) is essentially the CurCK of Shulman.

There is much critiquing of these ideas, for example Prescott, Bausch and Bruder (2013) suggest that the lines between KCS, KCT and KCC are not clearly defined. Although there seems to be general agreement that the subject knowledge needed for effective teaching goes further than just having a strong conceptual knowledge of the subject being taught (Rowland *et al.,* 2008), different research has emphasised different elements as particularly significant. Baumert *et al.* (2010), for example, in the context of secondary teaching, concluded that PCK makes the greatest contribution to pupil progress, but weaknesses in mathematical content knowledge are not offset by greater PCK. Content knowledge "remains inert in the classroom unless accompanied by a rich repertoire of mathematical knowledge and skills related to the curriculum, instruction and student learning" (p.139). Ma (2010), on the other hand, considers this interaction from the other perspective, stressing the importance of the mathematical proficiency of the teacher: “Without solid support from subject matter knowledge, promising methods or new teaching conceptions cannot be successfully realised” (p.38).

Rowland *et al*. (2000) similarly conclude from their research that while deep conceptual knowledge is necessary, it is not in itself sufficient to enable competence in teaching the subject. They also suggest that weaker subject knowledge might impact on pre-service teachers’ ability to carry out tasks such as planning effectively, a point picked up by Kahan, Cooper and Bethea (2003), who also conclude that good mathematical knowledge is necessary but not sufficient for effective teaching. In line with this conclusion, Askew *et al.* (1997) found that it was not the formal qualifications or the amount of subject knowledge that the teachers had which was significant in the effectiveness of their teaching, but rather the nature of their knowledge. They coined the term ‘connectionist’ to describe the teachers they found to be most effective in terms of pupil progress, because they seemed to pay attention to connections in three different but related ways: connections between different areas of mathematics, connections between different representations of mathematics and connections with pupils’ methods of calculation, with an emphasis on calculation being efficient. What distinguished the ‘highly effective’ teachers was therefore the connectedness of their subject knowledge “in terms of the depth and multi-faceted nature” of the meanings and uses of concepts in mathematics (p.69).

A further consideration is the awareness of the teacher of the need for secure subject knowledge. Cai and Wang (2010) found that Chinese teachers placed a much greater emphasis on this than their US counterparts. A particular emphasis was placed on understanding textbooks thoroughly, going beyond Shulman’s CurCK, with the importance of identifying and preparing to teach ‘essential points’ and ‘difficult points’ in the textbook curriculum highlighted by several Chinese teachers. There are clear links here to Ball, Thames and Phelps’s (2008) KCS.

2.4.3.4 ***Alternative approaches***

Other authors highlight the importance of pupil voice and the ability of the teacher to choreograph classroom discourse as key characteristics of effective teaching in mathematics (Clarke and Mesiti, 2013; Schoenfeld, 2013). Whilst these aspects can be seen as linked to Ball, Thames and Phelps's (2008) KCS and KCT, Barwell (2013) considers that teachers' own knowledge is in turn structured by the responses and contributions of the pupils.

Barwell's (2013) discursive psychology perspective looks at teacher knowledge from a very different perspective. Barwell is highly critical of Shulman's ideas, arguing that it is very hard to examine teachers' knowledge outside the classroom context; knowledge is contextual and can be changed or reconstructed accordingly. Therefore, detailed analysis of classroom interaction holds the key to understanding teacher knowledge, considering 'in the moment' teaching choices within the social context of the classroom. Scheiner *et al.* (2019) further suggest that teaching mathematics is not about the application of static types of knowledge, but rather is "about the complex dynamics of the usage and function of knowledge in context" (p.163). They therefore put forward the notion that specialised mathematics knowledge for teaching is a "process of becoming". Taking a similar stance to Barwell, they note that this knowledge develops and is situated within the context of the learning and teaching of mathematics. Barwell (2013) also argues that Shulman's approach is based on the assumption that knowledge is "categorisable, measurable and as represented in the teacher's mind" (p.599) and Scheiner *et al.* (2019) agree that categorisation is unhelpful because of the dynamic interaction between various facets of knowledge within an "organic whole" (p.165).

Rowland *et al.* (2008) developed a categorisation of knowledge for teaching mathematics, the 'Knowledge Quartet', linked to Shulman's categorisation, but to facilitate purposeful feedback and reflection. Their 'foundation knowledge' is the theoretical knowledge, background and beliefs the teacher has "irrespective of whether it is put to use" (p.30). It includes Shulman's SMCK but goes beyond this to include knowledge of mathematical pedagogy and beliefs, including beliefs about why and how mathematics is learnt. The other three dimensions relate to how this is utilised in the planning and teaching of a lesson. ‘Transformation’ links closely to Shulman’s PCK and Ball, Thames and Phelps’ (2008) SCK and KCT with the choice of examples being highlighted as a key aspect of transforming teacher knowledge to present ideas to learners. ‘Connection’ is defined by Rowland *et al. (2008)* as “the coherence of the planning or teaching across an episode, lesson or series of lessons” (p.31) and is thus slightly different in meaning to the term ‘connectionist’ as applied by Askew *et al.* (1997). However, it seems likely that connectionist teachers would plan highly coherent teaching sequences using their knowledge of structural connections within mathematics. The final dimension of the Knowledge Quartet is ‘contingency’, concerning responding to pupils’ questions and ideas as they arise, and teaching in response to pupils’ learning. Rowland *et al.* (2008) state that this links to all of Shulman’s categories, but it could be argued that this is in essence Barwell’s (2013) and Scheiner *et al.*’s (2019) understanding of effective teacher knowledge from a situated perspective. A teacher’s contingent response draws on and applies all their ‘strategic knowledge’. Ironically, this term of Shulman’s (1986) for a teacher’s professional knowledge which is informed by a range of theoretical and case study knowledge, seems to apply aptly here. Askew *et al.*’s (1997) finding that connectionist teachers tended to work actively with pupils’ explanations, rather than merely listening to them and correcting, also supports the arguments for the importance of contingency. Kahan, Cooper and Bethea (2003) also specifically assert that recognising and responding to teachable moments is a key indicator of teachers’ mathematics subject knowledge.

2.4.3.5 ***Summary – influence of subject knowledge***

Whilst having limited mathematical subject matter knowledge will restrict a teacher’s capacity to teach for conceptual understanding (Ma, 2010), the discussion above highlights the complexity of the subject knowledge used by teachers of mathematics and the impact of this on their teaching. Although a range of models and views are apparent in the literature, there is agreement that teachers need and use a range of knowledge that goes far beyond simply being able to do the mathematics they teach. This knowledge is a focus of pre-service teaching courses and is enhanced through experience in classroom practice and further learning and development opportunities (Rowland *et al.,* 2008; Scheiner *et al.,* 2019).

2.4.4 *Beliefs related to the learning and teaching of mathematics*

2.4.4.1 *Introduction*

Rowland *et al.* (2008) consider that beliefs about mathematics, including beliefs about why it is learnt and how it is taught, constitute a key component of a teacher's foundation knowledge, providing the background on which pedagogical choices and strategies are based (see 2.4.3.4). Simon, Millett and Askew (2004) also recognise that it is teachers' own personal experiences and their beliefs about teaching and learning that influence their "moment-to-moment decision making" as they teach mathematics (p.157). In this section literature is presented to explore how teacher beliefs about the nature of mathematics combine with beliefs about learning mathematics and beliefs about how the subject can most effectively be taught.

2.4.4.2 *The influence of beliefs about the nature of mathematics*

Many studies (e.g. Skemp, 1976; Ernest, 1989; Askew *et al.*, 1997; Askew, 1999; Cai, 2007; Beswick, 2012) have looked at teachers' beliefs about the nature of mathematics and the impact these beliefs have on how they implement their teaching of the subject. Internationally, the beliefs of teachers of mathematics have been found to vary, with Chinese teachers, for example, placing a greater emphasis on the abstractness, purity and interconnectedness of mathematics than teachers from Western nations, who tend to have a more functional view of the subject (Bryan *et al.*, 2007; Cai and Wang, 2010).

Ernest (1989) suggests that a teacher's beliefs about the nature of mathematics are interconnected with their conception of their role and the intended outcomes for their pupils. Those who consider mathematics to be about accumulating skills and rules see themselves as 'Instructors', aiming to develop skills mastery in their pupils. Those who see mathematics as a unified body of knowledge to be understood see themselves as 'Explainers', aiming to develop conceptual understanding of this knowledge in their pupils. And those who see mathematics as an evolving aspect of human creativity see themselves as 'Facilitators', aiming to develop problem posing and problem solving abilities in their pupils. Ernest argues that these form a hierarchy, with instrumentalism at the lowest level and problem posing and solving at the highest level.

In line with Ernest, Askew *et al*. (1997) found that those teachers with 'transmission beliefs', who believed that being numerate primarily involved the ability to perform standard procedures and decode mathematical problems, focused more on teaching than on learning. They believed their teaching to be most effective when their instructions were clear.

With numeracy defined as "the ability to process, communicate and interpret numerical information in a range of contexts" (p.6), other belief systems identified by Askew *et al.* (1997) that influenced teachers' orientations towards teaching numeracy, were those of teachers with connectionist or discovery orientations. Teachers with connectionist orientations, as described in 2.4.3.3, tended to believe that being numerate included selecting efficient and effective calculation methods based on both the operation and the numbers involved, and also reasoning, justifying and proving results within wider mathematical contexts. These beliefs echo elements of Kilpatrick *et al.*'s (2001) model of mathematical proficiency, with an emphasis on conceptual understanding, procedural fluency, strategic competence and adaptive reasoning. In contrast, other teachers believed that being numerate primarily involved finding the answers to mathematical problems creatively through using a range of practical approaches, and hence tended to develop a 'discovery' approach to teaching where all methods of calculation were considered acceptable, with efficiency and effectiveness side-lined.

Askew *et al.* (1997) suggest that this "interplay between beliefs and practices is complex" (p.50) as their research found that teachers' orientations and beliefs may be more important than choices of classroom practices in their impact on pupil learning. For example, when children explain their thinking, teachers might listen for different aspects and respond to children in different ways. Their research found that transmission orientated teachers tended to listen for a match between a pupil's explanation and their own thinking, correcting any alternatives, and discovery orientated teachers paid attention to the range of methods used by pupils. However, the greatest progress on the numeracy tests given was made by the pupils of connectionist orientated teachers who worked "more actively" with the pupils' explanations, using these to develop their understanding of efficiency and more refined methods (p.47).

It seems likely that teachers with different orientations in their teaching of mathematics (Askew *et al.*, 1997) differ in their beliefs about the nature of understanding in mathematics. Such understanding was considered in section 2.4.2.2 in relation to the literature around proficiency in mathematics, but is further discussed below in relation to teacher's beliefs.

2.4.4.3 ***The influence of beliefs about understanding in mathematics***

Bryan *et al.* (2007), in their international study, found that teachers from both Eastern and Western cultures agree that "understanding is the ultimate goal of learning mathematics" (p.331). Their study also suggests that teachers internationally agree that an indicator of mathematical understanding is that pupils can use their understanding to problem solve flexibly in a range of situations, with a further indicator being that they can communicate what they have learnt. However, the notion of 'understanding' is complex and differences were apparent in Bryan et al.'s study, for example, with differing emphasis placed on aspects of this such as memorisation and understanding at concrete and abstract levels. The notion of memorisation is not explicit in Kilpatrick *et al.*'s (2001) model of mathematical proficiency discussed in 2.4.2, but teachers from both Eastern and Western cultures agreed that this plays an important role in developing mathematical understanding. However, although all agreed that "memorisation after understanding" is ideal, Chinese teachers also valued "memorisation before understanding" as long as this led to learning; such synthesis of memorisation and understanding was seen to enhance academic performance (p.338). In addition, whilst Chinese teachers considered the purpose of using concrete examples was to help students derive abstract concepts, US teachers used them to help students realise the connectedness between mathematics and real-life problem-solving situations.

Askew (1999) argues that a teacher's pedagogical decisions "will rest on some theory or beliefs, however informal or unarticulated, about the relationship between teaching and learning" (p.92). The importance of the cultural context of the teacher in this regard is also evident in research literature.

Cai and Wang (2010) discuss the background to the culture of mathematics teaching in China and the USA, with the different epistemological views of Confucius and Socrates having influenced the historical development of theories of learning and teaching in these contexts. For Confucius, truth and knowledge are gained from an authoritative figure and Chinese teachers therefore consider effective teachers to be those who successfully transmit existing knowledge to their pupils. Although this sounds superficially like Ernest's 'Instructor' role, there is a distinct difference: the aim here is for pupils to build conceptual understanding, albeit abstractly, with a focus on connecting pieces of knowledge. The Socratic tradition underlying theory in the USA sees knowledge and truth as self-generated to a large extent and built upon by questioning self and others. The US teachers in the study saw effective teaching as that which enabled students to "explore, generate and then use knowledge by themselves" (p.284), in essence the Facilitator at the top of Ernest's (1989) hierarchy.

The idea of mathematics teaching enabling pupils to understand connections is very apparent in the literature. As discussed above, it seems to be a key aspect of pure mathematics for Chinese teachers and is implicit in the relational understanding of Skemp (1976), the model of mathematical proficiency of Kilpatrick *et al.* (2001) and practical problem-solving approaches where pupils are encouraged to apply their understanding of connections. Thus Askew *et al.*'s (1997), connectionist teacher is an effective teacher who brings their beliefs about the connected nature of mathematics, reflecting the pervading Chinese approach, together with connected choices in how they teach it.

Whilst the cultural perspective forms the background to teachers' beliefs and practices, on an individual basis, a teacher's view of mathematics seems strongly related to their specific experiences as learners of mathematics and links with their attitudes and emotions, as discussed below (2.4.5.2). Di Martino and Zan (2010), for example, found that a personal description of a relationship with mathematics tended to include a vision of mathematics alongside perceived competence and emotional disposition.

Simon, Millett and Askew (2004) argue that teacher beliefs tend to be deeply rooted; when faced with new ideas in the reform context of the NNS, their case study teachers only made changes in line with their existing beliefs. Spillane (1999) similarly, found that reform ideas that closely fit with teachers' prior ideas gained "more attention" (p.169) and when the reform ideas promoted different views, their beliefs and practices were resistant to more fundamental changes. However, Walshaw and Anthony (2006) provide evidence of teachers together negotiating ideas about characteristics of effective teachers and learners of mathematics and of effective features of the mathematics environments, to establish a collective understanding of these ideas in the context of reform. This suggests factors such as collegiality and accountability might lead to adjustment of beliefs.

2.4.4.4 ***Practice varying from beliefs***

Although there is considerable evidence that a teacher's practice is influenced by their beliefs, Schoenfeld (2013) makes the point clearly that what teachers say they believe may not correlate with their actions in the classroom. It is how they actually teach that is most important as this is what impacts on students' learning. Cai and Wang (2010) also found this discrepancy, giving an example of Chinese teachers who said they believed that teachers should be flexible and respond to individual pupils' needs, but felt they had taught effectively when they had successfully taught to their lesson plan.

Ernest (1989) suggests that there are two main reasons for this possible mismatch. Firstly, the influence of the social context within which the teacher is working; the expectations of those they are working with, the curriculum and scheme of work, system of assessment etc. can lead teachers who work together to teach in very similar ways no matter what their individual beliefs are. This point is also made by Skemp (1976) who argues that a teacher with relational or conceptual understanding of mathematics might "make a reasoned choice" to teach for instrumental understanding, such as when pupils need short term, relatively quickly gained, procedural skills for examinations (p.24). Secondly, the teacher's awareness of their beliefs and the extent to which they reflect on them and are aware of viable alternatives, will vary. Ernest suggests, for example, that having an instrumental view of mathematics with a consequential 'Instructor' mode of teaching, requires little self-consciousness, reflection or awareness of other approaches.

Additionally, Beswick (2012) found that it is possible for teachers to hold different views about mathematics as a discipline and mathematics as a school subject. Beliefs from a mathematician's view of the discipline, coming for example from studying the subject at degree level, therefore do not necessarily influence classroom practice. Rather beliefs gained from experiences in teaching mathematics might override previously held beliefs.

2.4.4.5 ***Summary - beliefs related to the learning and teaching of mathematics***

Whilst it cannot be assumed how a teacher's practice is influenced by their beliefs, there are a range of interconnected elements to a teacher's belief system related to the nature, learning and teaching of mathematics. These seem to be influenced by a teacher's own background as a mathematician and their cultural context.

In making decisions about their classroom practice, a teacher's beliefs will inevitably sit alongside their subject knowledge for teaching, their attitudes and emotions.

2.4.5 *Attitudes to mathematics and emotions about the subject*

2.4.5.1 *Introduction*

Further research suggests that in addition to their subject knowledge and belief systems, a teacher's practice can be impacted by their relationship with mathematics, including their attitudes and emotions towards the subject. In this section, literature is presented which discusses various aspects of this in the context of a teacher's evolving relationship with mathematics developed from their background as a learner of the subject. Consideration is then given to the implications of this for a teacher's practice.

2.4.5.2 *Pre-existing attitudes and emotions*

Hannula notes the dichotomy that seems to exist between the typical view of mathematics as objective and logical and the affective responses shown by learners towards the subject (Hannula, 2011). Indeed, there seems to be general agreement that, for many learners, mathematics "is experienced in highly emotional ways" (Bibby, 2002, p.706).

The complexity of theoretical ideas around the nature of 'affective' responses in mathematics, concerned with concepts such as attitudes, emotions, motivations and beliefs, is acknowledged in the literature (e.g. Hannula, 2011, Lewis, 2013). Hannula (2011) suggests a useful distinction between rapidly changing affective states, which might vary with the particular context and situation the learner is currently in, and relatively stable affective traits which persist over time. Lewis's (2013) research with disaffected teenagers gave evidence that such motivational and emotional traits are "ever-present in students' experience of mathematics" (p.270) and influence the extent to which learners engage in the learning of mathematics.

The notion of deep, long term, attitudinal and emotional traits is also evident in DeBellis and Goldin's (2006) theorising, that draws on evidence from their longitudinal research with children aged 9-12. They suggest that mathematical intimacy and mathematical integrity may be particularly important in relation to developing a personal relationship with mathematics. They define mathematical intimacy as "deep, vulnerable emotional engagement” with mathematics (p.132), which Hodgen and Askew (2007) interpret as suggesting some degree of threat to one’s identity. While this might have negative connotations, and indeed DeBellis and Goldin state that having intimate engagement with mathematics does not necessarily lead to a positive relationship with the subject, DeBellis and Goldin also argue that through an individual’s ‘meta-affect’ or self-awareness of their emotions, potentially negative emotions can be transformed. For example, with recognition that difficulty can lead to further learning, frustration “could and should indicate that a mathematical problem is non-routine and interesting” (p. 137). They argue that mathematical integrity, “the individual’s commitment to mathematical truth, search for mathematical understanding or moral character guiding mathematical study” (p.132), combined with mathematical intimacy, influence both the nature of the mathematical learning and the depth of the consequent knowledge gained; those students who have strong mathematical intimacy and integrity have the potential for deep mathematics learning.

This notion of a personal relationship with mathematics is further explored by Di Martino and Zan’s (2010) study of secondary students’ essays on their relationship with mathematics. This research seems particularly relevant given the relative recency of secondary mathematics experience for most of my participants. Arising from their study, Di Martino and Zan present a model of attitude with three interconnected dimensions: emotional disposition towards mathematics, vision of mathematics and perceived competence in mathematics. Whilst this model has a narrower focus than some other models addressing attitudes and emotions in mathematics education (e.g. Hannula, 2011), Di Martino and Zan suggest this model is more useful than a simple positive/negative dichotomy of attitude to mathematics based on emotion. Almost all students in their study referred to at least one of the three dimensions as they described their relationship with mathematics and most referenced all three, usually in a deeply connected way. Statements about success in mathematics were linked to succeeding in tests by some and to understanding by others. In turn, understanding in an instrumental way was considered positive by some as they were able to identify and apply rules, whereas relational understanding was considered positive by others, referring to their understanding of why rules work and how they are linked (Skemp, 1976). Low perceived competence was often associated with an instrumental view of mathematics and was reinforced by repeated perceived failures. For many, the role of the teacher was a "crucial mediating factor" (p.43) between the three themes, often associated with "turning points" in a students' relationship with the subject; for example, one participant stated, "My relationship with this subject tuned upside down when I changed my mathematics teacher" (p.42).

Bibby (2002)'s study of primary teachers of mathematics also found a connection between these teachers' prior experiences of algorithmically or procedurally learning mathematics and their "expressing shame in mathematical contexts" (p.706). Their own mathematical knowledge was perceived by the participants to be "insufficient, inadequate or unreliable" (p.711).

Van der Beek *et al.* (2017) sought to go further in exploring the role of perceived competence, or mathematics self-concept, in mediating the relationship between mathematics achievement and emotion with secondary students in the Netherlands. They found that although the higher achieving students had more positive self-concepts and emotions than average or lower attaining students, overall the students' emotions were more strongly linked to their self-perceived ability than their immediate achievement. Martínez-Sierra and Garcia Gonzalez (2014) similarly argue that students' emotions to mathematical tasks are "triggered by cognitive interpretations of events" which might be consciously or unconsciously applied (p.235). There also seems to be a gendered effect, with Hargreaves, Homer and Swinnerton (2008), finding that even amongst higher attaining mathematicians, boys tended to have a more positive attitude than girls to mathematics and a greater tendency to think they had been successful compared to girls achieving similar performance.

2.4.5.3 ***Summary and implications – attitudes and emotions***

A prospective teacher, therefore, comes into teaching with attitudes and emotions to mathematics, including a personal mathematical intimacy, heavily influenced by their perceptions and memories of their experiences as a learner and with implications for their relationship with mathematics as a teacher (Bibby, 2002). Although Simon, Millett and Askew (2004) suggest that decisions about teaching approaches reflect a teacher's beliefs about knowledge, how it is learnt and how they should teach, such beliefs sit alongside affective issues in influencing a teachers' willingness, motivation and capacity to learn and develop as a teacher of mathematics (Spillane, 1999; Millett and Bibby, 2004) and their self-belief (Bandura, 1997; Eraut, 2004).

Two main ideas relating to the impact on teachers of their attitudes and emotions are now discussed, firstly the notions of self-efficacy and confidence and secondly motivation. These relate not only to the nature of a teacher's practice, but particularly to how this practice might draw on their background subject knowledge and beliefs to evolve through further learning and development.

2.4.6 *Confidence and self-efficacy*

Bandura (1997) introduced the concept of self-efficacy as "beliefs in one's capacity to organise and execute the courses of action required to produce given attainments" (p.3) – that is to say, a belief that one can achieve an intended outcome. It is a self-judgement of capability and impacts a person's behaviour in a range of ways, such as their decision-making about courses of actions, their resilience and how much effort they apply, and the optimism or pessimism of their thinking (Bandura, 2006). Bandura (1997, p.80) suggests that "enactive mastery experiences" are the most powerful influence on self-efficacy; perceived success in performing a task will increase self-efficacy related to that task, especially if it is perceived to be demanding and success is attributed to one's own effort rather than external support.

Researchers in teacher education have sought to apply Bandura's ideas to understand the impact of teacher's self-efficacy on both their teaching practices and student outcomes (Hoy and Spero, 2005; Morris, Usher and Chen, 2017). In a teaching context, self-efficacy can be defined as "beliefs teachers hold about their capabilities to carry out their professional tasks" (Morris, Usher and Chen, 2017, p.796). Conclusions have been drawn suggesting that teacher self-efficacy is a key motivational belief influencing their professional behaviours and consequently students' learning (Klassen *et al.*, 2011).

The related notions of confidence and self-efficacy are discussed by Eraut (2004) who found that confidence, including self-efficacy, is a vital component of ongoing learning and development in the workplace. Confidence was found to be key in terms of workers seeking advice and learning opportunities and acting on these, to the extent that he suggested a triangular relationship between challenge, support and confidence. In line with Bandura's mastery experiences, confidence was gained from successfully meeting challenges, while the confidence to partake in challenges depended on the perceived support received, a point also noted by Hoy and Spero (2005) in the context of early career teachers. Eraut's research suggested that if no challenge was apparent and there was no support to encourage the worker to seek challenge or respond to challenge, then confidence and motivation to learn declined. However, the research drew distinctions in the meaning of the word 'confidence' as used by the participants. Whilst middle career workers tended to use this word to mean, in essence, Bandura's self-efficacy, early career workers were more likely to relate it to their relationships in the workplace than to the work itself. Confidence for them was about having the support of colleagues.

Other research also suggests that a teacher's career stage and the related extent of support is a factor influencing the impact of confidence on their learning and development. Seemingly referring to self-efficacy, Goos and Geiger (2010) suggest that beginning teachers may not feel confident to change their environment (ZFM) in order to make large scale changes to their practice; similarly any external promoted actions that are not internally supported may not sustain changes in practice. Hoy and Spero (2005)'s research also found that although Bandura's theory suggests that efficacy is "most malleable" in the early stages of learning, it tends to fall during the first year of teaching. This is due to underestimation of the challenges of teaching and the lower level of support received as a newly qualified teacher compared to a student teacher.

However, given appropriate support such as within a community of practice of fellow novices, such teachers can confidently and proactively seek to develop their practice (Cuddapah and Clayton, 2011).

In addition, Morris, Usher and Chen (2017) recognise the importance in a teaching context of teachers' knowledge and their beliefs about that knowledge on their self-efficacy. Although there is limited research on these ideas specifically within mathematics education, Bjerke's (2017) study of pre-service teachers' self-efficacy in the teaching of mathematics concludes that their perceptions of, and reflections on, their own mathematics subject knowledge and its role in teaching "are crucial in their developing identities as mathematics teachers" (p.73).

Most research on links between mathematics with self-efficacy and confidence has focused on negative aspects of this, highlighting the difficulties many teachers face. Many feel insecure with their subject knowledge in mathematics (Newell, 2011) and recount their experience of mathematics at school as a subject that caused difficulties and even "real emotional turbulence" (Brown, 2005, p.21). In contrast to those with strong mathematical integrity structures and high capability for mathematical intimacy (DeBellis and Goldin, 2006), for many teachers mathematics is linked with anxiety, emotion and negativity, with consequent impact on their attitudes to teaching the subject (Hodgen and Askew, 2007), their self-efficacy as teachers and hence their practice (Bandura, 2006).

Whilst some pre-service teachers tend to emphasise sensitivity, patience and supportiveness as positive qualities of their mathematics teaching, Brown (2005) argues that this is likely a mask to their continuing anxieties. Schuck (1999), also researching the attitudes and beliefs of pre-service teachers, uncovered the "disturbing" notion that many believed that gaining strong subject matter knowledge would lead them to teach less effectively through causing them to lose their empathy with struggling pupils (p.120). Hodgen and Askew, (2007) suggest that teachers even protect pupils from mathematics by emphasising the step by step procedures that are likely to lead pupils into negative perceptions of mathematics and an instrumental understanding. Indeed, there appears to be a potential vicious circle at work; Di Martino and Zan's (2010) evidence suggests that negative emotions about mathematics are associated with either an instrumental view of the subject or low perceived competence. It seems likely that without intervention, should such students become teachers of primary mathematics, they may well teach in such a way as to perpetuate the issue.

Leavy and Hourigan (2018) go as far as asserting that "It is essential that all teachers of mathematics possess positive attitudes to mathematics and experience enjoyment of mathematics" (p.772), because of the potential influence they have on the experiences and attitudes of the children they teach. This goes beyond a simple focus on making mathematics "fun" without due consideration of the potential for learning from games, puzzles and practical work (Schuck, 1999).

In this thesis the terminology self-efficacy is used when this can be specifically linked to the definitions of Bandura (1997) and Morris, Usher and Chen (2017) above. The more general term confidence is akin to self-assurance and may not link directly to the role of the teacher, as Eraut (2004) suggests. However, at times participants themselves used the term confidence meaning self-efficacy as a teacher of mathematics, and their original language is used. Similarly, where the word confidence rather than self-efficacy has been used in literature being discussed, this term is retained.

2.4.7 *Motivation to learn and develop as a teacher of mathematics*

Millett, Brown and Askew (2004) and Spillman (1999) found that motivation to change was a key factor in the rich ZoE necessary for a teacher to make deep changes in their practice and that this motivation, defined by Millett and Bibby as "the wants, needs and aspirations of the individual" (p.5) might be derived from a range of sources. Other research confirms the importance of both internal and external factors to motivation.

Eraut (2004), as noted above, connected motivation to learn with confidence and proactivity, finding through his research that much learning in the workplace occurs through experience, through being proactive in seeking learning opportunities and learning from feedback. This proactivity was dependent on the person's perception of the value of their work and their commitment to it. Spillman (1999) similarly concluded that the extent to which a teacher is proactive in gaining both support and further insights from colleagues determines the effectiveness of the ZoE. It seems too that for some teachers with low self-efficacy as mathematicians, feelings of inadequacy alongside strong self-determination can be used as positive motivation to proactively develop their subject knowledge for teaching (Bibby, 2002). Such internal motivational factors can also include a particular interest in mathematics and a desire to improve the quality of teaching (Millett, Brown and Askew, 2004).

External motivating factors to change and develop practice might come from pressure from school expectations and accountability measures; changes of role, such a becoming a subject leader; and changes in school or national policy (Walshaw and Anthony, 2006; Millett, Brown and Askew, 2004). These factors sit alongside the pressure for early career teachers in England to show sufficient competence to pass their NQT year (Department for Education, 2016). More positively perhaps, and linking internal and external factors, Walshaw and Anthony (2006) found that peer support and feedback provided not only the means for learning in relation to subject and pedagogical knowledge development, but also the motivation to improve practice.

2.4.8 ***Summary - The personal dimension of learning and development***

The literature reviewed above, whilst not exhaustive, outlines the complexity of the background of teachers of mathematics. The influence of their subject knowledge for teaching mathematics combines with their related beliefs, and their emotional and attitudinal relationship with the subject, to impact on their practice. An individual's relationship with the subject can then impact on their confidence and self-efficacy for teaching mathematics and, in turn, influence their motivation for further learning and development. It seems likely that these factors vary considerably between early career teachers.

Whilst concentrating on personal aspects, research discussed in this section has also recognised that the community within which the individual works is highly significant. This pattern is also seen when considering literature related to teacher learning and development through reflection on practice.

2.5 Reflection as a mechanism of teacher change

2.5.1 *Introduction*

The reflective and proactive dimension of teacher learning and development is considered separately from the personal factors outlined above because the research evidence suggests that this dimension is strongly impacted by a combination of both these and social factors. In this section, literature is reviewed to explore the meaning of reflective practice, the influences on the nature and depth of an individual's reflective practice and the social dimension of reflection as a mechanism of teacher change.

2.5.2 *The meaning of reflective practice*

There seems to be agreement in the literature that reflection is "essential" for teachers to actively construct their knowledge, beliefs and awareness and thus learn more about teaching and about themselves as teachers, leading to changes in their practice (Llinares and Krainer, 2006, p.438). However, there is also debate as to what the essence of reflection involves for the teacher, possibly because of difficulty in how to conceptualise the notion (Korthagen, 2010). Korthagen also warns that research into teachers' reflection is problematic as it "takes place in the teacher's head" (p.6).

There seems general agreement that the origin of the notion of reflection lies with Dewey (1909), who distinguished reflective thinking from everyday thinking, defining it as "active, persistent and careful consideration of any belief or supposed form of knowledge in the light of grounds that support it, and the further conclusions to which it tends" (p.6). Thus, reflection to Dewey involves chains of thinking, consideration and inquiry into the basis of beliefs and intelligent thought about the consequences of these. Schön (1995) built on Dewey's notion of inquiry as "thought intertwined with action", suggesting that reflection in and on action "proceeds from doubt to the resolution of doubt, to the generation of new doubt" and hence to the generation and testing of new knowledge for action (p.31). Schön considered that everyone has this ability to "generate new knowing" through 'reflection-in-action' (p.30), a process triggered by a surprise, where a performer reacts by restructuring their understanding of that situation in the moment to create a revised strategy for action; in essence where they are applying their contingent knowledge (Rowland *et al.*, 2008). Schön also states that everyone has the ability to reflect on reflection-in-action – this 'reflection *on* action' is a further mechanism of change where the person reflects critically on their actions and assumptions in order to inform further practice (Schön, 1983; Schön, 1995). This reflection implies inquiry into personal beliefs and values at the heart of one's actions (Schön, 1987).

The work of these two theorists suggests that reflection has a key purpose of moving thinking on in order to develop one's practice. Whilst their thinking is referred to by many seeking to apply these ideas into teacher education, there is recognition of the complexity of the notion of reflection, with different researchers emphasising different educational aspects and hence using different criteria to measure the extent of reflection (Korthagen, 2010). Most researchers seem to focus on what Gore and Zeichner (1991, p.121) term "a developmental version" of reflection that is focused on pupil learning. This definition seems apt for this study, alongside the perhaps more transformative definition used by Hodgen and Johnson (2004) in the context of NNS reform, "reflection as the reconstruction of experience and knowledge" (p.223). Additionally, Körkkö, Kyrö-Ämmälä and Turunen (2016) conclude from a synthesis of literature related to teacher professional development, that teacher reflection can occur at a range of levels, from a low level of "technical, subjective and rigid thoughts", to deeper reflection involving acknowledgement of the "subjectivity of knowledge and the relativity of truth" to the highest level where the teacher is able to question their own beliefs, values and assumptions (p.200). They found that with increasing experience and guidance, the depth of reflection of most pre-service teachers in their study increased.

The idea of reflection as a proactive mechanism of change is very apparent in Peter's (1995) model of professional growth. In this model (p.322) she suggests that reflection and enaction -"the translation of a belief or pedagogical model into action"- are the "mediating processes" of teacher growth between four analytical domains: the Personal Domain of teachers' knowledge and beliefs, the Domain of Practice where teachers both enact their knowledge and beliefs and experiment when they face challenges and problems, the Domain of Inference which consists of the "valued outcomes" a teacher is seeking to promote and against which criteria reflection and experimentation take place, and the External Domain, where external sources stimulate both reflection and experimentation.

2.5.3 *Influences on the nature and depth of individual reflective practice*

Gore and Zeichner (1991) stress the importance of the criteria against which teachers reflect and criticise earlier studies including Schön's for their lack of clarity in this regard. Korthagen (2010) considers this relates to the question of "what constitutes a good teacher" (p.5), and indeed Calderhead (1989) points to research of pre-service teachers' reflection emphasising their beliefs and conceptions of teaching and the kind of teacher they want to become. The "images" or "models" that such teachers might have as to the ideal they wish to achieve influence their perceptions of their own teaching and that of others they observe, essentially using the 'imagining' notion of Wenger (1998). Their evolving subject knowledge, understanding of different teaching approaches and awareness of children's performance expectations seem to be additional cognitive factors influencing their reflection (Calderhead, 1989). Calderhead concludes, in line with Körkkö, Kyrö-Ämmälä and Turunen (2016), that for pre-service teachers, reflection is demanding as it requires not only reflective awareness and critical thinking skills, but some degree of competence and confidence. Reflection without well-defined theoretical perspectives might similarly be limited and "haphazard" in nature (Johnson, Hodgen and Adhami, 2004).

There is evidence that the benefits of reflection are also limited for early career teachers even if reflection is emphasised in their ITE programmes; the "latency period" might take up to two years until the teacher has adjusted to their school context (Korthagen, 2010). Teachers in their first year of teaching in his study actually showed a decrease in the extent of their reflections comparing their everyday practice to their ideals. This seems unsurprising given Johnson, Hodgen and Adhami's (2004) finding that "normally two to three years are required for significant shifts to occur in beliefs and practices of most teachers" (p.214).

Others agree that reflection is enhanced by strong subject knowledge and experience. Schön (1995), for example, discusses how reflection-in action stems from a combination of the intellectual and practical knowledge a practitioner has and can apply in the moment to deal with a professional problem. In the context of teaching, both content knowledge and "content-related pedagogical knowledge" come into play at such moments, alongside the knowledge of identifying and solving problems (Ponte and Chapman, 2006, p.461).

Additional evidence, however, points to differences in the orientation of teachers with respect to reflection, which might mitigate the effects of inexperience. In line with the internal and external motivating factors of Millett, Brown and Askew (2004), Korthagen (2010) found a distinction between internally and externally orientated pre-service teachers. Some teachers wanted to reflect personally on their practice using their own knowledge and values; others felt a strong need for guidance and feedback to structure their reflections.

Further research supports this idea that some teachers might be particularly internally motivated or orientated to be reflective. Turner (2008) concludes from her case studies of early career teachers that particularly reflective teachers will continue to learn and develop whatever the extent of the collaborative nature of their CoPs (Wenger, 1998). Newell (2011), from his research with pre-service teachers, goes as far as suggesting that using very reflective teaching skills could be more effective for teacher development than having a strong mathematical background, as long as subject knowledge is "good enough" because reflective pre-service teachers show the "willingness and confidence" needed to proactively research subject and pedagogical knowledge before teaching (p.107).

The research literature above, alongside the reality of the reduction in the intensity of ongoing support and guidance for an NQT compared to a pre-service teacher in England, suggests that there are likely to be individual differences in the extent to which early career teachers in my research reflect on their practice.

Reflection can be viewed as an individual activity, but as mentioned in the earlier review of theoretical frameworks of teacher learning and development, this is not necessarily the case.

2.5.4 *The social dimension of reflection as a mechanism of teacher change*

With talk/collaboration and time identified by Millett, Brown and Askew (2004) as key conditions of a rich Zone of Enactment enabling teacher change, it can be argued that the effectiveness of reflection as a mechanism of change might depend on the extent to which an individual collaborates and reflects alongside others and the time available for this process within their CoPs. Johnson, Hodgen and Adhami (2004)'s research, for example, concluded that individual reflection is limited to what is known by the that person, whereas collective reflection enables a sharing of points of view related to shared experiences. Alongside this, time is needed for cycles of practice and reflection on the practice.

Eraut (2004)'s elaboration on the importance of time in relation to reflection further exemplifies this point. He distinguishes between three levels of informal learning:

implicit learning which takes place unconsciously, in the moment, using past experiences; reactive learning which involves intentional and conscious, but near-spontaneous, reflection; and deliberative learning where, possibly in discussion with others, time is set aside to think, review actions, plan learning opportunities and rehearse for future events. Whilst Eraut found that progress in learning was found to be dependent on a range of factors, including the challenge of the work and the opportunities for learning alongside others, for early career professionals learning was maximised when challenge was high but without being daunting and when time was available for reflection.

Millett, Askew and Simon (2004) describe a rich ZoE as where "innovations in practice and new knowledge can be mulled over, discussed with others, tried out in the classroom, reflected on again in an iterative process that results in changed, rather than amended practice" (p.152) and stress the importance of a supportive environment for these processes, implicit in the deliberative learning of Eraut (2004).

Wenger (1998) also suggests that reflective practice results from a combination of imagination and engagement. It involves the ability to both distance oneself to 'imagine' different perspectives and then to learn from this by engaging in participation, negotiating new ideas in practice and exploring new possibilities within a CoP. Thus, reflection alongside colleagues in a CoP can be more effective than individual reflection. Hodgen and Johnson (2004) found that teachers with dual or multiple identities as teachers, researchers, tutors and lesson-developers within a professional development project were particularly able to use the distancing the project enabled to reflect on their practice. They were able to use the time and space the project afforded to draw on their previous experiences to 'imagine' different practices and, alongside colleagues, to discuss, modify and retrial changes in their practice.

2.5.5 *The importance of reflection as a mechanism of change*

A note of caution is given by Lerman (2001) who states that there is a tendency for researchers to assume that reflection makes a positive impact on the practice of the practitioner. Whilst bearing this in mind, alongside the different perspectives on reflection outlined above, the combined research literature nevertheless suggests that reflection can for many teachers be a powerful mechanism of learning and development, albeit possibly limited in scope for early career teachers.

2.6 The influence of the social and organisational context within which teachers work

2.6.1 *Introduction*

The notion of collaboration and teacher learning being socially situated is a strong theme of the theoretical frameworks introduced in section 2.3 and, as discussed above, has been found to be a key aspect relating to the quality and impact of teachers' reflection on practice. It has also been seen to combine with the influence of the personal factors discussed in 2.4, particularly in relation to a teacher's confidence or self-efficacy, and their motivation to develop their practice.

This section briefly summarises some key points raised from the literature already reviewed and then adds some additional perspectives. These relate firstly to Levine's (2010) synthesis of types of teacher community and then to research noting that not all teachers benefit from collaboration within their school context.

2.6.2 *Summary from previous sections*

As might be expected in a model designed to discuss teacher change within the context of national and hence whole school reform, the influence of the school context is very explicit in Millett and Bibby's model and related research. A range of school based and wider professional development opportunities were available to teachers during the time of the NNS. Factors related to the nature of the school context and the extent of collaboration were behind the main finding that time, talk, availability of expertise and motivation to change were key conditions for deep-seated teacher learning and development (Millett, Brown and Askew, 2004).

The community is also the essence of Wenger's (1998) framework. Learning takes place within a landscape of CoPs, where newcomers learn from the expertise of full participants, developing their identity as they gain access to a range of activities, resources and opportunities for participation. Whilst less explicit in Goos' (2013, 2014) zone theory, organisational factors related to the school are at the core of the teachers' ZFM and both informal and formal interactions with colleagues can be the source of learning and development through promoted actions.

Pressures within the school context might impact on the way a teacher implements their beliefs about the learning and teaching of mathematics (Ernest, 1989, Skemp, 1976) and support, feedback and challenge from colleagues can influence an individual's confidence and motivation (Eraut, 2004). Collective reflection widens the perspectives of a teacher with shared points of view (Johnson, Hodgen and Adhami, 2004) and enables purposeful and supportive discussions which might be more effective in promoting change than individual reflection (Millett, Askew and Simon, 2004).

2.6.3 *Levine's synthesis of types of teacher community*

The previously reviewed literature recognises that various differences in school communities are likely to impact on the extent and nature of teacher change. Levine's (2010) synthesis of the nature of school communities and related literature adds further points for consideration that might be useful for interpreting the outcomes of my research. These are outlined below.

Levine (2010) presents four types of "teacher community" (p.109), focusing on how the nature of the community within a school impacts on individual teacher development. One of these is Wenger's (1998) CoP, but the other three represent slightly different perspectives on this notion. Firstly, a teacher community might be an inquiry community where teachers learn from asking questions about learning and teaching and research the answers together. Potari (2013) states that "the integration of research, theory and practice" (p.507) has been viewed as effective in mathematics teacher education, although identity tensions can exist between the dual roles of teacher and researcher when the teacher is also engaged in specific research practice. Much work with teachers in this area is guided by researchers working alongside teachers, although in Chinese schools there is an assumption that teachers work together in research groups to improve teaching quality (Paine and Ma, 1993). Whilst this approach seems highly effective, it is also dependent on the considerable time given to enable teachers to discuss, prepare and analyse their work. Less formally, a school where promotion of learning for staff as well as students is prioritised might consider itself to be a community of learners (Barth, 1984). Although Barth stresses the value of all members of a school community being "entitled to engage in its most important enterprise" (p.94), Levine considers the notion of community of learners as vague in terms of the actual mechanisms of learning and learning outcomes.

A third type of community considered by Levine is a teachers' professional community where the focus is on "shared norms, beliefs, attitudes and trust", rather than any specific "mechanism of learning" (p.116). Levine similarly considers this conception of teacher community as unclear in terms of actual mechanisms for teacher learning, although for beginning teachers this might be significant and possibly a pre-requisite for more learning-focused collaboration.

2.6.4 *Individualistic practice*

Finally, although the research literature generally notes the positive influence of the school community, it cannot be assumed that all teachers have such opportunities for developing shared knowledge or that they take up opportunities for this. Spillane (1999) found that teachers' Zones of Enactment varied "on a continuum from individualistic to social" (p.171), with those trying individually to carry out reforms having not only fewer opportunities to develop their understanding of new ideas, but "no reason to question their particular enactment" of these (p.168). As a consequence, changes to practice tended to be only superficial. Even for those partaking in "extensive support and ongoing deliberations with colleagues" there is no guarantee that a teacher will fully grasp recommended changes to practice (Walshaw and Anthony, 2006, p.367). More recently, Ball, Ben-Peretz and Cohen (2014), also from their US perspective, argue that although there is real potential in sharing good practice, "the teaching profession lacks adequate structures in the main to support the development of shared knowledge on a widespread basis" (p.318). Many teachers therefore act independently on untested ideas, assumptions and myths and thus "pose serious threats to professional practice and its improvement" (p.331).

2.6.5 *The importance of the social and organisational context*

Levine (2010) specifically notes the calls by recent researchers and policy makers for "teachers to overcome their historical isolation" (p.109). In the setting of the classroom, the community setting of the school, and wider professional settings such as formal and informal groups, meetings and courses outside their school (Ponte and Chapman, 2006, p.462), teachers think, act and reflect within a range of social contexts (Krainer, 2003). The influence of these contexts is likely to have a significant impact on an individual teachers' professional development (Jaworski, 2001), alongside personal factors such as their biography and responses to innovation (Peter, 1995). It seems that the greatest impact on practice happens when teachers are involved in extended mathematics education programmes (Askew *et al.,* 1997; Ball, Hill and Bass, 2005) where time is given for teachers to reflect on their beliefs and attitudes as well as develop their subject knowledge for teaching mathematics.

2.7 Practice and policy in England related to teacher development

In the UK historically there has been a very wide variation in teacher development practice between schools. Askew *et al.* (1997), for example, found that some primary schools benefitted from very strong leadership in mathematics with the effect that knowledge, beliefs and good practice become widely shared. In some schools there was a culture of discussing the teaching of mathematics and experienced connectionist teachers worked alongside less experienced teachers to demonstrate good practice. These influences within in-school communities of practice seemed to have a positive effect in terms of developing 'highly effective' teachers. However, this practice was by no means the case in all schools.

Following a period of "one size fits all" professional development courses led by local authority consultants during the period of the National Strategies (1997-2011), a new National Curriculum was introduced in England in 2014 during a period which again lacked any coherent policy of teacher development (ACME, 2013, p.3).

The context of variable provision for professional development at this time was also highlighted by Ofsted (2012). They recommended that teachers should be given opportunities to develop their expertise in areas such as "choosing teaching approaches and activities that foster pupils' deeper understanding" and "understanding the progression in strands of mathematics over time, so that they know the key knowledge and skills that underpin each stage of learning" (p.10). These aims seem consistent with key aspects of subject and pedagogical knowledge reviewed above and indeed Ball, Hill and Bass (2005) found, for example, that professional development that focused on specialised subject knowledge for teaching mathematics – "proof, analysis, exploration, communication and representations" (p.45) - led to the greatest performance gains for teachers on their overall subject knowledge.

Currently the NCETM website, funded by the government and available to all teachers of mathematics, provides a source of subject and pedagogical guidance, curriculum support and research information and is a means of sharing experience (NCETM, 2019). Alongside this, in 2014 a network of ‘Maths Hubs’ was set up across England to lead improvement in mathematics education. Funded by the government, led by “outstanding” schools and colleges and supported by advisory bodies including universities and the Advisory Committee on Mathematics Education (ACME), these Hubs have sought to raise standards to match those of high performing jurisdictions in Asia by learning from their mastery approach (ACME, 2014). At present a “Teaching for Mastery” training programme is offered through the Maths Hubs. This is a four-year government funded programme for schools to support their implementation of “teaching for mastery approaches” and to develop in-school leadership capacity in this regard (Maths Hubs, 2018). An element of this programme involves teachers from across schools collaborating in inquiry communities.

The Maths Hubs initiative and other local initiatives go some way towards the addressing the fragmented and inconsistent provision for Continuing Professional Development (CPD) identified by ACME in 2013. ACME (2016) suggest there have since developed “some interesting pockets of good practice” in the development of “collaborative learning groups”, for example where universities are working with schools over a sustained period of time (p.11). However, whilst some teachers might be accessing strong in-school support or external CPD courses, this is not guaranteed for all teachers. ACME (2016) reinforce their view that “there needs to be a commitment to a coherent and well-funded framework for professional learning provision across England” (p.9). They also stress the need for individualised and ongoing support for teachers of mathematics as they are on their own unique learning journeys and will need to “develop, refresh or build on different elements of their mathematics specific knowledge at different times” (p.6).

In summary, the teachers in this study have entered the teaching profession in England at a time of change following the implementation of a new National Curriculum in

2014 and an evolving emphasis on mastery ideas in the teaching of mathematics. The continuing varied provision for teacher learning and development in mathematics in schools nationally could be expected to be mirrored in the provision available to teachers in the study.

2.8 Literature review summary and theoretical framework

The three theoretical frameworks of Millett and Bibby (2004), Wenger (1998) and Goos (2013, 2014) all seek to understand why and how some teachers/professionals change their practice to a greater extent than others. Whilst space has not permitted extensive reviews of the frameworks, aspects of each that seem to be of most significance in relation to my study have been outlined. The national context within which my participants are teaching differs from the external influences in Millett and Bibby's model, but the notion of a teacher's learning and development taking place within the situation of their professional community and ZoE is particularly useful to consider in relation to the differing school based situations of my participants. From the broad theoretical framework of Wenger (1998) and Lave and Wenger (1991), the focus on the learning and development of the newcomer to a landscape of CoPs is particularly relevant. Moreover, the Zone Theory of Goos highlights the importance of how the individual teacher might develop their practice by acting on promoted actions for their learning and development within what is perceived as permissible in their school contexts. All agree that teacher change is impacted by a combination of social and organisational factors related to their school context and personal factors related to the teacher themselves.

The personal subject knowledge informing a teachers' practice is made up of a teachers' own mathematical proficiency (Kilpatrick *et al*., 2001), alongside wider subject knowledge needed to actually teach the subject effectively. This includes pedagogical content knowledge (Shulman 1986, 1987), specialised content knowledge that is specific to teachers (Ball, Thames and Phelps, 2008) and knowledge about connections within and between areas of mathematics (Askew *et al.*, 1997; Rowland *et* *al.*, 2008). A teacher's pedagogical choices and strategies are also influenced by deeply rooted beliefs related to the learning and teaching of mathematics (Rowland et al., 2008; Simon, Millett and Askew, 2004). These include interrelated beliefs around the nature of mathematics itself (Ernest, 1989; Askew *et al.*, 2007), the nature of understanding of the subject (Bryan *et al.,* 2007; Cai and Wang, 2010) and the best way to teach mathematics in order to secure the learning regarded as necessary for mathematical proficiency (Askew, 1999). A teacher's beliefs are informed by their subject knowledge for teaching and are related to their experiences as a learner (Di Martino and Zan, 2010; Cai and Wang, 2010). A teacher also enters the profession with attitudes and emotions towards mathematics, which combine with their subject knowledge and beliefs to impact on their practice, their confidence and their motivation. This includes their self-efficacy as a teacher of mathematics and their motivation to further develop their practice (Bibby, 2002; Morris, Usher and Chen, 2017; Bandura, 1997; Eraut, 2004; Spillman, 1999).

Reflection on practice is an essential driver of teacher learning and development (Llinares and Krainer, 2006), carried out by individuals to inform their own personal practice through reflection in and on action (Schön, 1995; Korthagen, 2010; Gore and Zeichner, 1991) and enhanced by discussion and reflection in a collaborative environment (Johnson, Hodgen and Adhami, 2004; Eraut 2004; Wenger, 1998). Teachers work within a range of social and organisational structures (Levine 2010) and the school provides a community within which new teachers can learn with and alongside more experienced colleagues (Wenger, 1998; Lave and Wenger, 1991).

To provide a clear theoretical background to my research, the framework in Figure 2-3 represents a synthesis of the literature reviewed. This model highlights the main influences on the teacher of mathematics and connections between them.

The characteristics of the teacher themselves, their learning and development through their reflection on practice and their learning and development through the influence of the school context combine to influence their evolving practice.

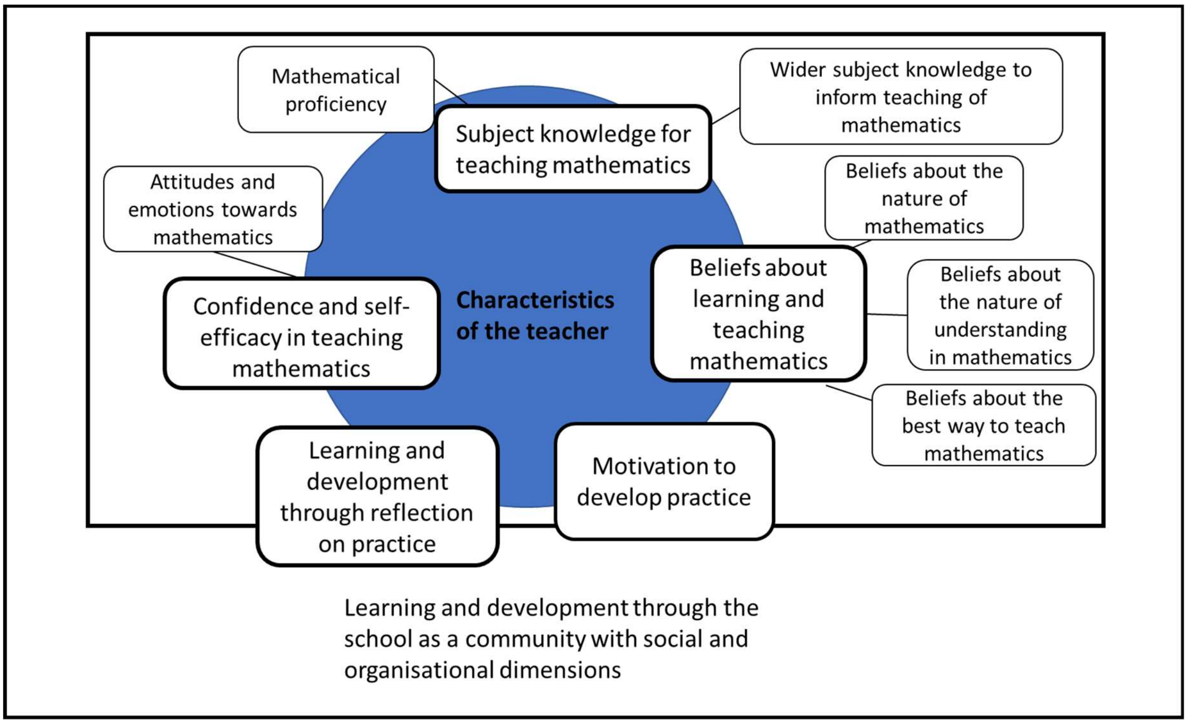


Figure 2-3 Theoretical framework: a model of the interacting influences on early career primary teachers' teaching of mathematics.

To conclude this chapter, I return to my research questions to discuss my potential contributions to knowledge and the implications of these in the light of the literature reviewed in this chapter.

> Main research question: How do factors related to the teacher themselves and factors related to the school context combine to influence the evolving practice of early career primary teachers' teaching of mathematics?

As reviewed above, prior research suggests that influences on the evolving practice of a teacher of mathematics relate to their individual characteristics. This includes the interrelated aspects of subject knowledge, their beliefs about the learning and teaching of mathematics, their emotions and attitudes towards mathematics, and their confidence and motivation. Learning and development can take place through the teacher's individual reflection on practice and through wider discussion, reflection and change within the wider school context. There are suggestions in the literature that a limited amount of teaching experience might impact on some of the factors, but there is scope for further research with early career teachers to enhance this understanding.

The detailed narratives from my research should provide deep personal insights into the relative importance of these factors and how they interrelate for early career primary teachers of mathematics.

Sub-questions:

> How do early career primary teachers perceive the influences on them as teachers of mathematics?

My research seeks to pay particular attention to the perspectives of early career teachers on how influences impact on their evolving practice. Whilst other researchers have noted teachers' perspectives on specific aspects of their practice, my study seeks to extend research into teachers' perspectives on the interacting nature of these influences on their evolving practice over a full two year period.

> How does the evolving practice of mathematics specialists compare with non-specialists?

Whilst the literature suggests a teacher's background impacts on their practice, my study seeks to understand this more fully by exploring and comparing the perspectives of early career primary teachers with strong mathematical backgrounds with those having the minimum required mathematics qualification.

> Does my data align with the views expressed in existing literature? Where does my analysis extend understanding and have any contradictions emerged?

In the discussion chapter of the thesis I will analyse my findings in the light of the literature reviewed and the theoretical model developed from the existing research. This will enable me to ascertain the alignment of my data with previous research and my contributions to knowledge in this field. These research questions are also applicable to the methodological literature discussed in Chapter 3 and these contributions will be discussed in the conclusion chapter.

What implications do the findings of my research have for ITE providers, policy makers and advisory bodies, and the research community?

Whilst the literature relating to current policy and practice in England in relation to teacher development reviewed in 2.8 provides a general background to the current situation, the outcomes of my study will enhance this with personal narratives relating to the actual practice of individual early career teachers. These will provide examples of the current provision for their continuing professional development and the perspectives of the teachers themselves on the impact of such provision. I will seek to extend the literature by suggesting ways in which these stakeholders might further support early career teachers of primary mathematics.

3 Methodology

3.1 Introduction

In this chapter I describe my methodology, explaining how I worked, what decisions I made, how I used the relevant literature to inform my approaches and how I sought to innovatively adapt my approaches to data collection and analysis to enhance a methodology designed to be fit for purpose and ethically secure.

After detailing my researcher worldview and theoretical perspectives, I set out my research design including my data collection techniques, and my approaches to data analysis. While ethical considerations were an integral part of the study and hence ethical matters and decisions are addressed throughout the methodology, the final section of the chapter draws these together to present a full overview of ethical considerations.

3.2 Researcher worldview and theoretical perspectives

Bryman's (2012) model of influences on social research highlights the importance of the epistemological and ontological perspectives of the researcher. Whilst some social scientists seek to adopt an objectivist position, considering social phenomena and their meanings as external factors "independent of social actors" (Bryman, 2012, p.33), it would be difficult to conceptualise my study in these terms. Along with many current social researchers, in my study I make no ontological assumptions that knowledge relates to general, scientifically applied principles (Thomas, 2011). Rather than trying to identify objective truth, I am researching people and their evolving perspectives. Hence this study requires a longitudinal approach and the seeking of subjective knowledge that is socially constructed. The voice of the teacher is particularly important in my research as this will enable me to understand their attitudes, beliefs and emotions around the teaching of mathematics and will give me a perspective on their choices and decisions when planning and teaching mathematics lessons.

Knowledge in this sense has to be seen as “personal, subjective and unique” (Cohen, Manion and Morrison, 2007, p.7) and as such not quantifiable in any meaningful sense.

An interpretivist epistemological position, focusing on the interpretation of actions and the social world by accessing the thinking of participants (Bryman, 2012), neatly fits my study. I am not seeking to measure or quantify the performance of teachers, but to gain access to their thinking, their perspectives and their commentary on their evolving practice. The real world of the teacher is complex and formed of multi-relationships. A teacher’s perceptions are therefore not formed in isolation but are inevitably impacted on to some extent by the contexts within which they work. To put it another way, behaviour is always situated (Barker, 1965). This in itself is a fascinating aspect of a teacher’s evolving practice - an aspect to be explored rather than side-lined in this study.

The worldview of the researcher with their epistemological and ontological assumptions inevitably has an impact on the way they view the relationship between theory and research and hence their methodology and research tools (Cohen, Manion and Morrison 2007). However, the notion of theory is a complex issue and the term is used in the literature in different ways (Thomas, 2009).

For interpretivist social studies such as this one, where researchers may be looking for “illustration rather than proof” (Cohen, Manion and Morrison, 2007, p.12), Thomas’s (2011) use of the term “an explanatory model” of the subject being researched is a helpful view of theory (p.112). Silverman (2011) elaborates that such models “provide an overall framework for how we look at reality” (p.470). A model tells us the nature and status of knowledge, what reality is like in this context and what factors it contains. Gaining such knowledge involves searching for patterns and finding links between ideas that emerge from the data, connecting these with relevant literature and seeking to explain the findings (Thomas 2011). As such, as Burton, Brundrett and Jones (2014) explain, in qualitative studies, theory building might be perceived as an “ever developing entity” (p.53).

Although I aim to identify what influences a teacher's evolving practice in teaching mathematics and to develop a theoretical model of how these influences interact, I am not looking for proofs or laws but rather to gain a deep understanding of these influences, acknowledging that each participant has their own value position (Thomas, 2009), their own perspectives and their own interpretations of any questions asked of them. By taking a holistic view of the narratives of my participants (Thomas, 2011; Kumar, 2014), I am seeking to provide examples of "compelling description of the human world" (Kvale and Brinkmann, 2009, p.47). As O'Leary (2017) states: "People are complex, their social systems are complex, their morals and values and where they come from are complex" (p.7). The role of the researcher in studies such as mine is to try to understand this complexity.

My study therefore sits within an interpretivist approach and a generally inductive orientation in the role of theory in relation to research (Bryman, 2012). Whilst I have sought to compare the findings from my research with themes from my reading, my study is not deductive in the sense of testing a fixed theory or a predetermined conceptual framework (Thomas, 2009; Burton, Brundrett and Jones 2014; Pedder, 2015). I have been open minded in relation to ideas emerging from my data and sought to use an informed inductive approach to my analysis (Pedder, 2015). As someone who has taught mathematics for a number of years in primary schools and has been a primary mathematics consultant and university lecturer, my interpretation is inevitably coloured by my history, my educational philosophy and values, and my understanding of the relevant literature (Pedder, 2015). However, I have aimed to present a faithful representation of the views of my subjects, and to minimise the biases I have brought to the study by ensuring my analysis is thorough and based securely in the evidence collected.

This study involves qualitative research, analysing the subjective meanings of "issues, events and practices" (Flick, 2018, p.604) and seeking to understand these phenomena in "context-specific settings" using words and images (Golafshani, 2003, p.600; O'Leary, 2017). The adaptability of qualitative methods when researching the "multiple realities" of school based interpretative study (Lincoln and Guba, 1985, p.40) is a particular advantage over statistical based quantitative approaches. Bogdan and Biklen's (2007) assertion that the qualitative approach should assume that "nothing is trivial, that everything has the potential of being a clue that might unlock a more comprehensive understanding" (p.5) has encouraged me both to consider the potential of all aspects of the data collected and to think about my study as an investigation, a building of theory using the clues available to me.

3.3 Research Design

3.3.1 *Introduction*

Having considered my worldview and understanding of theory building in relation to the study, this section focuses on the research design, the means of achieving the goal of my research (Flick, 2018). This needs to be appropriate for answering the research questions, ethically sound and fit for purpose. My use of a qualitative longitudinal approach, and the specific research tools I adapted, inevitably drew on my epistemological and ontological assumptions as I focused on collecting data to build my understanding in relation to the research questions:

How do factors related to the teacher themselves and factors related to the school context combine to influence the evolving practice of early career primary teachers' teaching of mathematics?

Sub-questions:

- How do early career primary teachers perceive the influences on them as teachers of mathematics?
- How does the evolving practice of mathematics specialists compare with non-specialists?
- Does my data align with the views expressed in existing literature? Where does my analysis extend understanding and have any contradictions emerged?

- What implications do the findings of my research have for ITE providers, policy makers and advisory bodies, and the research community?

In this section I justify the use of a longitudinal study, set out the practicalities of carrying out this approach for my project and outline the methods used. I then consider how the data collection evolved over the course of the study to enable me to deepen the quality of the data and keep participants, who had already been interviewed several times, positively engaged.

3.3.2 *Longitudinal qualitative research approach*

A longitudinal approach involves studying individuals or a group over an extended time period, collecting data on a number of occasions (Menard, 2008; Bryman, 2012). This approach supports understanding of transitions between statuses or situations, illuminates how people cope, manage or adapt to change over time and can identify patterns of trajectory (Millar, 2007). The approach can also help identify the causes, mechanisms and long-term effects of change (Stevens, 2018) and examination of "critical moments", as discussed by Thomson *et al.* (2002, p.339). These points are highly relevant to my research. A longitudinal approach permits the study of the participants' perspectives of changes and developments in their teaching of mathematics over time and indeed changes in these perspectives. Thus, a greater depth of understanding in relation to the research questions is possible than from a single data collection point, or from different individuals at different points in time.

In setting up the context for my research, my study also includes an element of life history, a method emphasising "the inner experience of individuals and its connections with changing events and phases throughout the life course" (Bryman, 2012, p.712). Participants outlined for me the history of their relationship with mathematics to enable me to gain an increased perspective of the mathematics backgrounds upon which they built as teachers of mathematics.

The longitudinal and life history qualities of the study require caution. As Cohen, Manion and Morrison (2007) highlight, such studies rely on participants' memories, which vary in accuracy and depth of detail, and their reflection on past events "through the lens of hindsight" (p.215). However, "essentially the validity of any life history lies in its ability to represent the informant's subjective reality," (p.200) and this is appropriate in my context. These approaches allow participants to talk about what is or has been particularly important or significant in their life experiences (Smith, 2011) in terms of their mathematical history prior to the study and their progress as a teacher of mathematics during the study.

Participation in longitudinal studies has been found to affect the ongoing behaviour of participants. My awareness of this "panel conditioning effect" (Bryman, 2012, p.65) enables investigation of this effect to be part of the study, rather than being considered a limitation.

3.3.3 *Pilot study*

Bearing in mind advice that pilot studies enable effective planning of research methods and procedures, allowing reflection and subsequent modification before embarking on a main study (Kumar, 2014), I set up a pilot study with participants chosen on the same basis as those for the main study. I asked four pilot participants to be involved for a year, involving three data collection points. This pilot process was very useful, enabling me to streamline my research methods whilst I was growing in confidence and gaining experience as a researcher. I will refer to the adaptations made in the data collection sections of this chapter.

The pilot stage was also very effective in terms of the quality of the data collected, to the extent that I invited the pilot participants to continue for a further two data collection points and become the first of two cohorts in the study.

3.3.4 *The participants*

I selected four participants for the pilot study (Cohort 1) and six for Cohort 2, from consecutive years of the University of Leicester PGCE course. As a course tutor I had worked with all the participants prior to the study. The number of participants recruited was deliberately larger than anticipated to be required to allow for attrition, an inevitable risk of a longitudinal study, with participants potentially withdrawing through choice or circumstance (Hermanowicz, 2013; Bryman, 2012). My sampling was purposive, allowing the selection of participants with specific characteristics relevant to my research questions (Thomas, 2009). Half of the participants had studied mathematics beyond GCSE and opted to take the mathematics specialism as part of the PGCE course; the others had not. The mathematics specialists for Cohort 2 had been recruited to the new Primary with Mathematics PGCE. In terms of practicalities, my participants needed to have secured teaching jobs locally. I also decided to only invite to take part those who had completed the PGCE at a high grade of teaching competence, as assessed against the National Teachers' Standards (2011), so that I could focus on their mathematics specific teaching in the confidence that they could plan, organise and manage a class without difficulty.

All those I invited to participate agreed to do so and met with me at the end of their PGCE year for the first data collection point. However, two of the participants from Cohort 2 subsequently withdrew because the headteachers who then employed them did not grant further access. Data from these two participants, who were not mathematics specialists, was destroyed. Having chosen a sample size to allow for attrition, eight participants provided more than sufficient data for the scope of the study. However, with two non-specialists withdrawing, the range of participants became slightly more restricted and five out of eight of the remaining participants were mathematics specialists. The participants were all employed in different schools.

Table 3-1 provides a summary of the participants, who between them cover a range of mathematical backgrounds. All names are pseudonyms reflecting the gender and ethnicity of the participants. The participants are introduced fully in Chapter 4.

Cohort 1 (Completed PGCE course June 2015)	**Mathematics specialism on PGCE course**	**Highest mathematical qualification and mathematics related professional work prior to teaching**
Rahma	Yes	A level
Gina	No	GCSE
Penny	Yes	Master's degree, employment in the credit and risk department of a building society
Emily	No	GCSE

Cohort 2 (Completed PGCE course June 2016)	**Mathematics specialism on PGCE course (Primary with Mathematics PGCE)**	**Highest mathematical qualification and mathematics related professional work prior to teaching**
Orna	Yes	Degree
Chloe	Yes	Joint honours degree including mathematics, employment as events project manager
Evie	Yes	A level
Rakesh	No	GCSE

Table 3-1 The participants

3.3.5 *Time frame of data collection*

One of the key decisions in a longitudinal study is to decide on the number and frequency of data collection points (Hermanowicz, 2013; Bryman, 2012). Hermanowicz (2013) suggests that these should depend on the research question and the amount of time necessary to be able to examine changes between points. When designing my study, I considered that a frequency of twice yearly would be likely to maximise the quality of the data. This would give me a number of opportunities to trace participants' perceptions of their evolving practice and the influences on this over time. It would also allow sufficient time to have elapsed between meetings that they would have taught many mathematics lessons and possibly been involved in some type of learning and development opportunities themselves. By making self-imposed changes through their own proactivity and reflection on practice and implementing suggested changes, I considered that within a half yearly span the participants' teaching of mathematics was likely to have evolved, or they would be able to reason why it had not. I also considered the demands I put on the participants and thought that twice yearly meetings would not greatly inconvenience them. My research questions were formed to be investigated within the time span of a PhD, so whilst a three or four year study might have increased the quality of the data even further, I decided on a one year pilot study during which I would assess this frequency pattern, followed by a two year main study. The pilot year did indeed confirm that the frequency was appropriate in meeting the expectations outlined above and, within the time span available, five data collection points were used for each of the eight participants, as set out in Table 3-2.

Data Collection point	**Timing of data collection**
Meeting 1	During or soon after the final week of the ITE course (June)
Meeting 2	Approximately halfway through the first year as a qualified teacher (January/February)
Meeting 3	Near the end of the first year as a qualified teacher (June/July)
Meeting 4	Approximately halfway through the second year as a qualified teacher (January/February)
Meeting 5	Near the end of the second year as a qualified teacher (June/July)

Table 3-2 Data collection points

I also needed to consider where I would meet with participants and how I would arrange meetings, noting Ball's (1993) point that participants tend to present themselves differently depending on the setting. The first meeting for each participant took place at the University of Leicester. Once the participants were working in schools, I considered that they would probably be more relaxed, less inconvenienced and have easy access to documentation they might want to discuss, such as children's books, if I met with each one in their own school. I arranged this, requesting that a quiet area be used so that interruptions were avoided. I contacted participants well in advance of each meeting to arrange a mutually convenient time. In planning each meeting, I aimed to include content that could be covered in 45-55 minutes and so requested an hour of the participant's time.

3.3.6 ***Data collection***

To inform my choice of research tools, I explored both generic interpretivist literature and literature related to how other researchers in my area explored similar themes.

3.3.6.1 ***Approaches used by other researchers in this area***

Those exploring attitudes, beliefs and values have generally employed an interpretative approach with qualitative interview techniques, although the style of interview varies. Cai (2007) and Cai and Wang (2010), for example, used structured interviews and Brown (2005) used an unstructured approach. Others have used scaffolds: Di Martino and Zan (2010), for example, investigated secondary school students' attitudes to mathematics through narrative, with students asked to write an essay entitled "Me and maths". Lewis (2013), in his work with disaffected teenagers, developed a chart with axes showing time in school years against relationship with mathematics. The completion of a chart by each teenager as part of their semi-structured interview was an effective way of stimulating talk and gave a simple, but useful, visual life history (Figure 3-1).

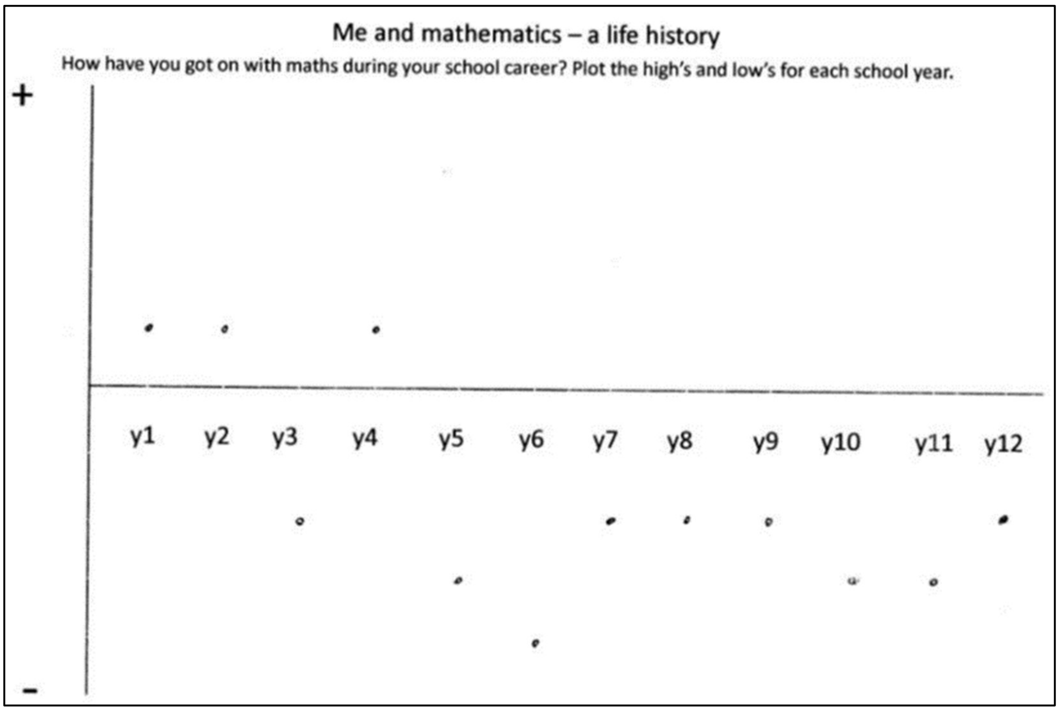


Figure 3-1 Life history graph (Lewis, 2013, p.111)

Literature relating to the evaluation of the impact of subject knowledge on the teaching of mathematics also suggests a range of possible tools. Barwell (2013), from his perspective of discursive psychology, considers lesson observation vital and this was used by Ball, Thames and Phelps (2008) to explore categories of subject knowledge and Rowland *et al.* (2008) as they developed the Knowledge Quartet. Other researchers look elsewhere, analysing other stages of the teaching process, including planning and reflection (Kahan, Cooper and Bethea, 2003; Prescott, Bausch and Bruder, 2013) and the construction of concept maps (Askew *et al.,* 1997). As part of her research on teachers' developing expertise in enquiry in mathematics, Makar (2014) sought teachers' perspectives on their progress by asking 'What has been your best lesson and why?' and 'What has been your worst lesson and why?'. Other researchers have used quantitative testing of both teachers and pupils to link subject knowledge to pupil progress (Baumert *et al.*, 2010; Lim-Teo *et al.*, 2007).

Samková and Hošpensová (2015) used concept cartoons, originally created in the early 1990s by Keogh and Naylor for use in science classrooms (Naylor, 2015), to research pre-service teachers' subject knowledge. Keogh and Naylor's strategy involved presenting children with cartoon pictures where speech bubbles from characters gave various alternative viewpoints about a scientific concept. The aim was to generate critical and constructive discussion which elicited and challenged children's thinking about, and understanding of, scientific concepts. Samková and Hošpensová (2015) adapted this idea, using concept cartoons to present contingent situations, of the type described by Rowland *et al*., (2008), to pre-service teachers for them to analyse and discuss in order to investigate their subject knowledge. The alternative 'children's' responses presented in the concept cartoon allowed participants to consider a range of responses, including some that they might not have considered in a real-life context.

Samková and Hošpensová's (2015) and Lewis's (2013) data collection strategies are examples of participatory visual techniques. Further reading highlighted the benefits of such techniques in providing additional and complementary data to verbally answered interview questions (e.g. Niemi, Kumpulainen, & Lipponen, 2015; O'Kane, 2000; Wall *et al*., 2013). They can add breadth and depth, facilitating deeper thinking and assisting participants to reveal additional information, views and emotions that may not have been revealed though verbal questioning alone. Davidson *et al.* (2009) describe such data as "visual quotes of participants' experience" (p.13).

'Participant generated' visual data, classified by Prosser (2007) and subsequently Wall *et al.* (2013) as data which is generated by participants during the data collection process, can be particularly empowering, giving participants a greater voice in the research process and allowing them more control over the content of the discussions (O'Kane, 2000). It can also be motivating and fun for the participants (Wall *et al.*, 2013), a particular consideration when participants are involved in a longitudinal series of interviews.

A range of tool designs have been used in educational research for participant generated visual data collection. In addition to those discussed above, other researchers have used the structured visual tools 'Diamond Ranking' and 'Q-sorting' approaches which facilitate both qualitative and quantitative analysis of subjective opinions and ideas. Diamond Ranking is a technique that can be used within interviews to explore the participant's perceptions or ideas, as they rank images or statements within a nine section, diamond-shaped structure (Wall *et al.*, 2013) (Figure 3-2).

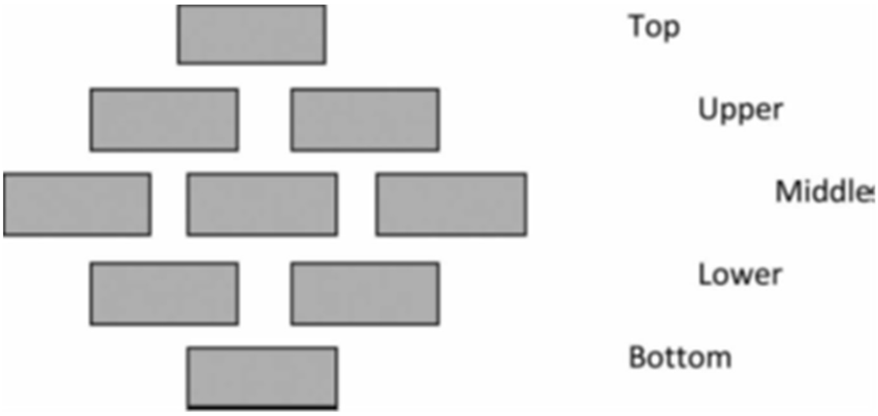


Figure 3-2 Diamond ranking (Wall et al., 2013, p.6)

Usually the activity of ranking these is accompanied by the participant talking through their rationale for how they placed the items within the diamond structure and the sorting exercise acts as a stimulus for discussion. Niemi, Kumpulainen and Lipponen (2015), for example, used diamond ranking with primary aged pupils, asking them to rank photographs of various classroom experiences according to their preferences for each style of activity. The participants had to articulate their reasoning for their positioning of ideas on the template which made clear their understanding of the relationships between these. Diamond ranking when used identically with more than one participant can be analysed quantitatively and thus statistical comparisons can be made between participants.

Q-sorting similarly involves the sorting of statements into a defined template and can be analysed using both quantitative and qualitative analysis (Demir, 2016) (Figure 3-3). In particular it offers an in-depth and systematic approach to analysing subjectivity through rigorous design and analysis (Thomas and Watson, 2002).

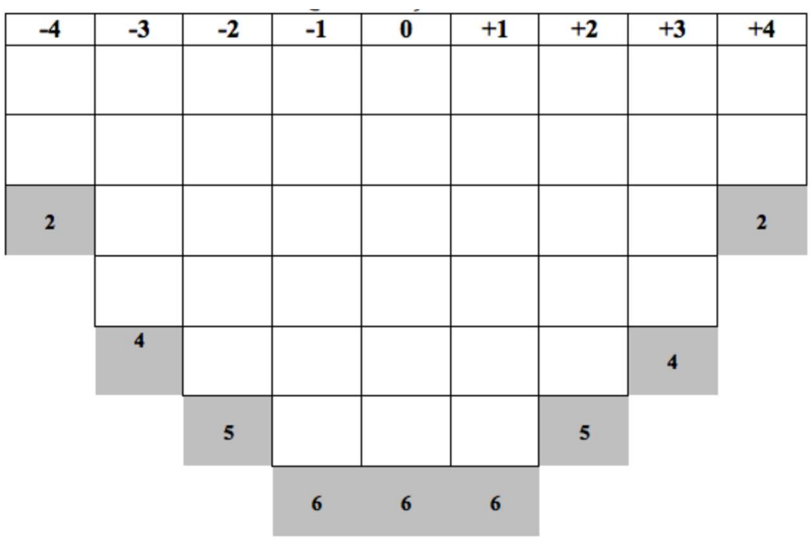


Figure 3-3 Q-Sort Template (Demir, 2016, p.298)

Although the literature reviewed suggests visual techniques can be very valuable to the researcher, the quality of data is dependent on the quality of the facilitation and how the data relates to other data being collected (Wall *et al.*, 2013). O'Kane (2000) also warns that with participants more in control of the direction of the discussions, these may become limited in scope to those areas the participant finds significant and is willing to discuss.

3.3.6.2 *Rationalising the use of interviews as the main form of data collection*

It is not a simple case that certain data collection methods fit certain research approaches, but rather the researcher's methods and the way these are used are a natural extension of their research orientation and their specific research questions. Although it would have been interesting to observe my participants teach and this could have provided some additional evidence of their evolving practice, I rejected data collection by observing lessons on the basis of maximising my research time for hearing my participants' views on how their practice was evolving and what was influencing this. Also, as my research questions focus on the participants' perspectives, I was not seeking to make any judgements about the quality of their teaching myself. However, I did draw on some of the other approaches outlined above in my research design, recognising that my choices of methods were also impacted by my values (Bryman, 2012) and my decision to adopt a longitudinal qualitative approach.

My specific interest in the perspectives of the participants led me to a choice of semi-structured interviews as the basis for each data collection meeting with my participants. An interview, as a form of purposeful conversation usually conducted between two people and directed by one of these to gain information from the other, is a very common method of collecting data in qualitative research (Bogdan and Biklen, 2007). Whilst interviews provide the opportunity for a conversation specific to the topic the researcher is interested in, with the interviewer setting the content of the questions and their order (Flick, 2018), they also provide insights into what the interviewee considers important and relevant within that topic (Bryman, 2012). In social studies they are used to investigate human experience and understand this from the point of view of the subject, allowing them to describe their situations and perspectives in their own words (Kvale, 2006). Kvale and Brinkmann (2009) suggest that an epistemological approach of knowledge construction leads to an interviewer acting like a “traveller” exploring a landscape, asking questions and engaging in conversations with the inhabitants, seeking to construct knowledge as they explore (p.48). Such an interviewer is likely to be reflecting during the course of the interview so that interviewing and analysis are “intertwined phases of knowledge construction” (p.49). A semi-structured interview, where the interviewer has a prepared interview guide but the flexibility to digress from this if they feel it is advantageous to do so (Bryman, 2012), seems a useful starting point for such an approach.

Although interviews are widely employed in qualitative research, this approach is not without criticism. The information gained comes with caveats; interviews provide indirect representations of people’s experiences rather than direct information about the experiences themselves (Silverman, 2011), interviewees will only say what they are prepared to reveal and may have “incomplete knowledge and faulty memory” (Walford, 2007, p.147) and they may also not actually say what they mean (Hitchcock and Hughes, 1995).

As my study was heavily dependent on obtaining high quality data from interviews, I needed to ensure that my meetings with participants were fit for purpose. Validity and reliability in qualitative research need to be considered differently from their usual meaning in quantitative studies (Thomas, 2011; Golafshani, 2003), so I followed Cresswell and Miller (2000) and Bogdan and Biklen (2007) in focusing on credibility and a secure fit between what actually took place in meetings and what was recorded as data. This is in agreement with Lincoln and Guba (1985) who suggest that trustworthiness is a good criterion of the quality of a qualitative study. I therefore strove to carry out the meetings with integrity, comprehensiveness and attention to ethical considerations to ensure credibility, authenticity and trustworthiness.

There is extensive coverage in the literature about the importance of the relationship established between the interviewer and their interviewee. “The interview is a complete piece of social interaction” (Hitchcock and Hughes, 1995, p.164) and hence the social dynamics of interviewing are significant. Hitchcock and Hughes highlight that this relationship is shaped by “the knowledge each has of the other” (p.167), including the degree of friendship and the relative status. Kvale (2006) specifically highlights the importance of recognising the power dynamics within an interview and Bogdan and Biklen (2007) suggest that to interview subjects “you are likely to be seen not just as a researcher” (p.94). This was very relevant to my study where the participants knew me as a tutor on their ITE course and might continue to meet me in professional contexts. I therefore paid particular attention to creating a relaxed and open atmosphere when I met with my participants, treating them as experts (Bogdan and Biklen, 2007), and emphasised particularly at their first two meetings that my role was purely as a researcher. To give the participants confidence and have a motivating effect, I sought to keep interviews positive and focused on their strengths (Cooper and McIntyre, 1996; Brown and McIntyre, 1993). I used two devices to record each meeting so that the participants were not distracted or slowed down by note taking and I could be fully attentive. By keeping my questions clear and open, remembering and reflecting during the interviews and using probing strategies (Kvale and Brinkmann, 2009; Pedder, 2015; Ball, 1993), I sought to minimise bias and achieve high validity (Cohen, Manion and Morrison, 2007). Whilst recognising that an interview is an unusual situation and is not a typical conversation (Bogdan and Biklen, 2007; Hitchcock and Hughes, 1995), I aimed for interviews to be collaborative and informal (Cooper and McIntyre, 1996). I emailed participants in advance to let them know the main themes of each meeting, so that they could reflect on their practice in advance and hence be less likely to feel any stress in the meeting and be more likely to speak in depth and detail.

In addition to the interview, each meeting also involved the sharing of documentation which gave evidence to support the participants' discussion in the interviews. Because each session was not simply a verbal interview, I refer generally to the times I met with participants as 'meetings'.

3.3.6.3 ***Meeting format***

In longitudinal qualitative studies, two approaches to structuring interviews are generally used, firstly repeating the same questions on the same themes in each interview, mirroring longitudinal quantitative designs, and secondly using different questions on the same themes and including questions on newly emerging themes (Hermanowicz, 2013). As can be seen in Appendix 2, which provides the meeting schedules, I used both approaches and the content of meetings included both some identical questions and other topics of discussion which evolved in format and emphasis.

Meeting 1, at the end of their ITE course, focused on each of the eight participants' relationship with, and attitude to, mathematics and their progress in teaching the subject as a pre-service teacher. To build my understanding of their background as a mathematician, I asked each participant to sketch a graphical representation of their relationship with mathematics from as far back as they could remember, as they narrated, using a similar style of chart to Lewis (2013). Further questions were designed to probe the participants' beliefs, attitudes and subject knowledge for teaching mathematics, their perceptions of the characteristics of effective teachers of mathematics and effective learning of the subject and their perspectives on their development as pre-service teachers of mathematics.

Adapting Makar’s (2014) approach, within each meeting (other than the first meeting for Cohort 1) participants talked about planning and teaching two particular lessons: their chosen ‘best’ and ‘most challenging’ mathematics lessons since the previous interview. I used the word ‘challenging’ rather than ‘worst’ to avoid any assumptions that they had taught badly; rather I was interested to hear about what they found difficult to teach. I only asked Cohort 1 about their ‘best’ lesson at Meeting 1, in my concern to keep the interview positive, but reflected that talking about a ‘challenging’ lesson should not cause distress, especially as the participants would have chosen this lesson themselves.

In advance of their first meeting I asked participants to choose these lessons from their final placement as a pre-service teacher and, from this first meeting, they knew that this would be part of every meeting. Participants generally came very well prepared to talk about these lessons and explained why they had chosen them. They brought copies of lesson plans and examples of children’s work to share with me as they described the lessons. This strategy provided insights on a range of aspects of their subject knowledge, changes in their practice and their ideas about effective teaching.

I started Meetings 2 to 5 by asking participants to talk about the setting in which they were teaching: the year group/set they were teaching, whether they planned lessons with others, what schemes/resources they used etc. Although such “conditions” are usually established in initial “base round” interviews (Hermanowicz, 2013, p.198), this was important in each meeting in this study because of changes that can take place in school contexts.

In addition to asking each time about their best and most challenging lessons, I consistently asked participants how their teaching of mathematics had developed, with a follow up question as to what had influenced this. I also asked about their professional development opportunities since my previous visit. Meetings 3 and 5 included asking participants to talk about their relationship with mathematics as a teacher of mathematics over the past year, again drawing a graph of this relationship, and I sought each time to gather their views on the characteristics of effective teachers. I also asked whether they had supported other teachers in their teaching of mathematics and what they felt their next steps for their development were. Documentation participants brought to meetings to supplement their interview responses included written lesson observation feedback notes from school leaders, records of professional development and examples of children's work.

3.3.6.4 ***Adapting the format***

One of the benefits of longitudinal studies is that data collection and analysis can be implemented in parallel, following the tradition of grounded theory (Bryman, 2012; Glaser and Strauss, 1967). My analysis, which is discussed in detail in 3.4, was ongoing throughout the study and informed my further data collection. I also continually reflected on the quality of my interviewing, recording my thinking in my research journal, and made some changes to the schedules to further increase the depth and detail of the data. For both of these reasons the format of the meeting schedules evolved over the study.

After the first Meeting 2 interview, I decided to give control to participants of the order they answered the questions related to their two chosen lessons, their professional development and how their practice had evolved, writing these on cards so that they could see all four questions at once and decide on the order to talk about them. As these questions were interlinked, giving this control facilitated the flow of narrative, for example, a 'challenging' lesson could lead to adaptations to practice which then resulted in a 'best' lesson, hence the participants would talk about the lessons in this order. As I reflected:

> Giving the cards with the four questions on worked very well. The interviews felt more comfortable, I referred to my question sheet less and the participants had more control over how and when they shared with me. (Research Journal, 3rd February 2016)

I also sought to support the participants in their articulation of their ideas. In Meeting 1, for example, I was keen to find out my participants' views about the nature of mathematics and learning in mathematics. Echoing Cai (2007), I asked, *"In your view what is mathematics?"* and followed this up with *"Some people believe that a lot of things in mathematics must be accepted as true and remembered and there really are no explanations for them. What do you think?"* and *"Some people think mathematics is abstract and therefore we need to help children to think abstractly. What do you think?".* When analysing this data it was apparent that the Cohort 1 participants had found these follow up questions difficult to process and their answers were limited in depth. For Meeting 1 for the second Cohort I therefore created a concept cartoon using a similar approach to Samková and Hošpensová (2015) (Figure 3-4).

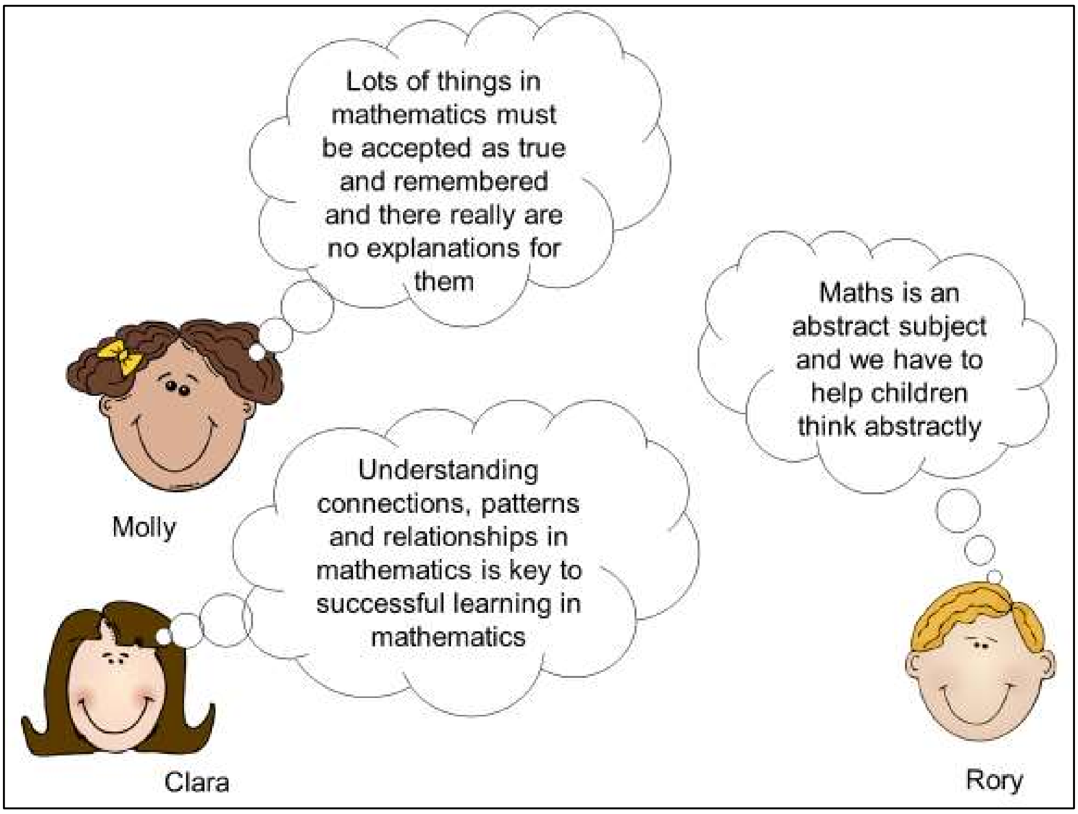


Figure 3-4 Concept cartoon used by participants in Cohort 2 to discuss their ideas about the nature of learning in mathematics.

This enabled me to visually present these questions as points of view spoken by characters and thus both support and challenge the participants' thinking, enabling them to compare the ideas and talk about the extent to which they agreed with each character. I also added an additional idea based on Askew et *al.*'s (1997) beliefs of connectionist teachers, represented as Clara's point of view. I found clear benefits of this approach:

> The concept cartoon idea worked very well and made these points much more accessible than asking them individually. The addition of the Askew idea in the cartoon was very helpful as all identified with this. The participants also linked ideas from the quotes in a coherent way. (Research Journal, 27th June 2016)

I also used a concept cartoon to enable the participants to talk about secure learning in mathematics. Again, having gained limited depth of response to my question *"How would you define effective learning of mathematics?"* with Cohort 1 participants at Meeting 2, I created a concept cartoon for Meeting 3 where I presented four ideas asking "How would you order these in terms of how they best describe secure learning in mathematics?" (Figure 3-5).

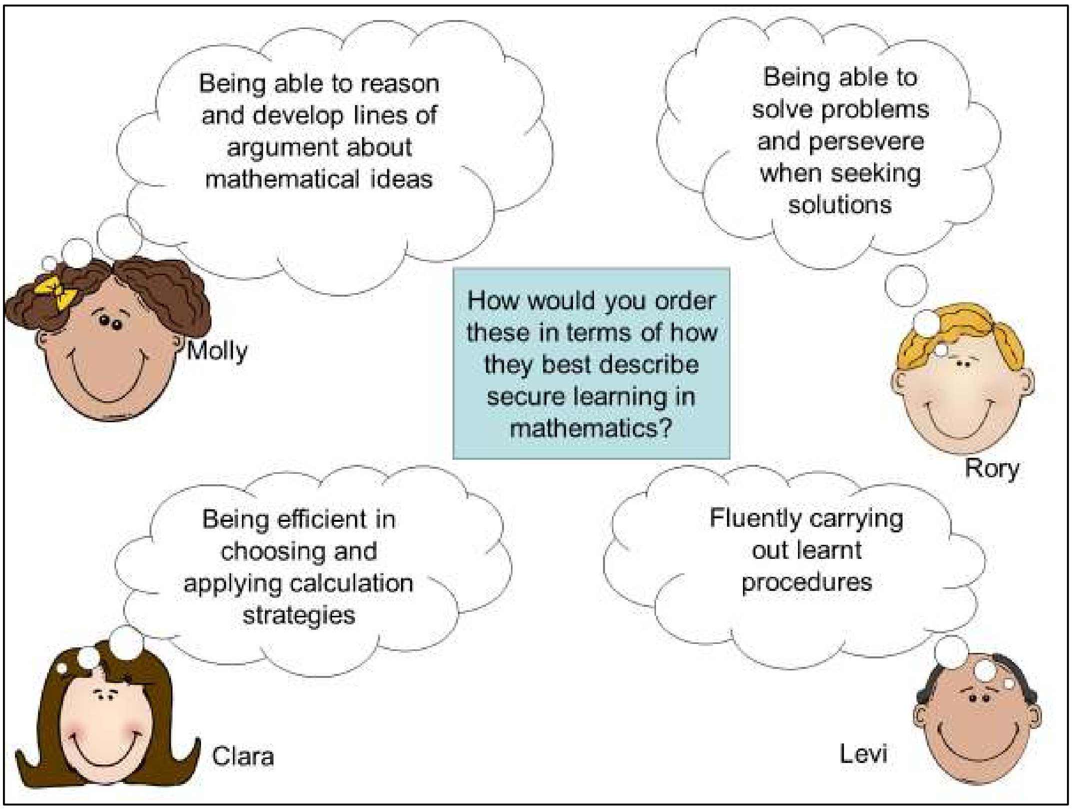


Figure 3-5 Concept cartoon used by participants in Meeting 3 to discuss their ideas about secure learning in mathematics.

For Cohort 2 I adapted my question in Meeting 2 to be more specific: *"Looking from the point of view of a child, how would you describe secure learning of a mathematical concept and how do you assess this?"*, and then used the concept cartoon in Meeting 3. In Meeting 4, to add variety and probe my participants' interpretation of the word 'mastery', I followed this thread of questioning with the question *"What do you understand by the term mastery in mathematics?".*

Another thread of questioning, one that I used throughout the series of meetings, was to seek my participants' views on the characteristics of effective teachers of mathematics. I included this question in the first round of meetings because I thought it would give the participants an opportunity to tell me about the type of teacher they wanted, with experience, to become. In reality, participants tended to talk about characteristics of their own teaching and in effect discussed strengths of their own practice.

Table 3-3, shows how I increasingly scaffolded participants' articulation of the characteristics of effective teachers to gain further insights into their thinking about this and hence about their own strengths as a teacher of mathematics.

Meeting 1	Verbal question: *"In your view what characteristics does an effective teacher of mathematics have?"*
Meeting 2	In the first interview of this round I verbally informed the participant of what she had said at Meeting 1 in response to the question above and asked her to reflect on this with the question *"In your view now what characteristics does an effective teacher of mathematics have?"* Her limited response prompted me to show all the other participants their Meeting 1 responses in written form as they answered this question, with the result of greater depth in responses.
Meeting 3	*"This time last year you said effective teachers of mathematics …….* [again, I showed the points in written form]. *Has your practice this year changed your beliefs about the characteristics of effective teachers?"*
Meeting 4	Verbal direction of an activity: *"At each of our previous interviews I have asked you about what you feel are the characteristics of effective teachers of mathematics. I have summarised your ideas on these cards. I'd like you to organise these for me on the chart with those you now feel to be most important at the centre and those less important towards the edge. I have spare pieces of card if you would like to add any further points."* *"I'd like you now to organise them according to what you feel are your strengths as a teacher of mathematics, with those characteristics you feel are your strongest at the centre."*
Meeting 5	Verbally whilst showing photographs of their charts from Meeting 4: *"At each of our previous interviews I have asked you about what you feel are the characteristics of effective teachers of mathematics and last time you arranged these on a chart for me with those you felt to be most important at the centre and those less important towards the edge. Looking at this again now, is there anything you would change or add to this?"* *"Last time you also arranged these by your current strengths. Is there anything you would change or add to this now?"*

Table 3-3 The thread of questioning about characteristics of effective teachers of mathematics

By Meeting 4 for Cohort 1, I was also aware that although I was maintaining very positive relationships with my participants, I wanted to keep the interviews fresh and interesting for them, and so was considering how I could vary my approach to obtain high quality data through a more practical, visual approach. For Meeting 4, I designed a simple chart of concentric circles for the participants to sort their previous ideas according to importance and strengths (Figure 3-6), as they verbally articulated their thinking, so that I could analyse more closely any differences between what they felt was most important and what they perceived their own strengths to be. Rather than repeat this in Meeting 5, participants reflected on a photograph of their completed chart from Meeting 4. In Meetings 2 to 5 I asked a follow up question about what had influenced their thinking, if participants had not already articulated this, as this was very relevant to my research questions.

Figure 3-6 Blank chart used for sorting of statements related to characteristics of effective teachers.

As the series of meetings progressed for Cohort 1, and I was analysing the data to date, I also looked to gain more depth of understanding of participants' perceptions of their subject knowledge and the importance of subject knowledge. To address this, for Meeting 4 for Cohort 1, I created cards relating to a range of aspects of subject knowledge from the literature review and asked participants to sort these according their strengths onto the concentric circles chart, articulating their thoughts to me as they did so (Appendix 3). Follow up questions gave me their views as to which aspects they felt they had developed most in their practice and which they felt to be most important. I decided to use the activity with Cohort 2 at their Meeting 2 and then ask these participants to reflect on a photograph of their completed activity in Meeting 4. Although Penny, the participant with the strongest mathematical background, found sorting the cards quite challenging: *"she was finding it hard to say what were her strengths were"* (Research Journal, 9th February 2017), the subject knowledge activity was useful and generally well received. Here I reflect on using the technique with Orna:

> The subject knowledge cards worked really well and she talked very eloquently about which were her strengths etc. It worked well putting them on the target board although she moved them all over to one side because she said she found it easier to think of them as a more linear progression. Not surprisingly, as a maths graduate, she put statements about pure subject knowledge in the middle. I am glad I included this question for Meeting 2 rather than leaving it for later interviews. (Research Journal, 23rd January 2017)

By Meeting 4 therefore, as well as collecting a vast quantity of verbal data, I had also used three visual techniques to support my interviewing: graphs of each participant's relationship with mathematics, concept cartoons and a concentric circle chart. A further visual tool was the use of influence maps, a tool I designed and created for Meeting 5 for Cohort 1 to draw together their ideas on what had influenced their evolving practice as teachers of primary mathematics (3.3.6.6 below). The design and use of these visual strategies was influenced by my reading about participant generated visual data.

3.3.6.5 ***Participant generated visual data***

The reported benefits from the use of visual data were ones that were attractive to me to deepen the reflective thinking of my participants and enhance the quality of data collection in my study, particularly given my focus on the participant view of their development. I felt that the motivational and interest-generating element was very relevant given the longitudinal nature of the study. I did not want the interviews to be boringly repetitive. The maintenance of positive, constructive interviews was essential and visual techniques could provide variety and interest. In building on previous data collection and adjusting the nature of the interview questions and tasks in response to my ongoing analysis, I felt an effective way to do so was by being innovative in adapting my questioning into more visual activities.

In that my study is qualitative and I am not looking to statistically compare my participants, I chose to design sorting activities using a similar approach to the ordering/ranking of 'Diamond ranking' or 'Q-sorting' but without the precise structuring. My participants' ideas about the 'characteristics of effective teachers' statements varied and I was interested in each participant's views on their own previously stated opinions. I did not want to restrict the structure too much and therefore simply asked my participants to arrange the statements on a board of concentric circles. Similarly, with the subject knowledge cards, I wanted an overview for each individual rather than a statistical comparison. I consider it likely that my participants' discussion as they carried out these activities and the opportunity I had to ask probing question to clarify choices, further deepened the thinking of each participant and therefore the quality of the data. I reflected on Rakesh's meeting:

> He talked extremely well about subject knowledge cards as he was basically evaluating himself against all the statements as he was sorting them. (Research Journal, 26th January 2017)

Wall *et al.* (2013) argue that both using the structure and the physical act of ordering the items engage participants at a deeper level than would have been likely without. This motivational aspect of participation could have been particularly strong in this 'characteristics of effective teachers' card sort as these were ideas that the participants themselves had voiced in previous interviews.

To obtain the most useful and relevant data from the visual techniques I used, I carefully considered the design of my visual tools and how I introduced them to the participants.

3.3.6.6 ***Influence maps***

For the final meeting for Cohort 1, I developed a new visual tool to assist participants in talking in greater depth and breadth about the influences on them as a teacher of mathematics and in particular to discuss the relative importance of these factors and the way the factors combined. As the study had evolved and the focus narrowed, this was to become a particularly important data source for the study.

Rather than using an open question such as *"What has influenced you as a teacher of mathematics?"* I decided to provide some prompts to ensure that participants discussed the likely influences that both the literature and the ongoing data analysis to date suggested would have an impact on their evolving practice as teachers of mathematics, even if to discount these, thus ensuring breadth in responses. I therefore made four prompt cards:

- 'My own background as a learner of mathematics and my feelings about the subject'
- 'My school context and changes within the school context – i.e. the influences that I have had from being here in this particular school'
- 'My own self-imposed changes/actions through my proactivity and reflection on practice'
- 'My beliefs about what makes a good mathematician'.

The 'background' card was aimed at participants considering their own subject knowledge, emotions and attitudes to mathematics.

The literature relating to beliefs about learning and teaching mathematics focuses on beliefs about the nature of mathematics, beliefs about the nature of understanding in mathematics and beliefs about the best way to teach mathematics (2.2.4). I decided to ask specifically about participants' 'beliefs about what makes a good mathematician' after considering that this notion could appropriately bring together these three related aspects of beliefs; I expected participants to talk about the beliefs they held regarding the type of mathematical proficiency they wanted to develop in the children they taught and the impact of this on their practice.

In order to ensure that the participants considered the relative size of these influences, and where these influences overlapped, I gave participants circles of translucent plastic in different sizes and colours and asked them to match the largest influence to the largest circle, the second largest influence to the second largest circle, and so on (Figure 3-7). They were then asked to arrange the circles to match the impact of these influences and the relationship between them, overlapping them if appropriate, and to verbalise their thinking as they did so (Figure 3-8 gives an example). Thus an interactive approach was used, with some structure given for their thinking, but without the constraints of Diamond Ranking or Q-sorting. Participants were free to create and adapt their mapping to fit their way of thinking.

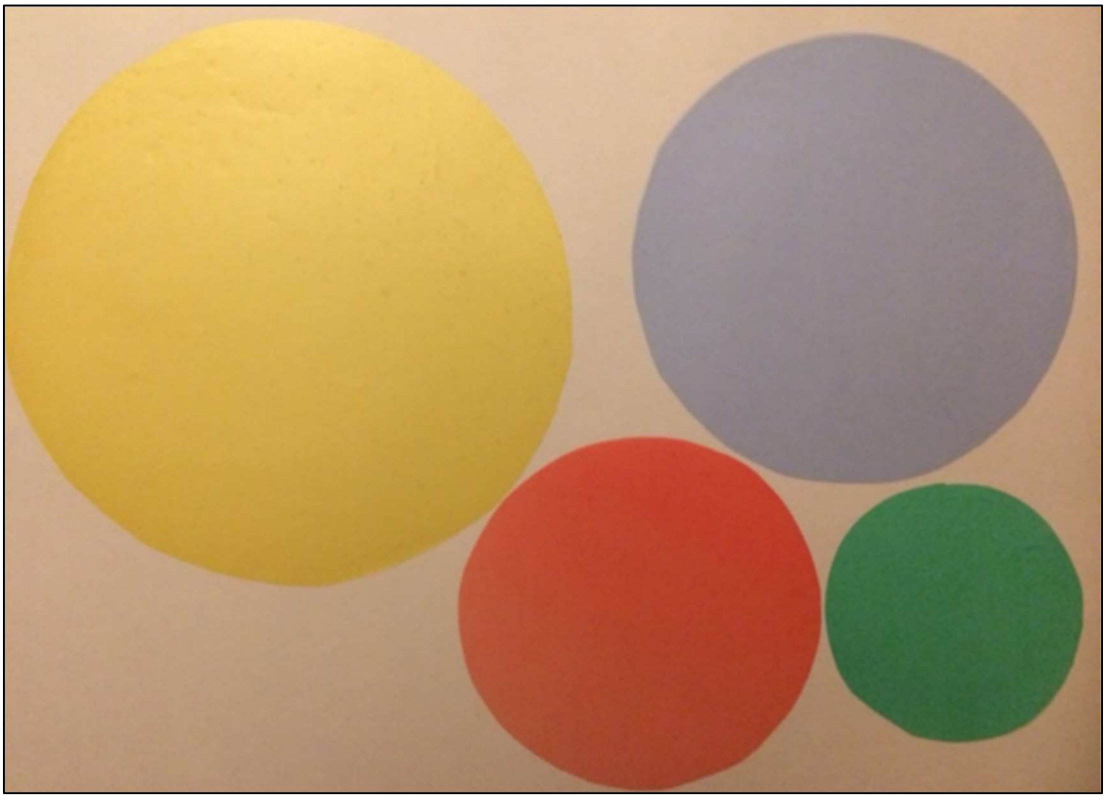


Figure 3-7 Circles of translucent plastic used to create influence maps

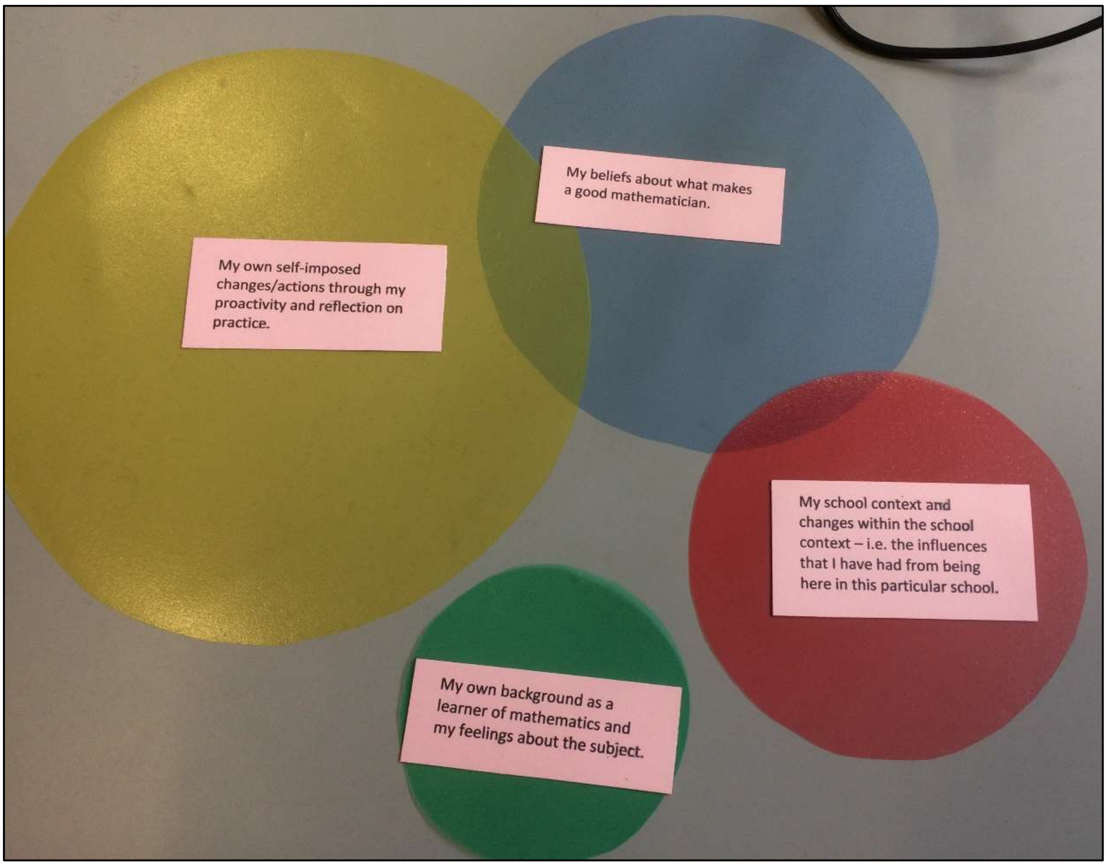


Figure 3-8 Rahma's influence map

I planned various follow up questions that could be used to further probe about the impact of these influences, for example: *"How do you think having a strong mathematics background has impacted on your teaching of the subject? Has your attitude to teaching mathematics changed? What are your beliefs about what makes a good mathematician? Have you felt well supported by your school in these first two years of teaching? How do you feel about changes imposed by your school? What motivates you to develop your own practice?"*

The design of the tool thus facilitated detailed narratives from individuals, gave them some control over the content of the discussion and allowed some visual comparison between participants. With the enhanced quality of the data being immediately apparent when using the influence maps at Meeting 5 with Cohort 1, I decided to use the approach with Cohort 2 at both Meetings 3 and 5. The control that participants took over the use of the map to express their opinions demonstrated that a benefit of using the tool was the ready engagement of participants who had already been interviewed several times. This aspect was evidenced by specific comments made by Rakesh at Meeting 3; he clearly found the process stimulating:

> *That was a really good opportunity for me to reflect on what different things have influenced me and how I feel like I've progressed based on different elements, so that was a really helpful exercise.*

The influence maps are a major focus of the presentation of the findings in Chapters 4-8 and their innovative use is reviewed in the Conclusion chapter.

3.4 Data analysis

3.4.1 *Introduction*

Analysing qualitative data is "a highly personal activity" because there are no definitive rules that must be followed; rather the process involves sense making, finding structures within the data, and using interpretation and creativity (Jones, 1985, p.56). In considering my approaches, I am aware that the findings of analysis "may say more about the researcher than about the data" (Cohen, Manion and Morrison, 2007, p.469) with the choice of methods for analysis; the choice of categories and focuses; and the reflective interaction between the researcher and the data, all being in the hands of the researcher. For meaningful and useful findings to result from qualitative data collection, it is imperative that this is analysed methodically using approaches that are fit for purpose (Attride-Stirling, 2001; Cohen, Manion and Morrison, 2007); caution and self-awareness are required to give a valid and trustworthy interpretation of the data (Brown and McIntyre, 1993).

In considering approaches to analysis, two significant challenges I needed to consider were how to reduce or summarise the data in order to make analysis manageable, but without losing meaning from it, and how to do so in a transparent and credible way (Daley, 2004). Qualitative research, because of the very nature of its sources, tends to result in complex and "cumbersome" data sets (Bryman, 2012, p.565) and in my study I finished the data collection having undertaken 40 separate meetings with participants, with 40 transcripts of up to an hour's length and many pieces of documentation relating to each participant. An additional consideration was that of the longitudinal dimension of the study. Analysis of a particular data collection point necessarily involved both analysis of that data in itself, but also analysis of its relationship to previous and subsequent interviews with the same participant (Thomson and Holland, 2003). Hence my analysis needed to fully recognise change. I read widely to support my understanding of approaches to data analysis and my analysis evolved to become a unique approach. The story of my data analysis is told below.

3.4.2 ***Transcription***

Following the advice of Braun and Clarke (2006) and Riessman (2008), I firstly familiarised myself with my data through transcription, transcribing every meeting from each participant before the next one in their series. Initially this was a very time-consuming process, but the purchase of a foot pedal and suitable software, and the extensive use of the auto-correct function of Word, greatly increased the speed of the process. I set up numerous short cuts in auto-correct so that, for example, typing 'qu' automatically created the word 'question', 'sch' created the word 'school' and 'coet' became 'characteristics of effective teachers'.

I found it fascinating to hear each interview again, listening and writing out the words phrase by phrase. Whilst I was very careful to faithfully record the words spoken, I acknowledge that transcription is a subjective process (Bird, 2005). Analysing the data with a qualitatively interpretivist rather than a linguistic approach, my transcriptions were inevitably incomplete and to a limited extent selective (Riessman, 2008) as in seeking to balance efficiency and accuracy in my transcribing (Bird, 2005), I did not attempt to record all the nuances of speech and non-verbal communication. However, I did note when participants laughed or where their tone of voice was particularly significant, such as the use of irony, and I listened back to key points later in the analysis to remind myself of the tone of voice used. As suggested by Bird (2005), I created my own conventions to support my understanding of the transcriptions, for example underlining stressed words, using sequences of dots to show pauses and writing in any useful asides, for example, my interpretation of a markedly long pause. I tended to make occasional small changes to grammar to support the sense of the written word, and omitted words that for the purpose of this research seemed completely irrelevant, such as ‘like’ as used in the sentence: “I wanted, like, the children to understand this”.

I included photographs of documents discussed in a meeting within the transcription document so that I had full records of each meeting.

Having transcribed an interview, I checked this thoroughly by listening to the full recording again and added notes of initial analysis and summary in a column alongside the narrative, plus any additional points of explanation. Appendix 4 shows an example of a piece of transcription illustrating many of the features discussed above.

After transcribing, I then created a mind map of each meeting.

3.4.3 ***Initial mind mapping***

I started mapping from the first data collection point, simply as an informal way of summarising points from my interviews and noting points of interpretation. Having not read about mapping at this stage, my maps were in my own informal style and contained lists, bubbles with key points which were often closely linked to specific questions asked, lines to show connections between these and summaries of overall themes. They contained factual information discussed by the participants during the meeting or taken from their documentation, my participants’ interpretations of their situation, and my interpretations of their situation, both at a lower level of individual specific points and at a higher level of synthesis, as I sought to draw together some overarching themes. Figure 3-9 is an example of one of the maps.

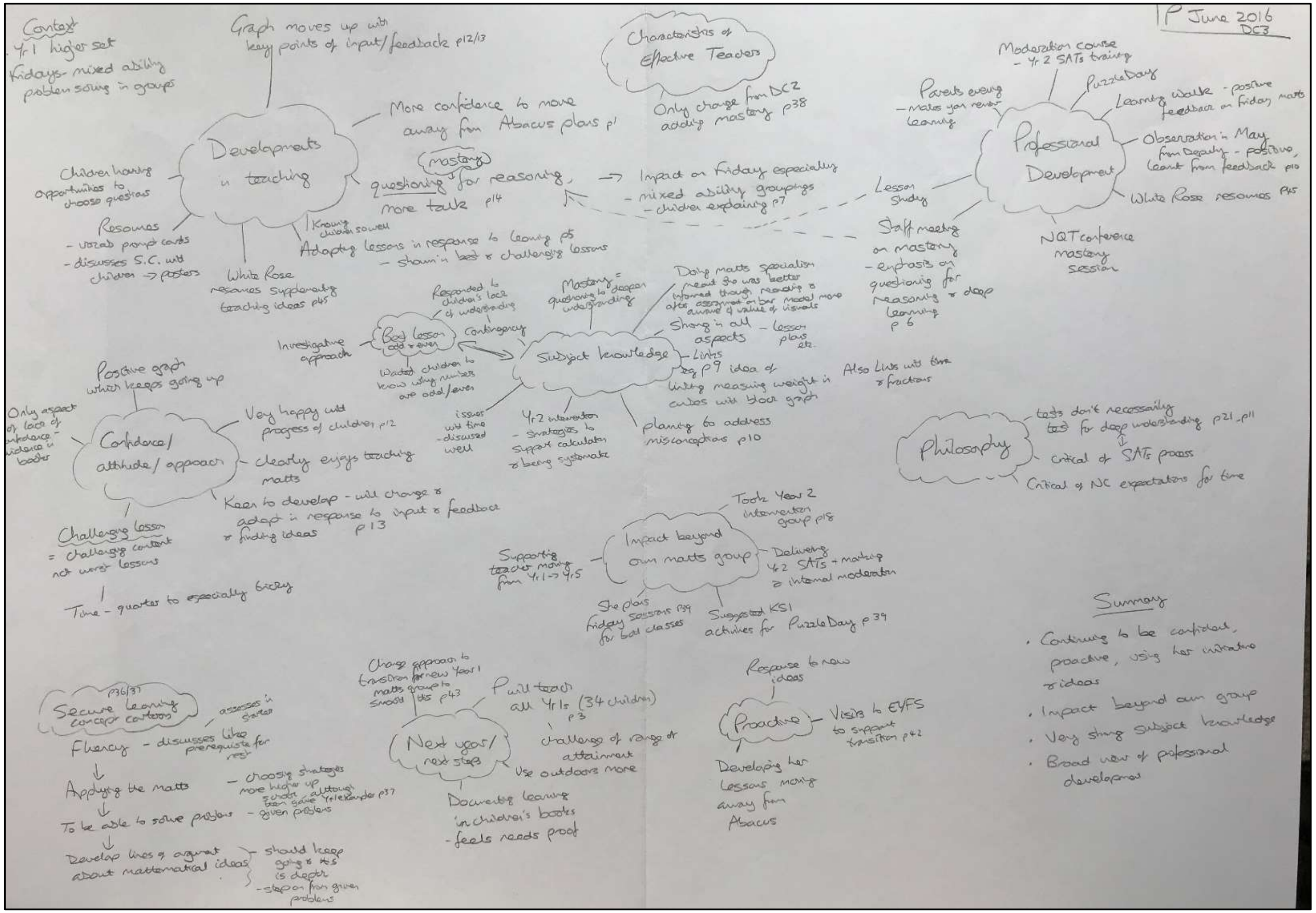


Figure 3-9 An example of one of my initial mind maps, created instinctively before consulting literature.

These initial maps were a very useful analytical tool for me as I sought to clarify what I had learnt from each interview, but they were not in a form that others could easily read and interpretation and comparison between maps was difficult.

However, the process of transcription and mind mapping helped me to reflect on points made by my participants, enabled me to understand these to a greater depth than was possible during interviewing and thus enabled initial consideration of interesting and potentially significant ideas and concepts. The process also supported my preparation for the next set of meetings and, by retaining a thorough memory of the previous meeting, I was able to refer back to points from this meeting in the subsequent one. Not only did this impact on my use of probing questions in the subsequent meeting where I could be really specific with a question depending on what I had learnt from the previous meeting, ethically it was important to show the participant that I knew and valued the data they had previously given.

In 3.4.6 I describe how I developed my analytical use of mind mapping later in the study. Initially I attempted to deepen my analysis through coding my data.

3.4.4 ***Coding***

My initial attempts at more thorough data analysis involved a traditional coding approach. I started this process with the initial interviews of Cohort 1 participants and went through a process of mind mapping the main points from each meeting, hand coding the transcriptions and creating an initial node tree, using codes such as 'feelings about mathematics' and 'subject knowledge'. This basic coding seemed to have organisational merit, enabling labelling, separation and summarising of data (Charmaz, 2006). I learnt how to use NVivo software and set up an additional series of nodes incorporating data from Meeting 2. I was aware that whilst codes can be merely descriptive, in order to develop analysis further, they needed to reflect a greater depth of thinking (Bryman, 2012). I realised that at this stage my codes were mostly functional and I struggled to more meaningfully code the data and combine the data sets from Meetings 1 and 2. The breadth of data collected also meant that coding was both very time consuming and complex. It seemed that I was often multiple coding pieces of text and I reflected that my nodes were unhelpfully overlapping. I revised the nodes to be more specific and to more meaningfully reflect concepts, ideas and meanings that were noticed in the data (Braun and Clarke, 2006), for example 'awareness of self as a mathematician' and 'teaching for conceptual understanding'. My coding became more interpretive and analytical and alongside this I created 'cases' and 'sets' within NVivo, following the advice of Bazeley and Jackson (2013), so that I could analyse my data by participant attributes and by timeframe.

However, a major limitation of a coding approach is the fragmentation of data and potential loss of meaning and context for coded fragments (Coffey and Atkinson, 1996; Bryman, 2012). This can lead to a mismatch between the analysis and the raw data on which it is based (Braun and Clarke, 2006). This became a very significant issue in my analysis; I felt I had lost the bigger picture of my data and that rather than supporting my analysis, the coding was confusing it. Also, at this stage I had two transcripts for each Cohort 1 participant and I could only see the confusion continuing as further data was collected. In the meetings the participants were telling me the story of their evolving practice and I decided to look for an alternative approach to analysis. I found this in narrative analysis.

3.4.5 *Narrative analysis*

Narrative analysis includes a broad "family" of methods for "interpreting texts which have in common a storied form" (Riessman, 2008, p.11). Individual stories can be preserved and detail accumulated to provide a more complete understanding of the individual or group to which they belong.

There is no simple agreed definition of a narrative (Riessman, 2005) and I have chosen to follow Coffey and Atkinson (1996) and Riessman (2008) in not attempting to distinguish between a narrative and story. Riesman's definition of a narrative as "a bounded segment of talk that is temporally ordered and recapitulates a sequence of events" (2008, p.116) seems to cover the specific narrative-style responses that my participants related to particular contexts such as the story of their relationship with mathematics over time; the story of their development as a teacher of mathematics since my previous visit; and specific narratives of their best or most challenging mathematics lessons and their work with individuals. The stories told ranged from extended narratives of their experiences with mathematics over many years to brief retelling of events within a single lesson.

Coffey and Atkinson (1996) suggest that stories are an obvious way for interviewees to talk as they retell experiences and events. This may be especially so for teachers; Cortazzi (1993) explains that narratives seem to be an important part of how teachers talk about their practice amongst themselves, with positive stories providing "direction, courage and hope in their work" and negative stories functioning as a "social lubricant", reducing friction (p.139). He argues that the narratives of teachers are valuable as a means of providing evidence of their ways of thinking and seeing their experiences as well as evidence of the actual experiences themselves, and this seems to apply aptly in my study. My participants' familiarity with me as a colleague in the teaching profession may have particularly led them to illustrate and elaborate interview responses with stories, and indeed my participants seemed increasingly relaxed and eager to share with me over the course of the study.

However, in my study there is also the sense of narrative at two extended levels. Firstly, at each meeting I gained extensive insights into each participant's unique story as a teacher of mathematics since our last meeting. The narratives from each meeting then combined to become the overall narrative, from the perspective of the participant, of their evolving practice as an early career teacher of mathematics and what had influenced this.

The literature related to narrative analysis suggests that narratives yield complex data which, with careful and transparent analytical interpretation, provide insights into events that are perceived by the speaker as significant (Riessman, 2008), highly relevant in this study given the importance of participants' perspectives. In narrative analysis the focus is on how the narrator makes sense of what has happened rather than merely reporting what happened (Bryman, 2012), as narratives appear to be a way of constructing identity alongside the recall and communication of events (Cortazzi, 1993) and are constructed for a particular audience (Riessman, 2008), relevant points of caution related to the identities of my participants and myself as members of the teaching profession.

The analysis of narratives is necessarily different to the coding approach outlined earlier, with accounts being preserved and treated as units in themselves rather than being fragmented (Riessman, 2008). Although there is not one agreed way of analysing narratives, it is helpful to consider further what a narrative can communicate to the researcher. Coffey and Atkinson (1996) draw attention to the 'how' and 'why' of storytelling. How narrators order and retell their experiences and why they remember and retell the content they choose to include were important in my study in relation, for example, to participants' choices and narratives of specific lessons and their recall of aspects of their past relationship with mathematics. Riessman (2008), in contrast, identifies four specific, albeit overlapping, types of narrative analysis: thematic, structural, dialogic/performance and visual, all of which were relevant to my study.

Riessman's thematic approach to narrative analysis focuses on the content of the narrative: what is actually said. The researcher looks for meanings, themes, ideas and connections in the narrative as a whole. These can be coded and patterns identified, in a parallel way to grounded theory, although maintaining a case-centred approach. This approach was essential as I sought to interpret the data I collected. The structural analysis focuses, in contrast, on how the content of the narrative is organised by the speaker and can add insights beyond the literal meaning of the text (Riessman, 2008). A very useful approach is that of Labov's (1972) six specific elements in a narrative and Riessman's (2008) elaboration of these: an abstract (with a summary and/or point of the narrative), orientation (information about time, place, characters, context), complicating action (events or plot), evaluation (the narrator's comments on meaning or emotion), the resolution or outcome of the story and the coda, as the story is ended and the dialogue returns to the present. Coffey and Atkinson (1996) suggest that applying these elements in structural analysis enables the researcher to not only see how the narrative is structured, but also gives a perspective from which to analyse and reflect on the purpose of the story.

Coffey and Atkinson (1996) suggest that function is “a principal analytical unit” (p.62), and in a less systematic way consider the purpose and effect of a story. They usefully subdivide effect into four categories: intended, unintended, implicit and explicit. Functional analysis is also an aspect of Riessman’s (2008) third type of narrative analysis: Dialogic/performance analysis. This includes recognition of the story telling as a performance and hence the interaction between the interviewer and interviewee and the notion that the interviewee is constructing a self-identity with an audience. Riessman’s (2008) final type of narrative analysis, visual analysis, was very relevant in my study, as the participants constructed narratives around their generation of visual data.

Labov’s elements, following Riessman’s (2008) work on these, and Coffey and Atkinson’s (1996) categories of function were particularly useful in the study in relation to the most dramatic story told by a participant; the story of a “disaster” lesson which had significant consequences for her. This narrative was analysed in particular detail because of the importance of this one specific event. The categories of functions were also very helpful when considering both the smaller scale narratives and the overall stories of the participants.

To carry out my narrative analysis, I developed the use of mind mapping, building on the informal and unstructured mapping I had carried out at the start of the study.

3.4.6 *Narrative analysis through mind mapping*

Having started to read about narrative analysis and having discussed the benefits of using mind maps as part of my analysis with colleagues at the Tenth Congress of the European Society for Research in Mathematics Education (CERME10) conference in February 2017, I consulted literature around concept and mind mapping and attended a course on mind mapping. I then started creating maps that more usefully enabled me to condense, analyse and compare the data from each meeting. The main points from the literature are outlined below before I introduce the mapping technique that I adapted from both concept and mind mapping approaches.

3.4.6.1 ***Concept mapping***

The literature indicates that there are a range of names and definitions of types of mapping. Novak and Cañas (2006) discuss their invention, and the subsequent evolution, of concept maps, termed in the literature Novakian concept maps (Ahlberg, 2004). The concept map was originally developed in 1972 as a concise tool to represent children's understanding of science concepts as ascertained through interviews.

To create a concept map, data is translated into a visual hierarchical form of concepts and the relationships between these, termed propositions (Novak and Cañas, 2006). Concepts are defined by Novak and Cañas (2006) as "perceived regularities or patterns in events or objects, or records of events or objects, designated by a label" (p.177). The concept maps may also show cross-links between concepts in different areas of the map. Criteria for 'good' Novakian concept maps are set out in Cañas, Novak and Reiska (2015), providing clear guidance as to how they consider concept maps should be constructed, for example with only one or a few words labelling each specific concept and linking line and no more than three or four sub-concepts linked below any given concept. Figure 3-10 shows such a concept map, which sets out the key features of this style of mapping (Novak and Cañas, 2008).

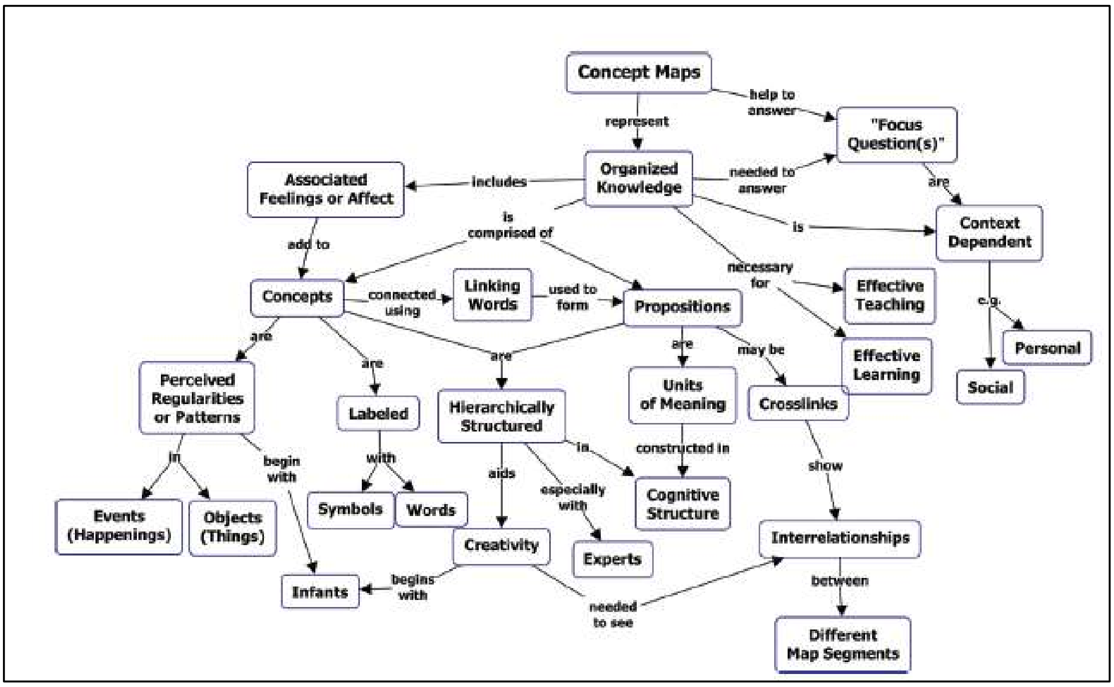


Figure 3-10 A concept map showing the key features of concept maps (Novak and Cañas, 2008, p.2).

Daley (2004) asserts that a key benefit of concept maps is the support they give the researcher to focus on the meaning of the data and the connections the participants make across concepts; they can be used to reduce data in a meaningful way and allow a visual means of identifying patterns and themes. The fact that each interview can be represented on a single map can also facilitate comparison and identification of similarities and difference between the data from a number of interviews.

Since their inception, concept maps have been used for a range of purposes in both quantitative and qualitative research, and more widely in teaching, for example to support learners in understanding the relationships between concepts (Davies, 2011; Eppler, 2006; Ahlberg, 2004), and in project and research planning (Daley, 2004).

Users of concept maps in both research and other spheres vary in the extent to which they apply the rules of Novakian concept maps (Cañas, Novak and Reiska, 2015), with some rigidly applying the criteria deemed necessary for a concept map and others clearly advocating that deviation from the traditional concept map is considered where appropriate e.g. Wheeldon and Faubert (2009). Indeed, Ahlberg (2004) points out that there are many ideas about concept mapping related to the definition of concepts, the specificity of focus of the maps and their structure. Others have looked to compare and contrast concept mapping with other types of mapping, particularly mind mapping, to identify for which purposes each is best suited.

3.4.6.2 ***Mind mapping***

Mind maps, first formally developed and advocated by Tony Buzan in the 1970s primarily to support memory (Buzan and Buzan, 2000), are maps created to express ideas, connections, patterns and associations (Lorrison, 2014). In a similar way to concept maps they can be used to record one's own or another person's ideas (Lorrison, 2014), but their structure and purpose, whilst similar, are considered to be different (Dixon and Lammi, 2014). Although Buzan's original rationale for mind mapping was essentially about supporting recall and memory by organising key words into a radial structure, later considerations included application in self-analysis, problem solving and creative thinking (Buzan and Buzan, 2000). Davies (2011) considers that the main purpose of mind maps is to form and explore creative associations between concepts. In contrast, he asserts that concept maps allow understanding of relationships between concepts and hence facilitate a deeper understanding of those concepts.

In terms of structure, mind maps tend to be radial and less formal than concept maps, key words are written on connecting lines and any idea can be connected to any other (Davies, 2011). They follow the logical associations of the author and therefore represent in visual form the creator's reflection on their thoughts and knowledge development (SUSTAIN, 2016). Techniques such as varied colour, line thickness, pictures and diagrams can be used to aid memory and enhance learning (Dixon and Lammi 2014), building on scientific recognition of the structures and workings of the brain (Buzan and Buzan, 2000). Figure 3-11 was taken from Buzan's website (Buzan, 2017) and summarises his thinking about the visual form of mind maps.

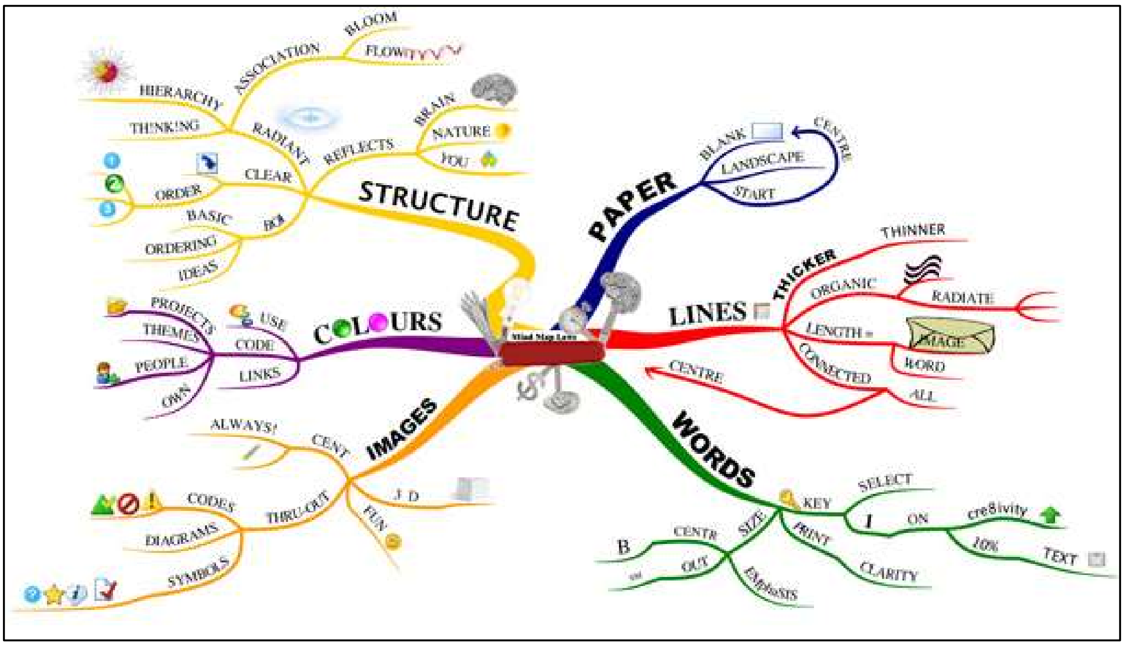


Figure 3-11 A mind map to illustrate features of a mind map (Buzan, 2017).

Mind maps seem to be used in situations where a free-form of creative ideas is required; a 'brainstorming' approach. Eppler (2006) suggests that a typical application of mind mapping is for personal note-taking and reviewing. However, whilst potentially easier to learn to use and apply than concept maps, mind maps tend to be idiosyncratic and can become complex and hard for others to read and interpret (Eppler, 2006). A specific difference between concept mapping and mind mapping appears to be that the proposition element of concept maps (with words linking concepts to articulate the relationship between these) is implicit rather than explicit on a mind map. Davies (2011) considers this to be a constraint of mind maps which renders them to be of limited use in analysis where the relationship between concepts is important to identify.

3.4.6.3 *Cognitive mapping and other approaches*

The limitations suggested here may account for the lack of examples of researchers using mind mapping in its basic form for data collection and analysis. However, some of the features of mind maps have been incorporated in wider interpretations of mapping. Scherp (2013), for example, uses the term cognitive map as "a graphical representation of an individual's conceptions or systems of conceptions about given phenomena" (p.67) and his use of such maps as a data collection tool within interviews uses features of both concept and mind maps. In this case the interviewer created the map from key words or phrases given by the informant (in the style of mind mapping) which were then linked with lines by the interviewer as the informant described relationships between them (in a similar way to concept mapping but without the formal rules applying). Figure 3-12 is an example of such a map. The informant's reflections on the evolving map deepened their responses and, Scherp argues, increased the validity of the data collection.

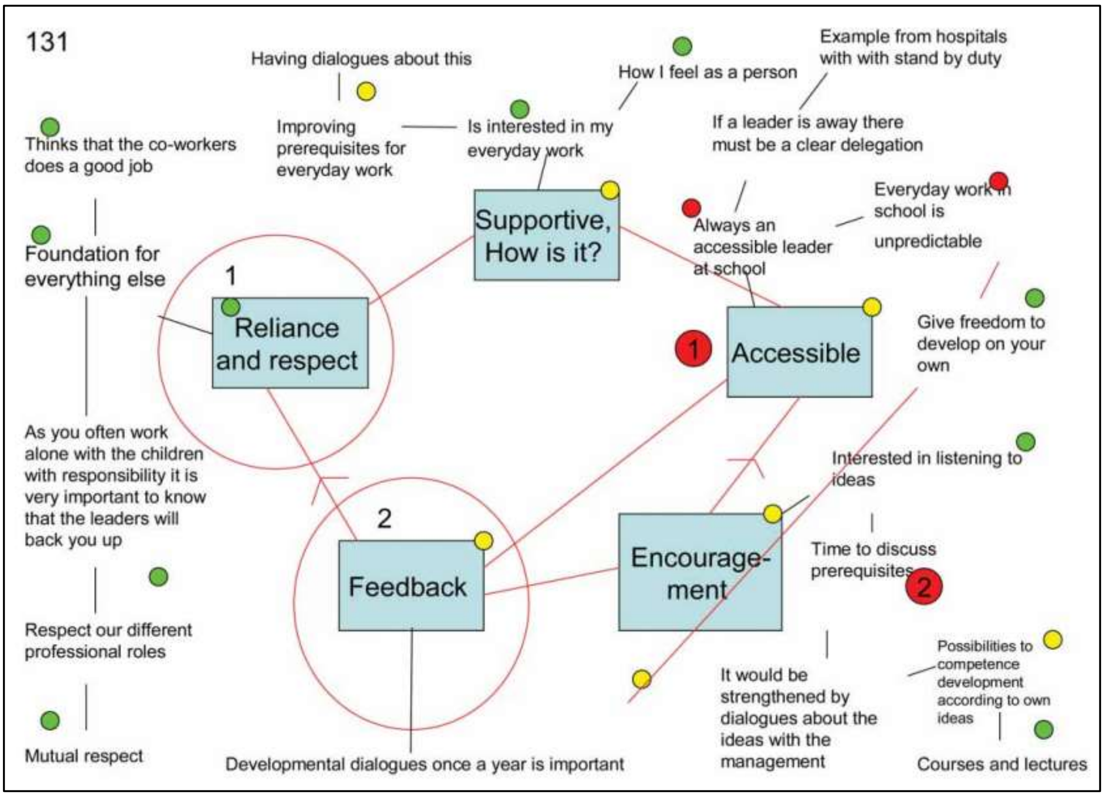


Figure 3-12 A cognitive map of school leadership that contributes to school development and how it is realised in practice (Scherp, 2013, p.72).

Jones (1985) describes her use of cognitive mapping as "a method of modelling persons' beliefs in diagrammatic form" (p.59). Her maps, created post interview from recordings or transcripts, were created to analyse interview data. Her approach records concepts and ideas in boxes and her beliefs or theories about the relationships or links between these are shown as arrows or lines depending on whether causality is present. Her maps therefore show similarities with a concept map, but are not hierarchical. In the tradition of mind maps, they have a free form. She describes how from cognitive maps of an interview she creates a summary map of the key categories and relationships which she can use to compare with other maps from other interviews. This leads to analysis of the similarities and differences and integration of categories and relationships. Thomas (2009) similarly describes his theme mapping of individual interviews in which he chronologically places quotations onto a diagram which give evidence of themes. He then uses lines and arrows to show connections. A key feature of Thomas's approach here that differs from Jones's is that it follows on after initial coding to identify themes. It could be said, therefore, that his process of creating an interview theme map is to aid clarity in organisation of data and presentation rather than in analysis.

3.4.6.4 ***Summary - mapping literature***

The literature therefore suggests that mapping can be very usefully employed in qualitative data analysis. In contrast to traditional coding, mapping enables meaningful reduction in data whilst retaining its coherence, avoiding fragmentation and retaining the wholeness of a person's view (Daley, 2004; Jones, 1985). It thus allows the researcher to immerse themselves in the fullness of the data and draw out (literally and metaphorically) the categories, concepts and relationships on which credible analysis depends. The major disadvantage according to Daley (2004), writing about the use of concept maps specifically, is their potential complexity. Alongside possible difficulties in reading complex maps, and determining which concepts are more important than others, she considers it may be necessary for researchers to employ additional data analysis strategies to complement the mapping. Nevertheless, she advocates their use as a tool where analysis of levels of hierarchy, interconnections and repeated concepts can indicate categories or themes.

3.4.6.5 ***Application in my study***

The purpose for my mapping was to summarise and analyse the narratives of my participants. Whilst I produced one map for each meeting, and hence each map is a summary of a participant's story as a teacher of mathematics since their previous meeting, each also contains evidence from the shorter, specific narratives within each interview.

The mapping that I used for my analysis was based in style on a mind map. I rejected the Novakian style of concept map because the information I wanted to include was not simply about hierarchical, interrelated concepts; a trial attempt at creating a concept map showed that this format was too restricting. However, the basic mind map in the tradition of Buzan was also insufficient because of the lack of clarity as to how ideas are related. The style I created uses the form of a mind map but includes coloured joins to indicate whether the next labelled line section is a sub-category/example of the previous or a consequence leading from that. The lines are coloured according to their purpose: factual information, interpretation by the participant and interpretation by me as a researcher. Each arm of the mind map is linked to the page of the transcript where there is evidence for this. Figure 3-13 shows a complete example of one of my mind maps.

Mapping enabled me to consider ideas and connections within the data, in essence the thematic narrative analysis of Riessman (2008), and went beyond consideration of the mere wording of narratives, to considerations of their structure and function. Each map is therefore a summary of factual information, as presented by the participant, alongside the participant's interpretations and my own interpretations of ideas related to their evolving practice as a teacher of mathematics and the influences on this.

I mapped these under three overarching themes of 'change', 'beliefs and attitudes' and 'subject knowledge', themes that inevitably arose from the nature of my questioning and the literature which informed the study. In effect each mind map was made up of three smaller maps, one for each theme.

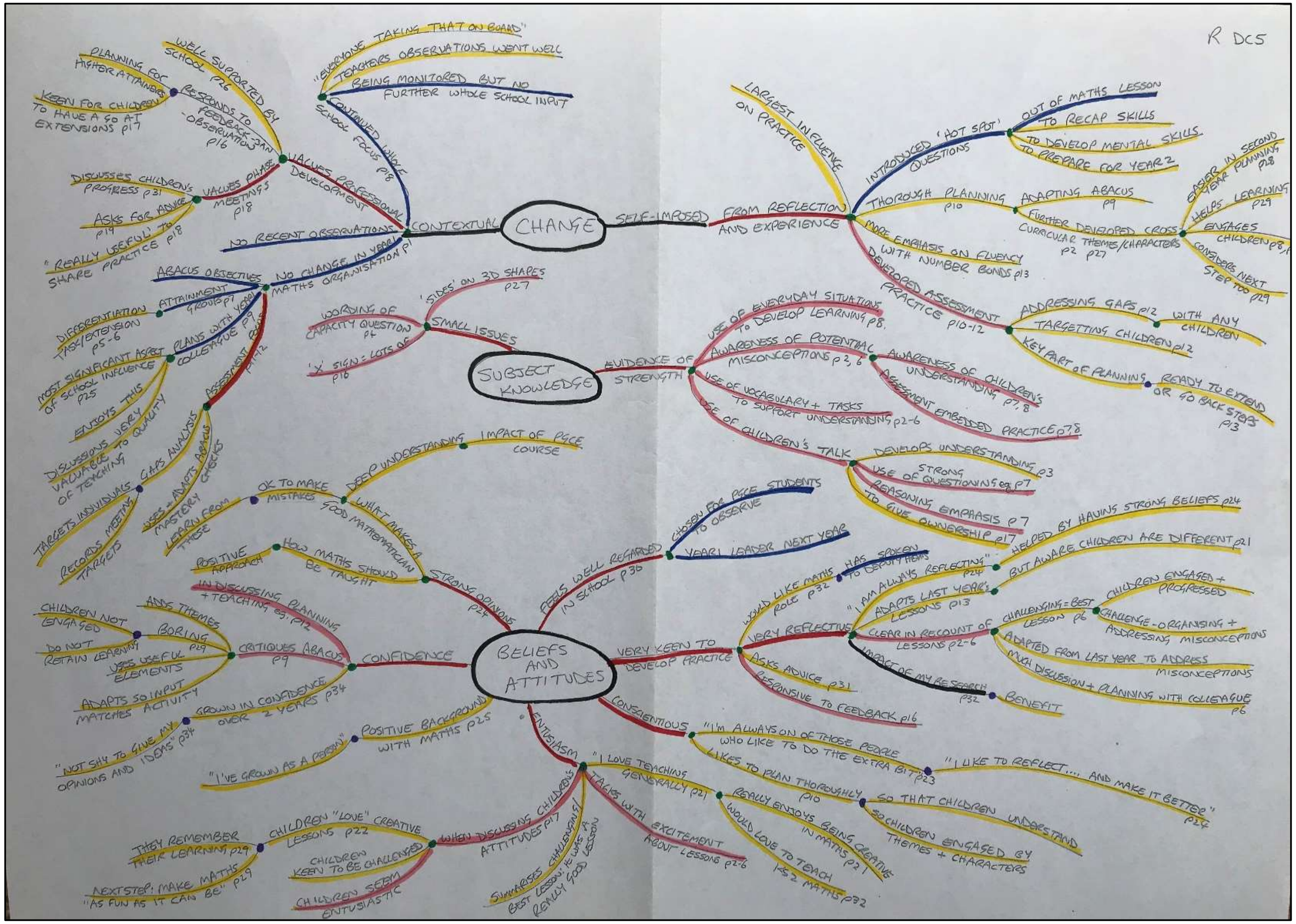


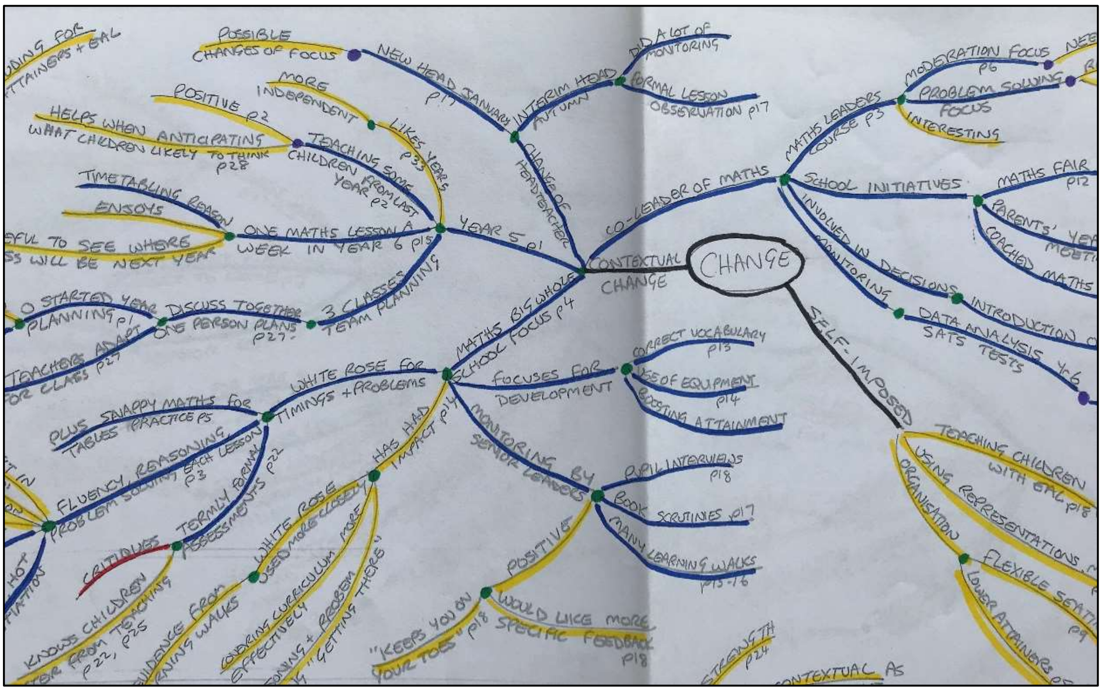
Figure 3-13 Complete mind map example – Meeting 5 for Rahma.

Coloured joins indicate whether the next labelled line section is a sub-category/example of the previous (green) or a consequence leading from that (purple). Lines are coloured according to their purpose: factual information (blue), interpretation by the participant (yellow) and interpretation by me as a researcher (red for synthesis, pink for examples). Each arm of the mind map is linked to the page of the transcript where there is evidence for this.

Being a longitudinal study, change was very apparent in the data, and indeed I specifically asked about changes and developments in teachers' practices. In every interview there were aspects of change that were 'contextual', related to the specific school context and aspects of change that were 'self-imposed'. My mind maps distinguished these two elements and then had branches linked to identified aspects of each. Usually the contextual thread included several factual elements and the participants' perspectives on these points, highlighting changes that were taking place within the school context that had been imposed on the participant and their views of the impact of these changes. The self-imposed changes thread included mostly participants' perspectives on how their practice was evolving. Evidence in this thread was generally from intended and explicit aspects of narratives (Coffey and Atkinson, 1996). Figure 3-14 shows two examples of the change theme.

The beliefs and attitudes theme included the perceptions of the participants of their beliefs and attitudes to teaching mathematics but also my interpretations from the meeting, with examples or reasons for these interpretations. In this theme in particular, I noted the implicit and unintended functions of the narratives as they revealed clues as to the beliefs and attitudes of the participant (Coffey and Atkinson, 1996). I thus gained my perspective on the self-identity of each participant as a teacher of mathematics from their performance in the interview (Riessman, 2008). Figure 3-15 shows two examples of this theme.

The subject knowledge theme was a summary of both the participants' perspectives on their subject knowledge for teaching mathematics and my interpretations of this from the evidence of the meeting, both from verbal explanations and from documentation. Implicit and unintended functions of narratives also revealed evidence of subject knowledge (Coffey and Atkinson, 1996). Figure 3-16 shows two examples of the subject knowledge theme.



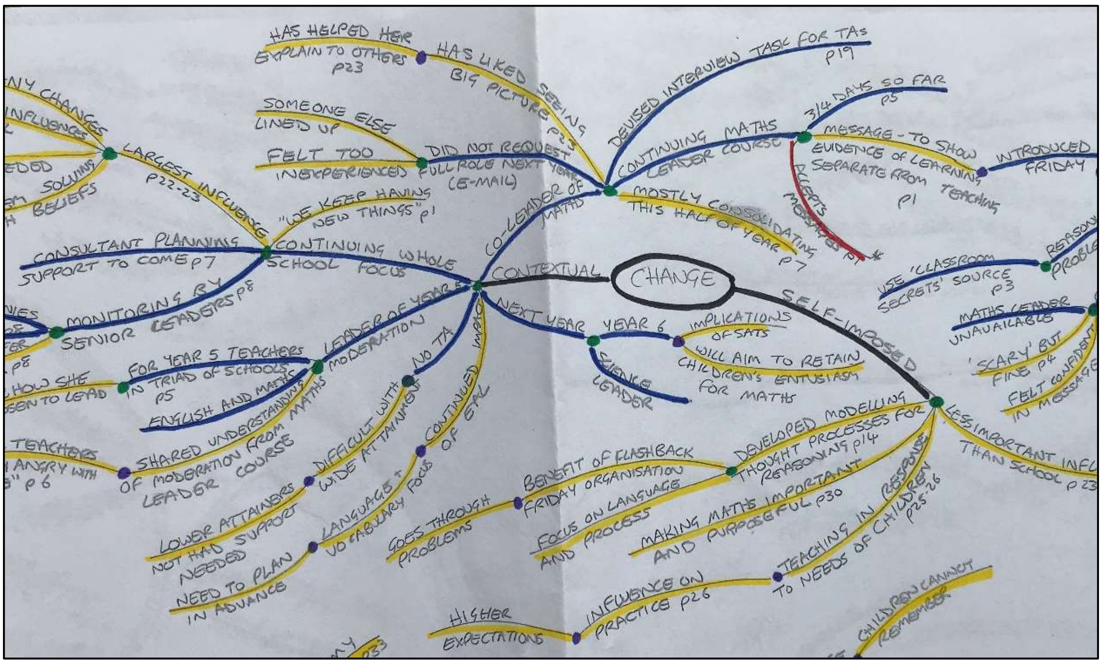
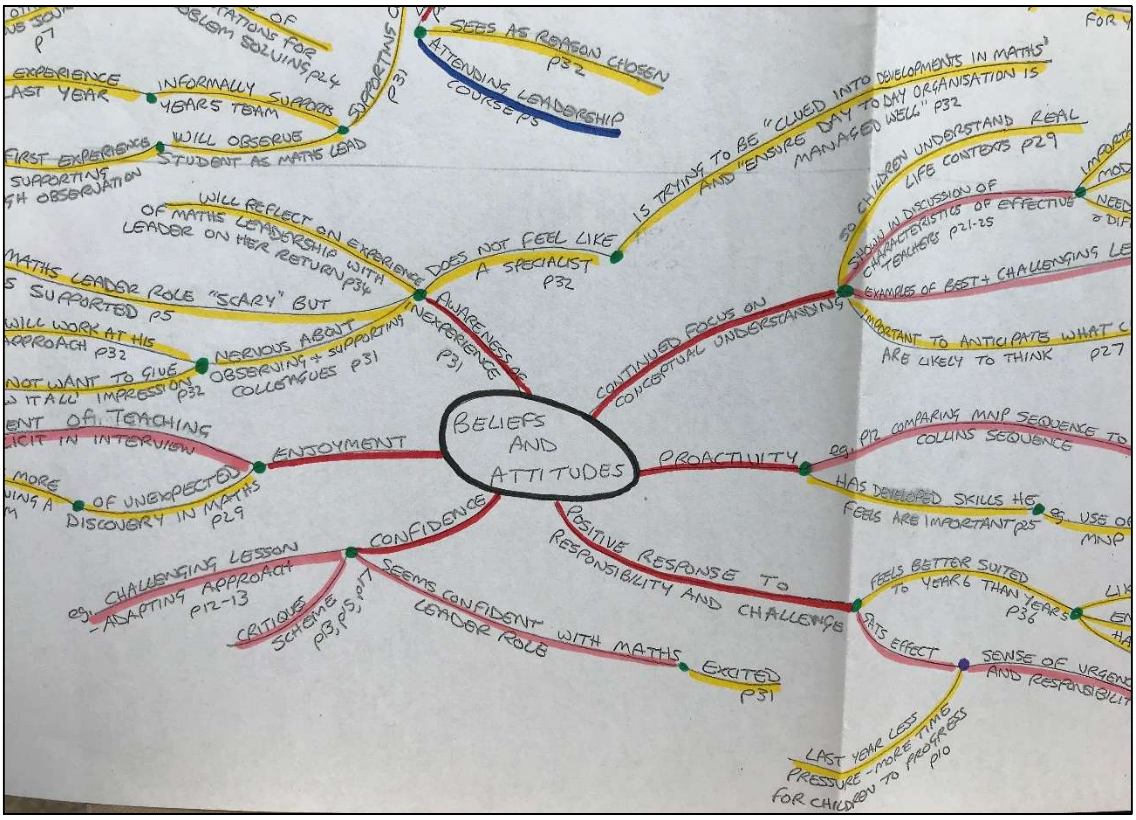


Figure 3-14 Examples of mind mapping of the change theme – from Orna at Meeting 4 (above) and Meeting 5 (below)

Coloured joins indicate whether the next labelled line section is a sub-category/example of the previous (green) or a consequence leading from that (purple). Lines are coloured according to their purpose: factual information (blue), interpretation by the participant (yellow) and interpretation by me as a researcher (red for synthesis, pink for examples). Each arm of the mind map is linked to the page of the transcript where there is evidence for this.



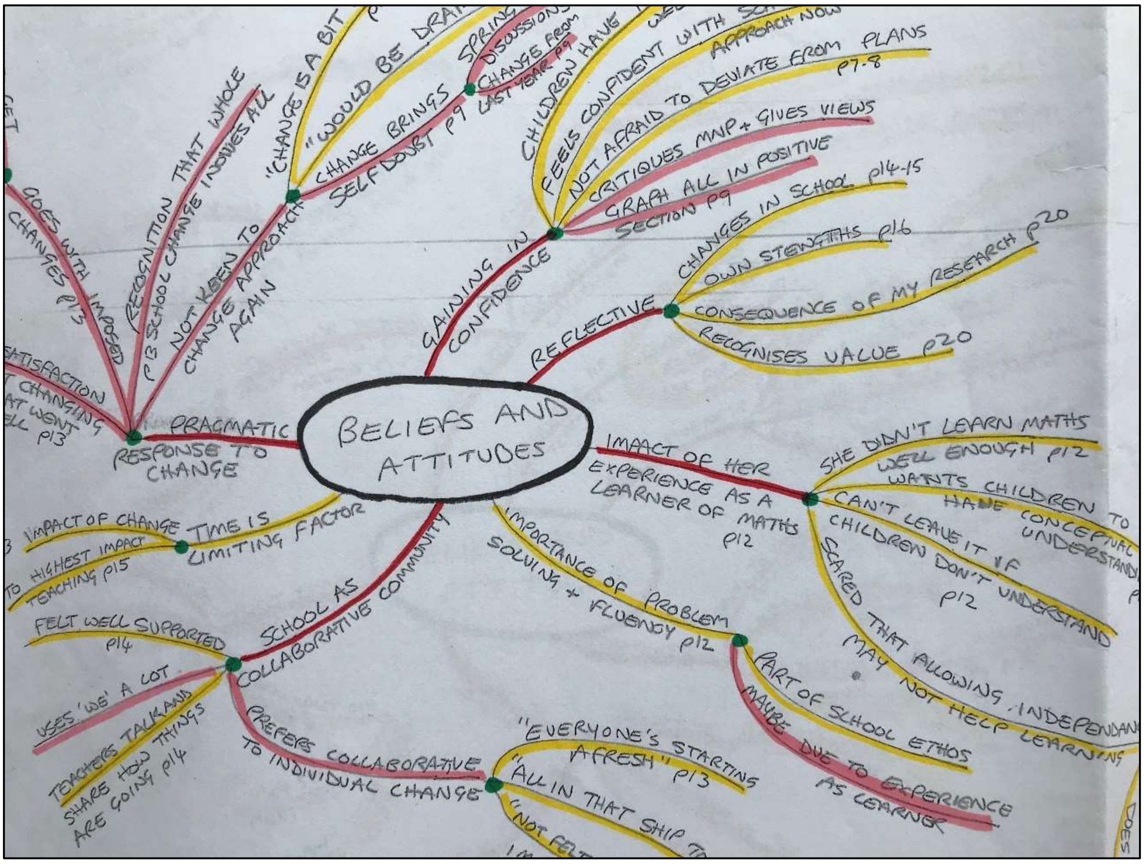
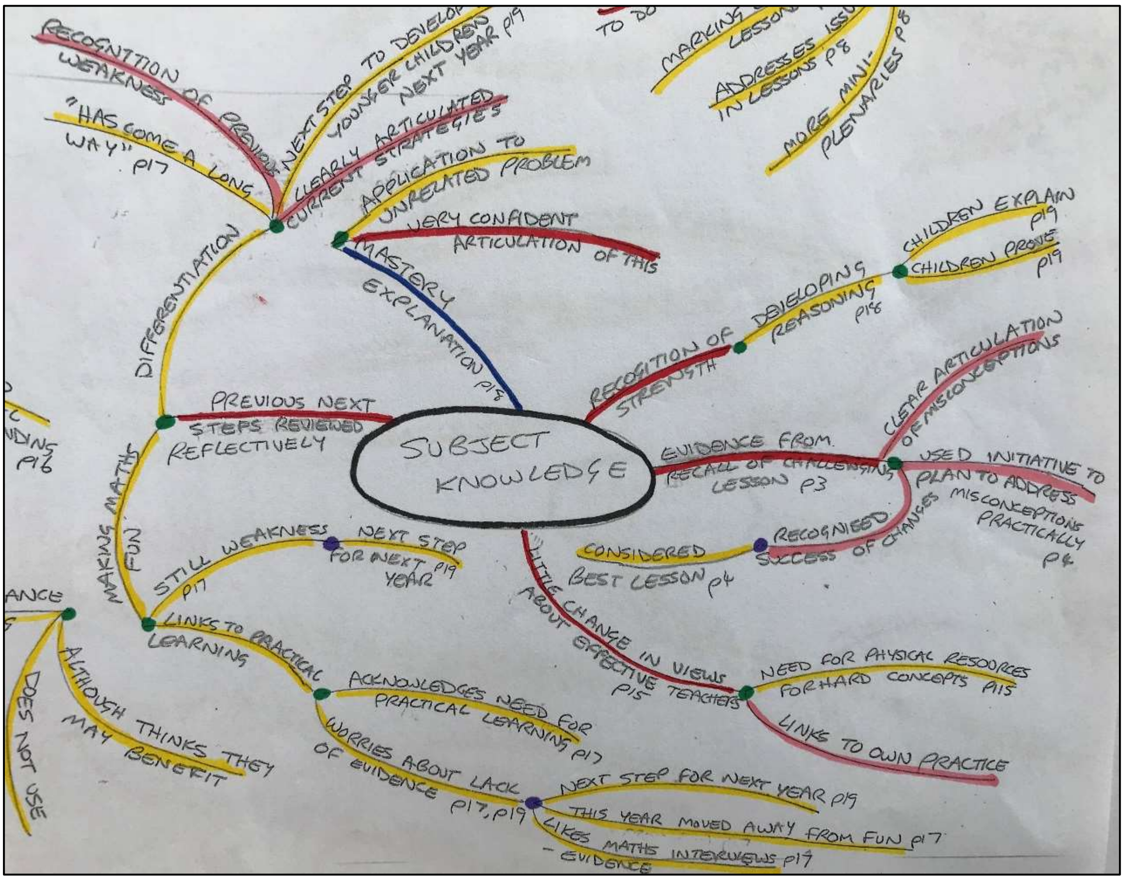


Figure 3-15 Examples of mind mapping of the beliefs and attitudes theme - from Rakesh at Meeting 4 (above) and Gina (below) at Meeting 5.



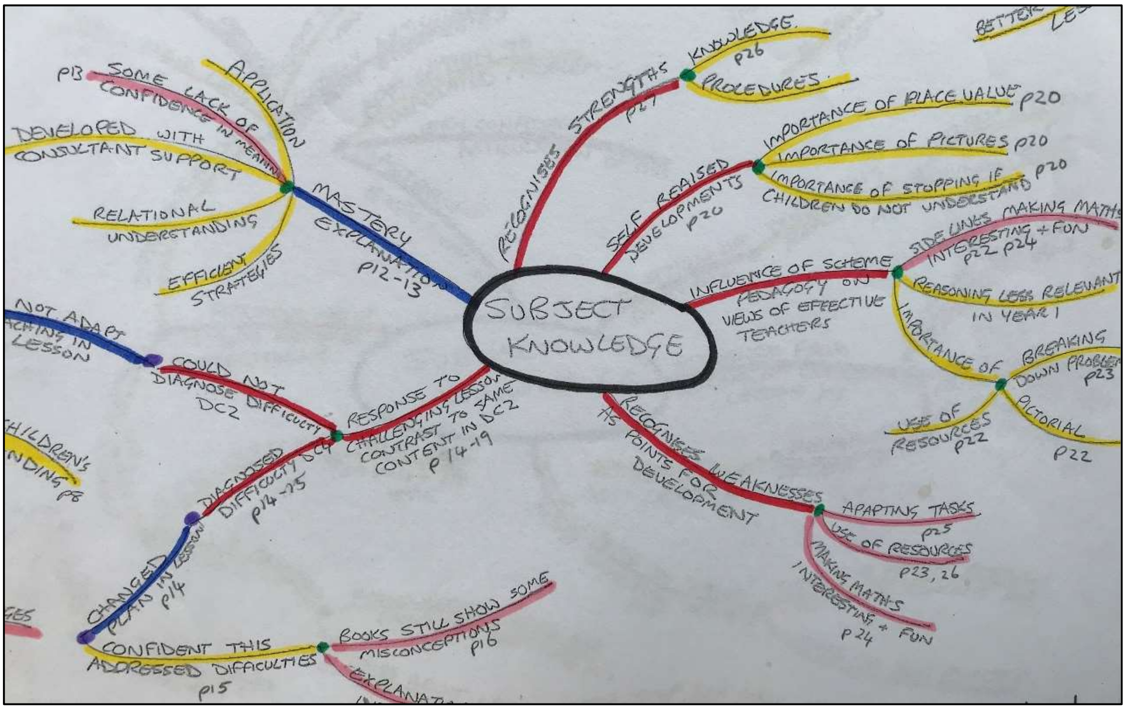


Figure 3-16 Examples of mind mapping of the subject knowledge theme from Gina at Meeting 4 (above) and Meeting 5 (below).

For each participant I therefore completed a series of five mind maps. Although recognising that the analytical quality of the mind maps improved once I changed the style of mapping to that outlined above, I decided not recreate the early mind maps from the first year of the study. By this time I knew my Cohort 1 participants and their data from earlier meetings very well, having revisited the data from each interview many times as I prepared for subsequent interviews and adjusted my interview schedules. I felt that there was little more to be gained at this point by recreating previously drawn mind maps, particularly with the slight shift in emphasis over the course of the study.

As explained in Chapter 1, the focus of my study narrowed to looking specifically at the influences on these early career teachers' teaching of mathematics. When I came to combine the data for a participant across the series of meetings I concentrated on this focus, starting with their influence map/s and the commentary given as they created these at Meeting 5. I scrutinised copies of each mind map for specific evidence related to the four identified influences on that particular participant's practice and their perceptions of these, also noting any influences I perceived in the data that were not expressed in these terms by the participant. I highlighted evidence related to each main influence in a different colour. I also reread the original transcripts and the documentation given or produced during meetings with this particular lens in mind. This enabled me to check that I had not missed useful evidence and to again bring all the data to mind. I was therefore able to consider the relative influences on each participant at earlier stages than the point/s for which I had an influence map.

At this stage I decided on three participants' narratives to discuss in particular detail in the thesis. To further support the analysis of these narratives and to check that I had covered all relevant evidence, I created an overall influences mind map for each of Rahma, Gina and Penny. Each overall map had four branches, one for each of the main influences, and then sub-branches from each of these for the other three influences. This structure enabled me to note links between the influences. As I highlighted data linked to each influence on the original mind maps, these points were noted on the overall map. This map therefore gave me an overview of the participant's data linked to the influences and how these interrelated. Figure 3-17 shows the overall map for Gina.

Having carried out this analysis, I considered that I knew my data intimately and had rigorous processes in place to enable me to write narratives of my participants to evidence the influences on their evolving practice as teachers of mathematics.

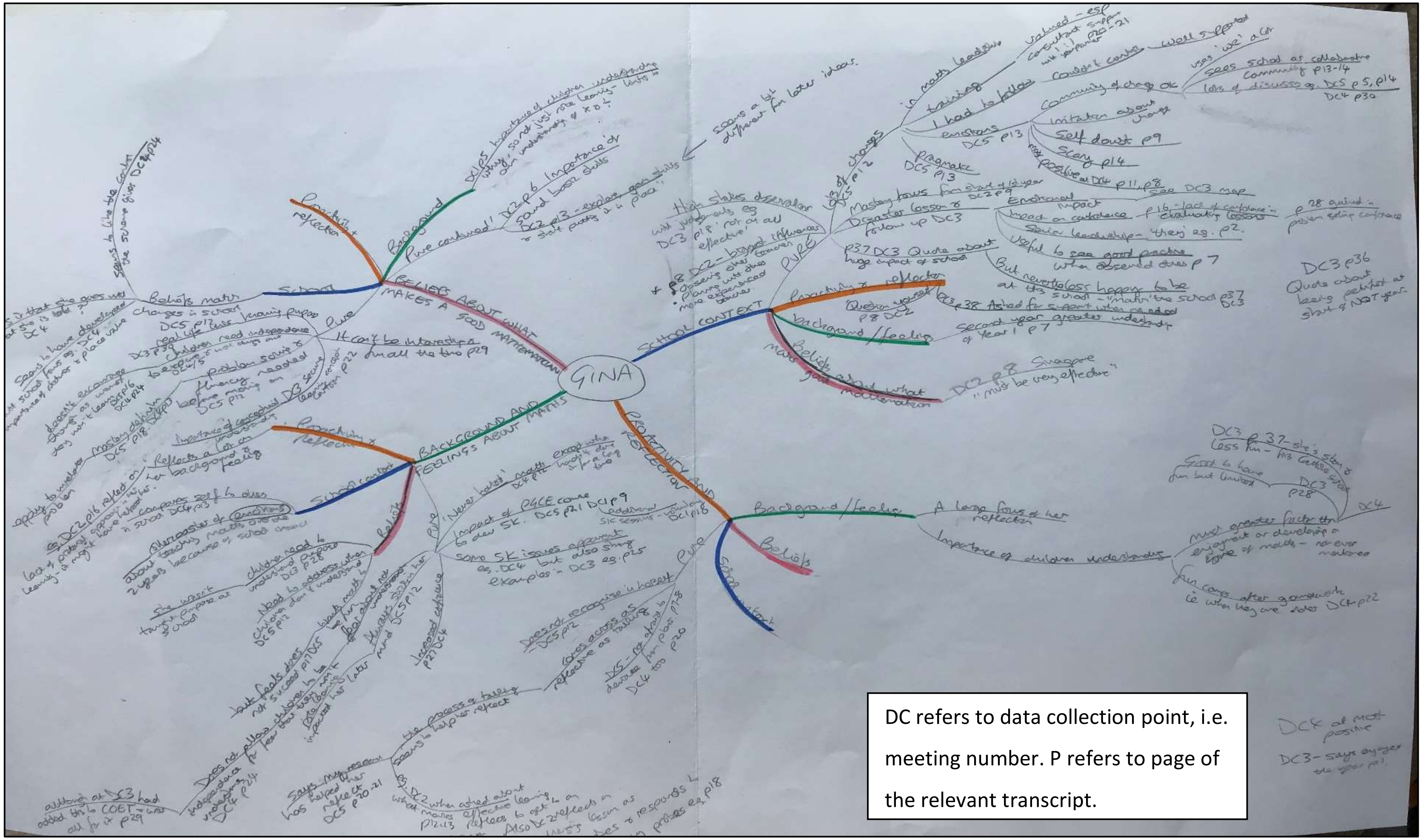


Figure 3-17 Overall influences mind map for Gina.

3.4.7 ***Extending the theoretical framework***

At the end of the literature review chapter I presented a model derived from the literature of the interacting influences on early career primary teachers' teaching of mathematics (Figure 2-3). The final stage of my analysis was to consider, with the benefit of my data and my analysis of this data, whether my research findings supported this model.

As I wrote the detailed narratives for my participants set out in Chapters 4-8, I followed a systematic approach and structured my writing around evidence of the participants' perceptions of the influences on their practice. Starting with their influence maps from Meeting 5 and their commentary around these, and then using evidence from across their series of meetings, I explored the specific factors they talked about relating to each influence and how these influences overlapped. The process of writing Chapters 4-8 again deepened my understanding of the data and I was able to put together the first draft of a new model to extend the initial one based on the literature.

As I wrote the discussion chapter, continually reflecting on the nature of my findings in relation to the literature, I refined the model further. The process of writing this chapter helped clarify my thinking and I explored different ways of visually presenting my model until I was content that it summarised the findings from my study. This is presented at the end of the discussion chapter.

3.5 Ethical considerations

Ethical considerations permeate any study in which people interact with each other and apply at all stages of the research process (Stutchbury and Fox, 2009; Cohen, Manion and Morrison, 2007). The research in this study has been designed, carried out, analysed and reported with ethical issues in mind and following the British Educational Research Association's ethical guidelines (2011; 2018) and those of the

University of Leicester (2015). I gained formal ethical approval from the University of Leicester for each of the pilot and main studies (Appendix 5a).

At the start of the study I read the latest BERA (2011) guidelines for ethical research and the Data Protection Act (1998), with awareness about the research specific particulars. I gained voluntary informed consent from each participant, ensuring that they were well informed about the project and knew that the study would not affect formal assessments of their teaching competence. Participants were assured that their interviews were confidential, that data would be anonymised and protected, and that they could withdraw at any time without giving reason (Appendix 5b).

Going beyond this, I spoke with the Newly Qualified Teacher Induction Coordinator at the local authority where most of the participants gained employment, to ask about the ownership of the teacher documentation that I was seeking to discuss and collect when I visited participants. Having found out that such documentation was the property of the school, I obtained permission from each headteacher to collect this data, in addition to permission to access their school to meet with the participant (Appendix 5c). This was carried out before Meeting 2.

All information about participants has been kept confidentially and anonymously, with pseudonyms used throughout. Although my previously established relationships with the participants may have positively influenced recruitment to the study, no incentives were given. I did not, for example, offer advice or guidance such as I would have given in my tutor role.

Whilst procedural elements go some way to ensuring a study is carried out ethically, wider ethical considerations need to go beyond these (Small, 2001) and ethical judgements rely on the values, beliefs and principles of the researcher (Bogdan and Biklen, 2007). The University of Leicester (2015) guidelines for carrying out ethical research are based on the Ethical Appraisal Framework of Stutchbury and Fox (2009) which outlines the breadth and complexity of ethical considerations. This framework suggests attending to research ethics should involve four dimensions of ethical thinking: ensuring that the research is worthwhile (Consequential thinking), conducted responsibly (External or ecological thinking), respectfully (Relational thinking), and correctly, avoiding harm (Deontological thinking). In reading this work at the start of the study, I recognised that beyond carrying out the procedural requirements for ethical permission, it was important to further develop my capacity to make ethical decisions regarding the design and conduct of my research (Small, 2002). It is within the day to day carrying out "ethics in practice", rather than the procedural ethics of gaining approval for projects, that the researcher's ethical competence is really worked out, and this involves adopting a reflexive research approach (Guillemin and Gillam, 2004, p.269). Thus, although I did not encounter any dramatic "ethically important moments", as described by Guillemin and Gillam (2004, p.263), critical reflection was an important element of my study and ethical considerations are woven into the methodology of the thesis beyond this section. For example, I sought to adapt aspects of the data collection process to not only increase the quality of the data, but also to attend to the motivation and engagement of the participants, as discussed in 3.3.6.5.

My participants were in their initial years of teaching; they were busy and had many demands on their time. As well as making clear to the participants why I was carrying out the research and the potential benefits of this to future teacher education, in order to be a responsible researcher, avoiding making excessive demands on the participants was important. I therefore did not request any documentation that they would not already be producing, I gave the participants many choices of dates and times for meetings and made certain that I was ready in school when they were available. I ensured that on the rare occasions that a meeting went beyond an hour, that I checked with the participants that they were happy to continue.

The relational dimension of Stutchbury and Fox's (2009) framework was very important given the longitudinal nature of the study with the continuing participation of teachers dependent at least in part on the maintenance of positive, constructive relationships. As discussed in 3.3.6.2 the shift from tutor/pre-service teacher to researcher/participant relationships and power dynamics was a major consideration in how I managed the interview process (Bogdan and Biklen, 2007; Kvale, 2006). I also made every effort to ensure that participants knew I was grateful for their time; as well as thanking them at the start and end of every meeting, I sent a follow up email of thanks each time. I also thanked headteachers for their permissions in writing and in person if I met them on my visits.

The credibility of the study relies on the deontological consideration of truthfulness and honesty in both data collection and the analysis and reporting of the data collected. In this study I collected a vast amount of data and I have conscientiously sought to represent this faithfully in this thesis.

In summary, throughout the study, I have endeavoured to carry out my research ethically, recognising this to be a complex and multi-faceted process. In going beyond simply carrying out the procedural requirements, I have sought to use my own ethical judgements to carry out my research responsibly and respectfully whilst ensuring that the study is worthwhile (Stutchbury and Fox, 2009).

3.6 Conclusion

This study was designed to enable me to gather and analyse high quality data in order to answer my research questions. In order to explore how factors related to the teacher themselves and factors related to the school context combine to influence the practice of early career primary teachers, I used a longitudinal qualitative methodology, and sought to explore participants' perspectives through the use of semi-structured interviews within a series of meetings. The range of participants enabled me to collect data from early career teachers with varied mathematical backgrounds and the longitudinal nature of the study allowed me to adapt and strengthen my data collection over the course of the project. Ethical considerations have permeated each stage of the study.

I collected a range of data from each of my eight participants. The richest and most useful were the interview transcripts and accompanying participant generated visual data, and these were the starting point for my analysis. Other documentation strengthened my understanding of their narratives, particularly lesson plans and examples of children's work and increased the validity of my study by the use of triangulation (Cresswell and Miller, 2000), principally formal observation feedback from school leaders.

In this study the use of visual data collection techniques was a particular feature of the interviewing process. Using innovative visual tools designed specifically for this study seemed to significantly enhance my data collection, supporting the depth and breadth of participants' discussion, empowering participants by handing them some control of the interview and stimulating their interest and motivation.

My approach to data analysis, while informed by relevant literature, was unique. Narratives were apparent at a range of levels, from the stories of specific lessons and interactions with individuals, to the overall stories of participants across the two years of the study. Having rejected traditional coding, the data collected from each meeting was analysed with a narrative analysis approach, using transcription and analytical mind mapping, and with data analysis informing further data collection throughout the longitudinal study. A second stage of analysis, combining data across the series of meetings, supported specific focus on the overall influences on participants as teachers of mathematics, and enabled the development of a new model extending that developed from the literature review.

The findings of the study are now presented (Chapters 4-8).

4 Introducing the participants

4.1 Setting the scene

In this chapter the structure of the findings portion of the thesis is set out and the participants are introduced. Although full data was collected from each of the eight participants, it is not possible within this thesis to write detailed narratives of them all. I therefore present three detailed narratives, the first two considering the participants' perspectives on each of the four main influences, and the third looking in particular detail at distinctive elements of the narrative, followed by a chapter presenting findings from the other five participants.

For the detailed narratives I have chosen those from Rahma, Gina and Penny because of their markedly different perspectives as to the influences on their development as teachers of mathematics. Coming into teaching with varied mathematical backgrounds and prior experiences, they all taught children aged 5-6 in their first two years of teaching, with Rahma and Gina planning and teaching alongside a more experienced colleague in a parallel class whilst Penny planned independently. Although teaching the same aged children and all seeking for these children to develop a deep conceptual understanding of mathematics, their narratives contrast in various respects.

Rahma considered her proactivity and reflection on practice to be the major influence on her development. Her narrative highlights her enjoyment of mathematics and her confidence and enthusiasm as she worked closely with her partner teacher to plan and teach enjoyable contextual lessons. In contrast, Gina considered the school context to be the most significant influence on her development, both because of whole-school changes in the way mathematics lessons were taught, but also through the intense support she received following a "disaster" lesson observation. A high priority for Gina was seeking to ensure that the children she taught did not develop the superficial understanding of mathematics she had at the same age.

Penny demonstrated very strong beliefs about what makes a good mathematician and, in a school where she had considerable freedom to plan and teach as she considered most effective, aimed to guide the children to become independent mathematicians. Penny's narrative is presented differently to Rahma and Gina's in order to highlight its distinctive features: Penny created additional categories for her influence map, gave substantial evidence of the combined influences of her strong mathematical background and beliefs about what makes a good mathematician despite not linking these on her influence map, and had a unique impact on others in her school context.

Chapters 5, 6 and 7 present the narratives of Rahma, Gina and Penny, looking in detail at how their commentaries provide insight into their views of the influences on them over the first two years of their teaching careers.

Chapter 8 highlights distinctive features and themes from the other five participants.

All participants are introduced below, using data that comes mostly from each participant's first meeting, at the end of the PGCE course. All the quotes in this chapter are from Meeting 1. A shortened form of meeting number is used from Chapter 5 onwards to indicate which meeting quotes are from: M1 stands for Meeting 1, M2 for Meeting 2, etc.

For reference, a table of the participants' mathematical backgrounds is provided at the end of the chapter.

4.2 Rahma

Rahma came into teaching after completing a degree in Psychology with Cognitive Neuroscience. She started her PGCE course at the age of 22, having gained some experience as a teaching assistant.

The highest mathematics qualification held by Rahma was an A level, although her degree also contained elements of mathematics, particularly relating to the use of data. The graph she drew during Meeting 1 of her relationship with mathematics shows a steep rise in positivity from the age of 14 (see Figure 4-1). Prior to this she seems to have lacked self-efficacy as a mathematician, fearful of making mistakes in a subject she saw as right or wrong. She reflected on her attitude as an 11 year old as "*hesitant*", "*reserved*" and "*always worried that I wouldn't have the correct answer*."

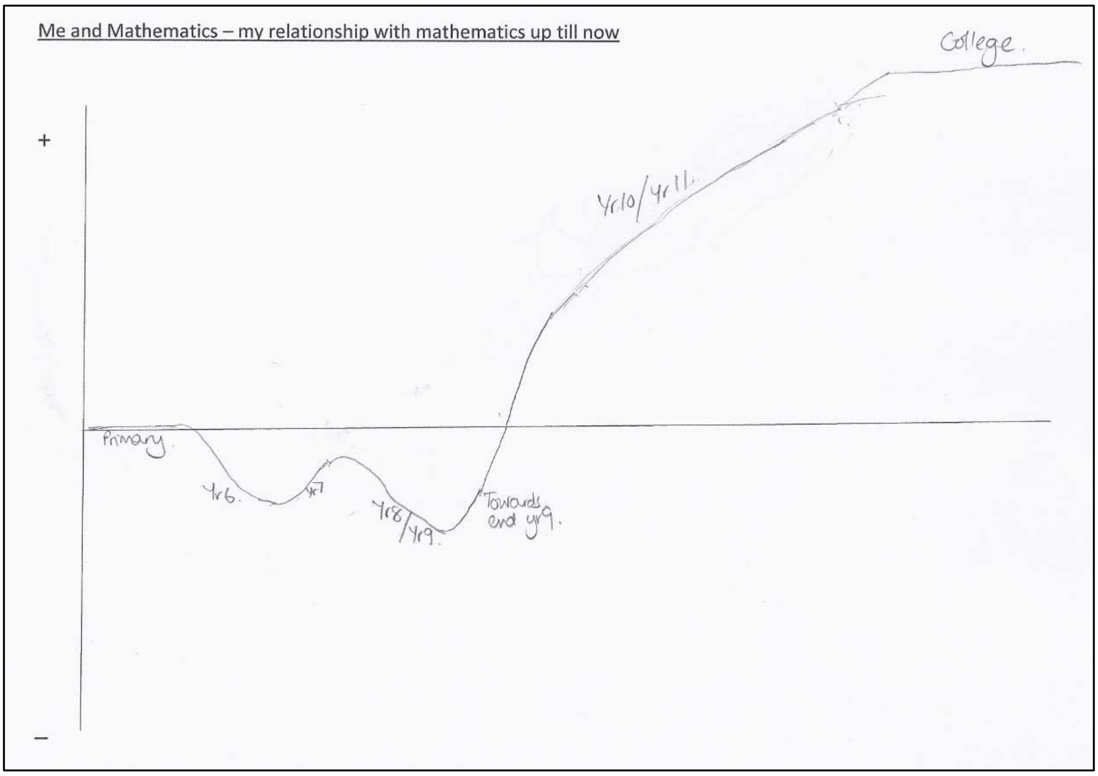


Figure 4-1 Rahma's graph of her relationship with mathematics prior to Meeting 1

Her subsequent studies for her GCSE mathematics were a time of a change in her personal relationship with mathematics from "*just memorising things*" to a situation where "*it was more of my own way of doing it", "I had that ownership to just do it by myself and make the mistakes*". Rahma continued to A level Mathematics because she enjoyed working out problems and thought mathematics would be a very useful A level. Rahma opted to take the mathematics specialism of the PGCE course, giving her some additional expertise in this area as a pre-service teacher.

For her first year of teaching, Rahma secured a job in an inner-city primary school where almost all children were of Indian heritage and most learnt English as an additional language. She was a Year 1 teacher, working with children aged 5-6, alongside Nadia, a more experienced colleague in a parallel class. For her second year she and Nadia continued teaching in Year 1.

4.3 Gina

Gina came into teaching one year after completing a degree in English. She started her PGCE course at the age of 22, having gained experience working with children, mostly in before and after school care.

The highest mathematics qualification held by Gina was her GCSE. Although she attained a high grade (A) she nevertheless seemed to have learnt mathematics superficially; she explained that she *"didn't have the understanding behind it because it was just rote"* and that by the time she started her PGCE course she was *"out of practice"* with her mathematics. It was whilst studying mathematics on the PGCE course that Gina says she developed the conceptual understanding that the literature suggests is essential to gain long term, secure understanding of mathematics (Skemp, 1976). The graph she drew during Meeting 1 of her relationship with mathematics shows a dip where she lost confidence and enjoyment in mathematics after her GCSE qualification, and a subsequent rise in interest as a pre-service teacher (Figure 4-2). Gina opted to take the English specialism of the PGCE course, giving her some additional expertise in this area as a pre-service teacher.

For her first year of teaching, Gina secured a job in a suburban Catholic primary school where most of the children were white British. She was a Year 1 teacher, working with children aged 5-6, alongside Alan, a more experienced colleague in a parallel class. For her second year she continued in Year 1, alongside Annabel, a newly qualified teacher.

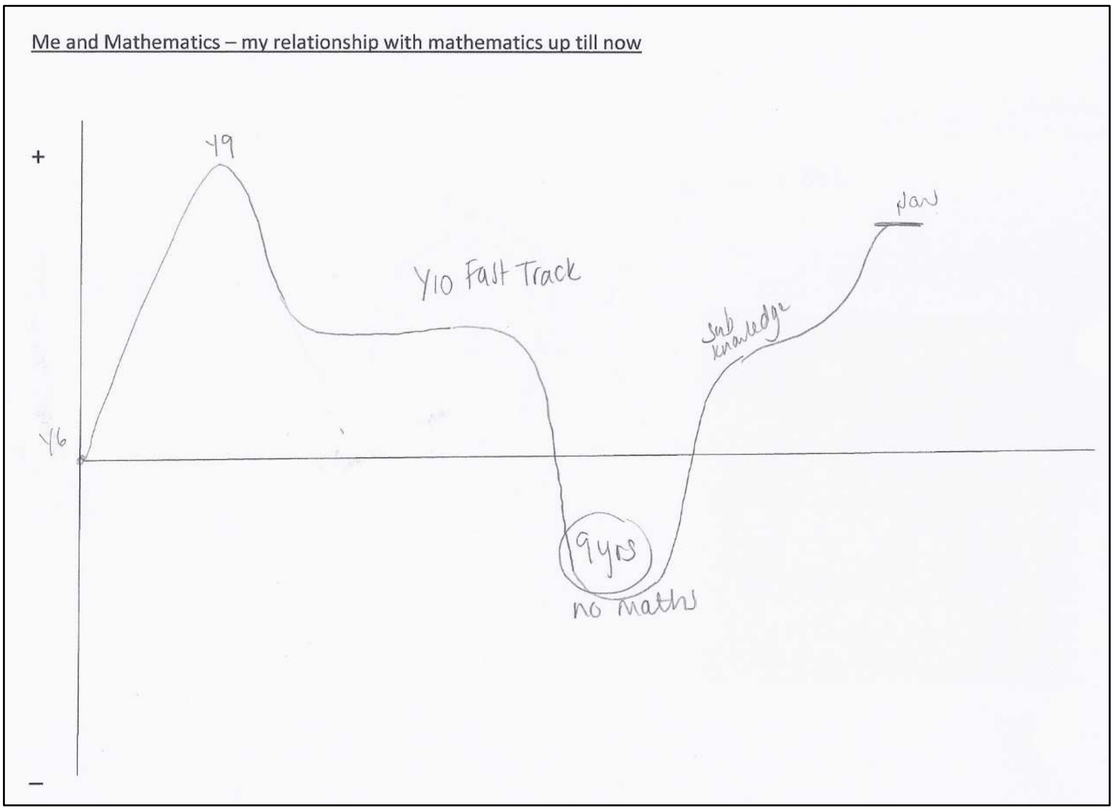


Figure 4-2 Gina's graph of her relationship with mathematics prior to Meeting 1

4.4 Penny

Penny came into teaching as a second career, starting her PGCE course at the age of 46. During her fifteen years working in the credit and risk department of a building society she used the mathematics she had gained through her undergraduate and master’s degrees in Mathematics. After subsequently volunteering in the large village primary school her children attended, she was employed there as a teaching assistant. The school benefited from her mathematical expertise as she carried out analysis on pupil data and taught extension mathematics sessions to the highest attaining Year 6 children. Penny took the School Direct PGCE route with this school and was placed in the school for two of her three placements as a pre-service teacher.

Penny’s graph of her relationship with mathematics from Meeting 1 shows a positive and upward trend from primary school onwards (Figure 4-3). She *“always enjoyed”* mathematics as a child and continued to enjoy the subject, finding interest in problem solving and modelling mathematics in her master’s degree and work in finance. Penny opted to take the mathematics specialism of the PGCE course, giving her some additional expertise in this area as a pre-service teacher; the steep rise in the graph during her PGCE course indicates her enjoyment of learning about *"the theorists".*

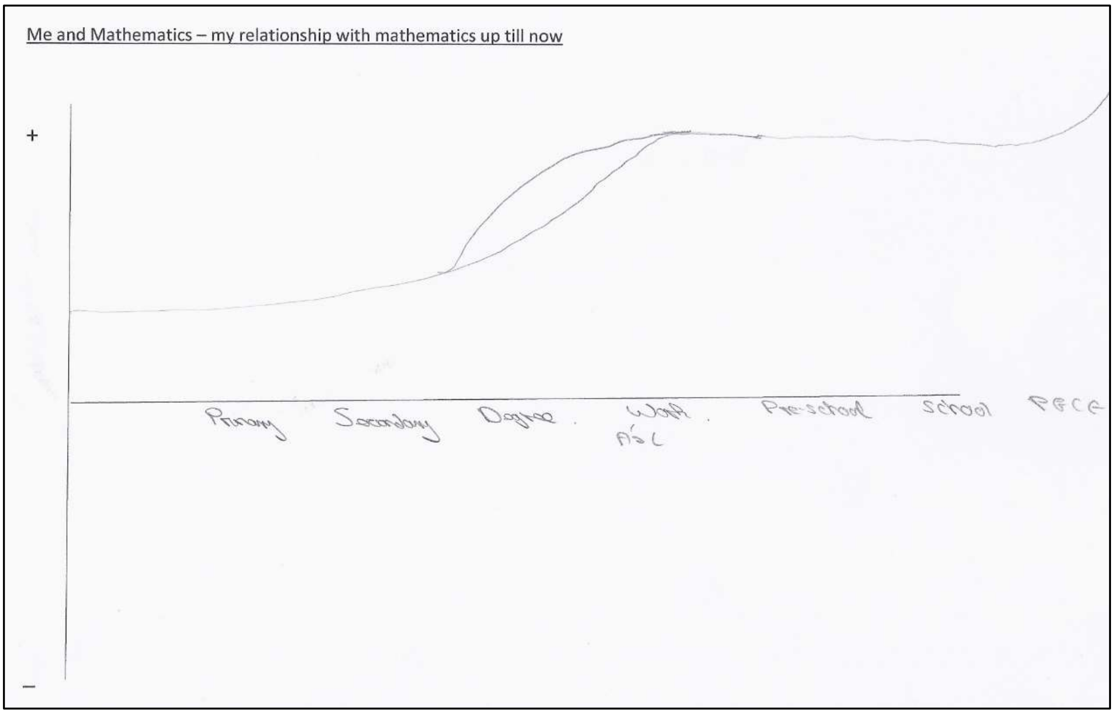


Figure 4-3 Penny's graph of her relationship with mathematics prior to Meeting 1

For her first year of teaching, Penny secured a job in the same primary school where she had been a teaching assistant, where most children were white British. She was a Year 1/2 teacher, working with children aged 5-7, alongside two more experienced colleagues in parallel classes. Children were not taught in class groups for mathematics and she generally planned her mathematics lessons independently, teaching the higher of two sets of Year 1 children from across all classes in her first year and then all the Year 1 children together in her second year, when the numbers of children of this age in the school were lower.

4.5 Orna

Orna came into teaching after gaining a first class degree in Mathematics, starting her PGCE course at the age of 21. Despite her strong background in mathematics, she had a complex relationship with the subject as a learner, as shown in her graphs of her relationship with mathematics drawn at Meeting 1 (Figure 4-4).

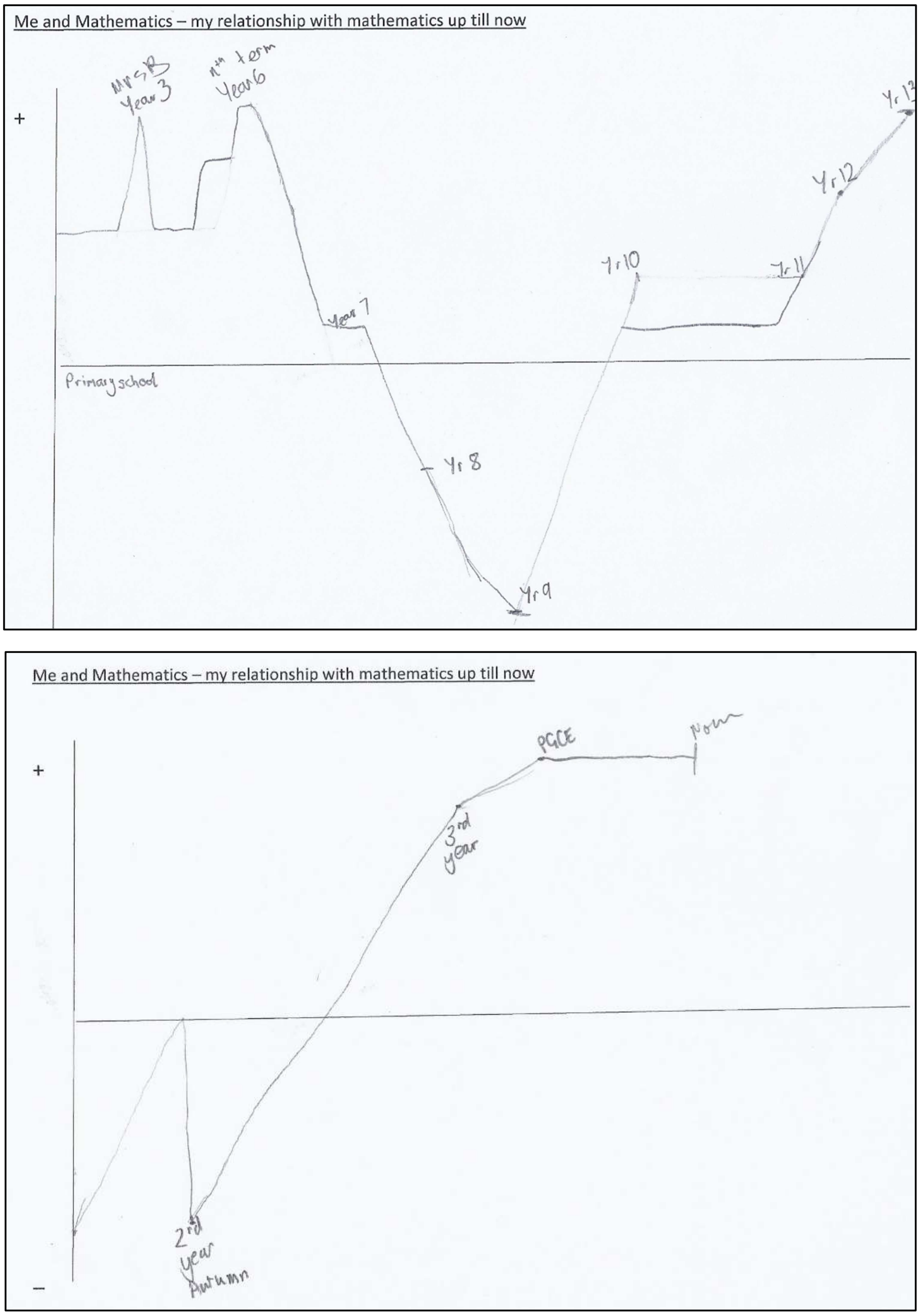


Figure 4-4 Orna's graphs of her relationship with mathematics prior to Meeting 1 – at school (above) and from the start of university (below)

Orna was clearly a very high attaining mathematician at a young age, for example, being selected for an extension project with a secondary teacher whilst still in Year 6:

> *We got to do the Year 9 SATs* [Standard Assessment Tests] *paper at the end of it which you wouldn't think Year 6s would find fun, but we thought was really fun.*

Mathematics in the early years of her secondary education lacked challenge to the point that she misbehaved:

> *I don't think I really did any maths, I used to not really do anything […] but the thing I liked about it was I was good at it.*

In her final two years at secondary school "*maths was more fun*" and she successfully gained a place to read mathematics at university. This section of her graph is also dramatic as at various times she was *"really frustrated", "not working as hard as I needed to", "chose modules based on which ones I thought I'd get best grades in rather than what I was interested in"* and *"disliked intensely"* the mathematics that included spacial awareness. However, she *"ended up feeling good about it"* and enjoyed studying the teaching of mathematics on the PGCE course where she took the Primary with Mathematics route:

> *It's nice to actually do things where I'm thinking mathsy rather than just thinking memorising or calculating; it's been interesting teaching the bits that I don't like.*

For her first year of teaching, Orna secured a job as a Year 4 teacher in a multi-ethnic inner-city primary school where nearly half of pupils learnt English as an additional language. She worked with children aged 8-9 alongside two more experienced colleagues in parallel classes. One of these, Liam, was the school's subject leader for mathematics. For her second year she moved into Year 5 and also taught one mathematics lesson a week to a Year 6 class.

4.6 Chloe

Chloe started her PGCE course aged 26, coming into teaching after a first career as an events project manager. She had previously completed a degree studying Geography with Mathematics following high grades in mathematics qualifications at school. The graph she drew during Meeting 1 of her relationship with mathematics (Figure 4-5) is distinctively smooth and positive, reflecting her commentary:

> *I've always had a positive relationship […] Ever since I was little, I had a strong attainment in maths […] In secondary I was always in the top set so I enjoyed maths, I enjoyed the ability to find an answer.*

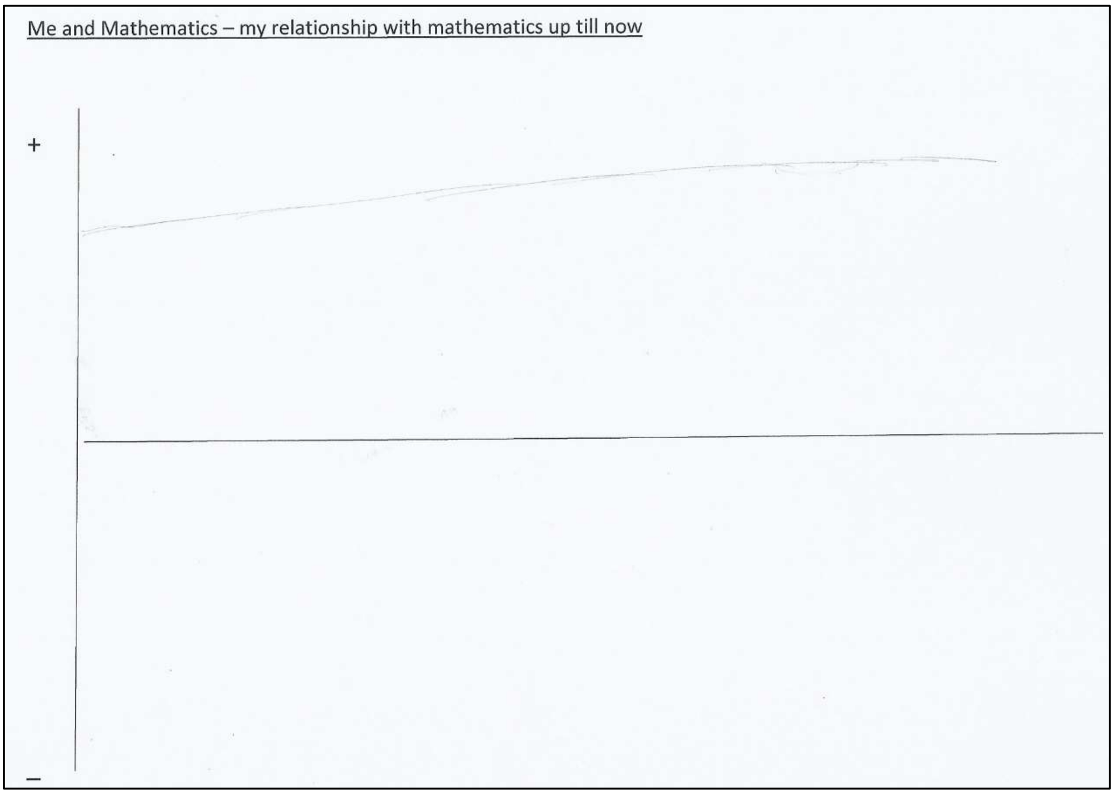


Figure 4-5 Chloe's graph of her relationship with mathematics prior to Meeting 1

Having studied engineering mathematics at degree level, she used some mathematics in her events career to *"create budgets and invoices"* and took the Primary with Mathematics PGCE course

> *because I do like the idea of encouraging children to like maths […] I'd like to try and make it actually enjoyable.*

For her first year of teaching, Chloe secured a job as a Year 3/4 teacher in a primary school with a large majority of white British children, on the outskirts of a small town, working with children aged 7-9. Although generally planning and teaching alongside two more experienced colleagues in parallel classes, children were set for mathematics with Chloe teaching the lower/middle attaining Year 4 children and planning independently. In her second year, the setting arrangements changed and Chloe taught one of two parallel Year 3/4 lower/middle attaining sets.

4.7 Evie

Evie came into teaching after completing a degree in History, starting her PGCE course at the age of 21. The graph Evie drew during Meeting 1 of her relationship with mathematics (Figure 4-6) shows a varied relationship with the subject, with high points in both primary and secondary schools when she *"liked it"* but dips when she found it *"difficult".*

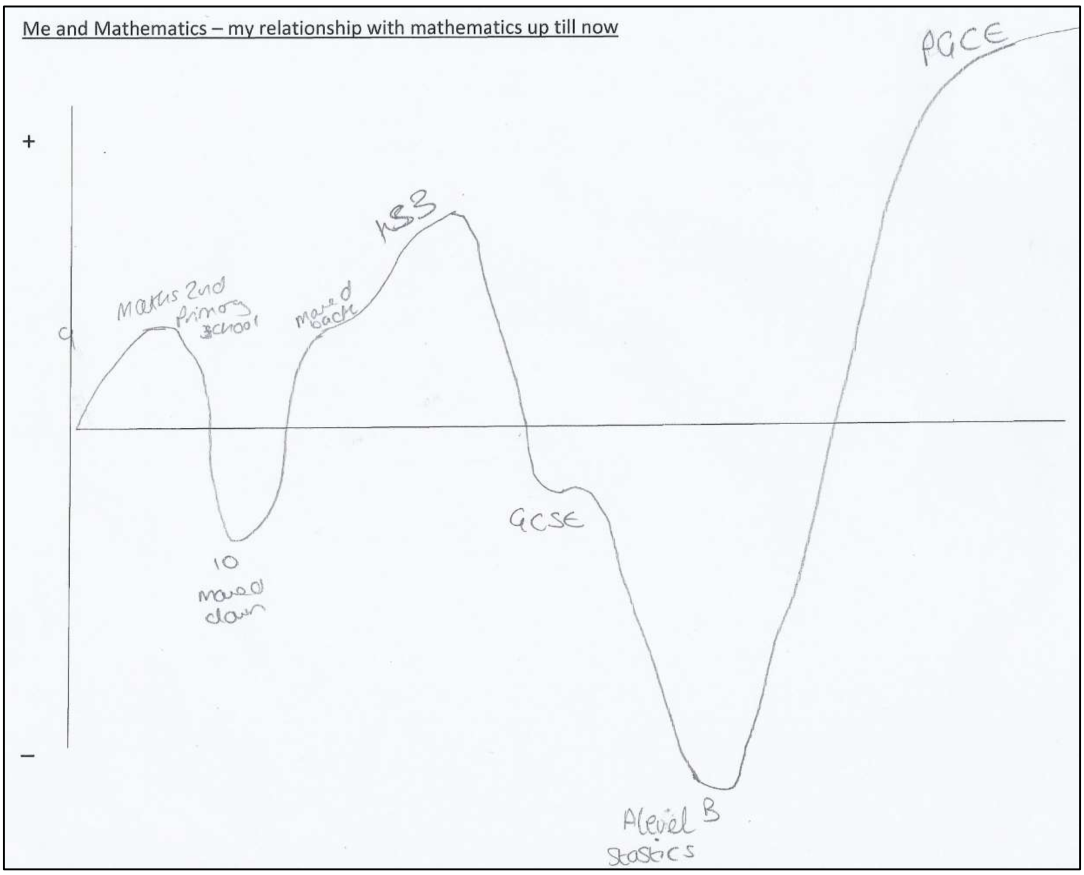


Figure 4-6 Evie's graph of her relationship with mathematics prior to Meeting 1

Evie chose to study mathematics to A level. With the benefit of hindsight and an emphasis during the PGCE course on teaching children to understand mathematics relationally (Skemp, 1976), Evie was able to rationalise why she found A level Mathematics so challenging:

> *It was really difficult and it would be a lot of hard work, tears, I'd just get frustrated that I couldn't see it, but then looking back at it from the* [PGCE] *course's perspective, I realised that up until then it was really a procedural understanding of why and I think that's why I struggled so much at A level, because I had to understand things.*

Despite this, Evie took the Primary with Mathematics PGCE course and commented during Meeting 1 on it being her *"favourite subject to teach".* With the difficulty level of the mathematics reduced, her love of the subject returned:

> *I just really like maths. I think I'm more of a logical minded person and I like that there's a set answer and […] maths is so important and I don't think children see that as much.*

For her first year of teaching, Evie secured a job in a large multi-ethnic city primary school where nearly half of pupils learnt English as an additional language. She worked as a Year 4 teacher with children aged 8-9 in a Year 3/4 phase team of five classes. Children were set for mathematics lessons, with Evie teaching one of two parallel Year 4 middle/higher sets. In her second year the setting arrangements changed and she taught the Year 4 higher set.

4.8 Rakesh

Rakesh came into teaching after completing a degree in English and using these skills in the workplace to write and review technical documents. He spent a year as a voluntary teaching assistant before starting the PGCE course aged 24.

Rakesh had the lowest mathematics qualification of all the participants with a GCSE at Grade C – the minimum required qualification for teaching in primary schools in England. The graph he drew during Meeting 1 of his relationship with mathematics (Figure 4-7) starts in Year 3 (aged 7-8) when he recalled that

> *I wasn't very good at maths, so the enjoyment was there but I wasn't very good at it.*

A specific occurrence had a lasting impact in this regard:

> *I have a very vivid memory of not being able to answer 5 times 5 is 25 in Year 3. I had a very tough maths teacher in Year 3 who made me stand up – "Why aren't you paying attention?" It was kind of an assumption I wasn't paying attention, not that I didn't know […] That started off quite a negative attitude towards maths.*

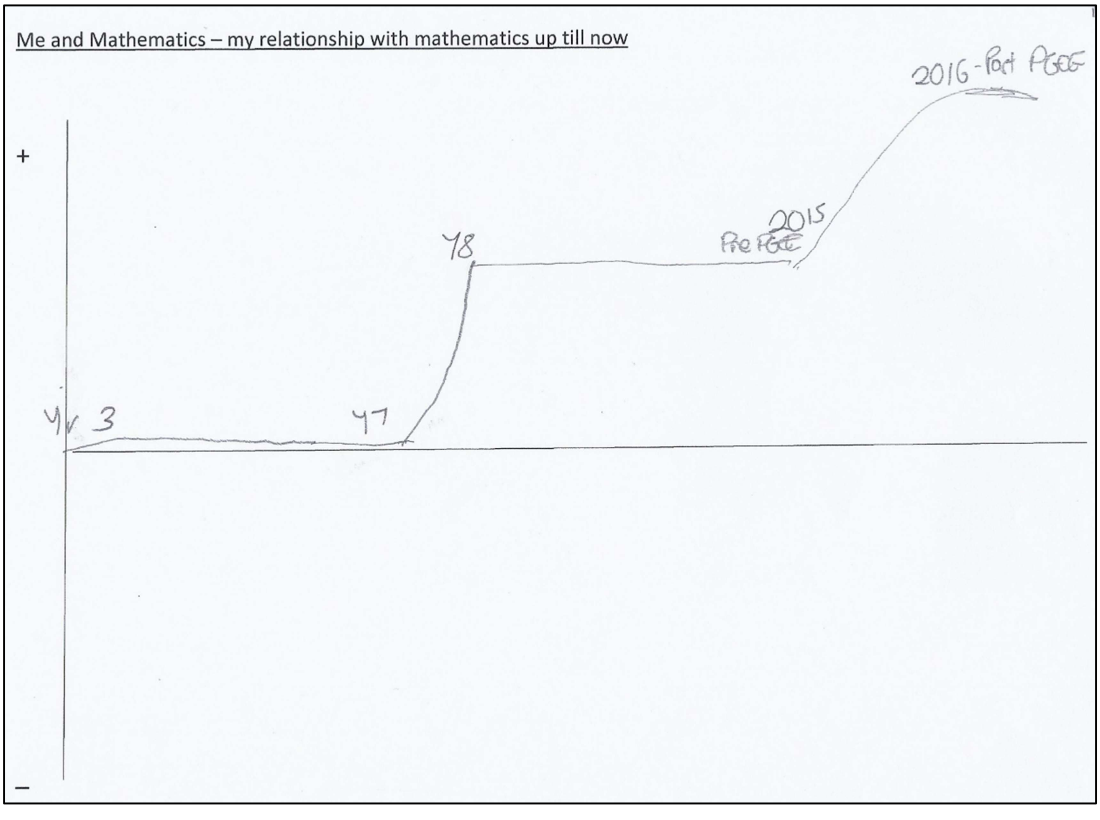


Figure 4-7 Rakesh's graph of his relationship with mathematics prior to Meeting 1

At secondary school Rakesh was placed in the first or second sets for all subjects other than mathematics, where he was initially in the fourth set:

> *I did manage to make it up to third which is where I was quite happy because I knew it wasn't my strongest subject overall.*

Rakesh's relationship with mathematics grew when working in school before starting the PGCE course:

> *I realised that I enjoyed maths teaching, which really surprised me because I came from an English background […] I think part of it is just that there are less variables involved compared to English.*

Rakesh opted to take the computing specialism of the PGCE course, giving him some additional expertise in this area as a pre-service teacher.

For his first year of teaching, Rakesh secured a job in a large multi-ethnic city primary school where almost all children learnt English as an additional language. He worked as a Year 5 teacher with children aged 9-10 alongside two colleagues in parallel classes, one of whom was also an NQT. For his second year he moved into Year 6, similarly working in a team teaching in three parallel classes and at the end of the Autumn term was asked to take on the role of temporary mathematics subject leader for the remainder of the academic year.

4.9 Emily

Emily started her PGCE course at the age of 23. She came into teaching after gaining a degree in Magazine Journalism and Feature Writing and then working in a primary classroom as a learning support assistant. The graph Emily drew during Meeting 1 of her relationship with mathematics shows a generally positive relationship with the subject (Figure 4-8). She recalled liking mathematics at primary school

> *because I was good at it […] I was very, very good at remembering maths facts and how to solve things. I liked the fact as well that once you had a method for something, you could just get on with it and do pages of sums.*

By the time she was taking her GCSEs

> *it was a lot more like investigating things and it got a lot more difficult and that's when I started to lose interest. I think as well at that point I found what I enjoyed – I was more arty, English and things like that, so maths sort of took a back seat.*

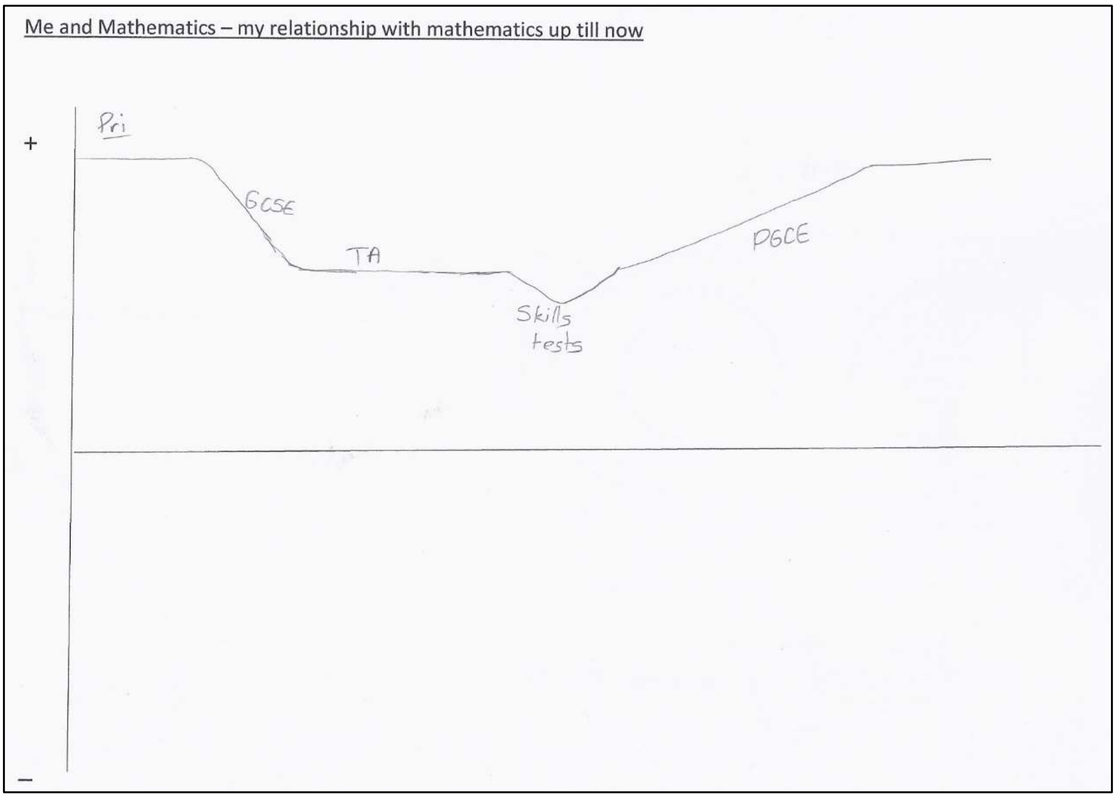


Figure 4-8 Emily's graph of her relationship with mathematics prior to Meeting 1

The skills test needed to start the PGCE course was a low point as she *"found it very difficult",* but this also started an upward trend: *"I liked the fact that I was getting it after I practised a bit*", and she enjoyed learning about teaching mathematics on the PGCE course. Emily opted to take the computing specialism of the PGCE course, giving her some additional expertise in this area as a pre-service teacher.

For her first year of teaching, Emily secured a job as a Year 3 teacher in a large village primary school where most children were white British, working with children aged 7-8 alongside two parallel classes. Children were set for mathematics lessons, with Emily teaching the middle of three sets. In her second year she taught in Year 6 and again taught the middle attaining set.

4.10 Summary chart of the mathematical background of the participants

For ease of comparison, a summary of the highest mathematics qualifications and professional work of the participants alongside their age when commencing the PGCE course, is shown in Table 4-1.

Participant	**Age commencing PGCE course**	**Highest mathematical qualification and mathematics related professional work prior to teaching**
Rahma	22	A level
Gina	22	GCSE
Penny	46	Master's degree, employment in the credit and risk department of a building society
Orna	21	Degree
Chloe	26	Joint honours degree including mathematics, employment as events project manager
Evie	21	A level
Rakesh	24	GCSE
Emily	23	GCSE

Table 4-1 The mathematical background of participants

5 Rahma

5.1 Introduction

Rahma is introduced in detail in 4.2. Having completed the PGCE course with the mathematics specialism, Rahma taught children mostly of Indian heritage in a Year 1 class alongside Nadia, a more experienced colleague in a parallel class.

Lesson observation feedback forms from senior leaders in her school show that Rahma was recognised in her school as a high quality teacher; feedback was very positive, with the summary of “making excellent progress” on both of her NQT mathematics observation forms. The formal mathematics observation in January of her second year was graded at the highest level in all areas of the teaching standards. As a consequence Rahma was asked to teach demonstration mathematics lessons to pre-service teachers: *“The headteacher and deputy said “oh you’re doing really well so it’s good that they observe you””* (M5) and to take on the leadership of the Year 1 classes alongside a teacher new to the school at the start of the subsequent academic year.

5.2 Influence map

In reflecting during her final meeting on what had influenced her during her first two years of teaching, Rahma created the influence map shown in Figure 5-1.

Rahma chose ‘My own self-imposed changes/actions through my proactivity and reflection on practice’ as the greatest influence on her development as a teacher of mathematics and overlapped this circle with her second influence – ‘My beliefs about what makes a good mathematician’. These beliefs she also linked with the impact of her school context in the form of her working relationship with Nadia, who Rahma considered to have similar beliefs. She separated the influence of her background and feelings about mathematics from the main trio of influences.

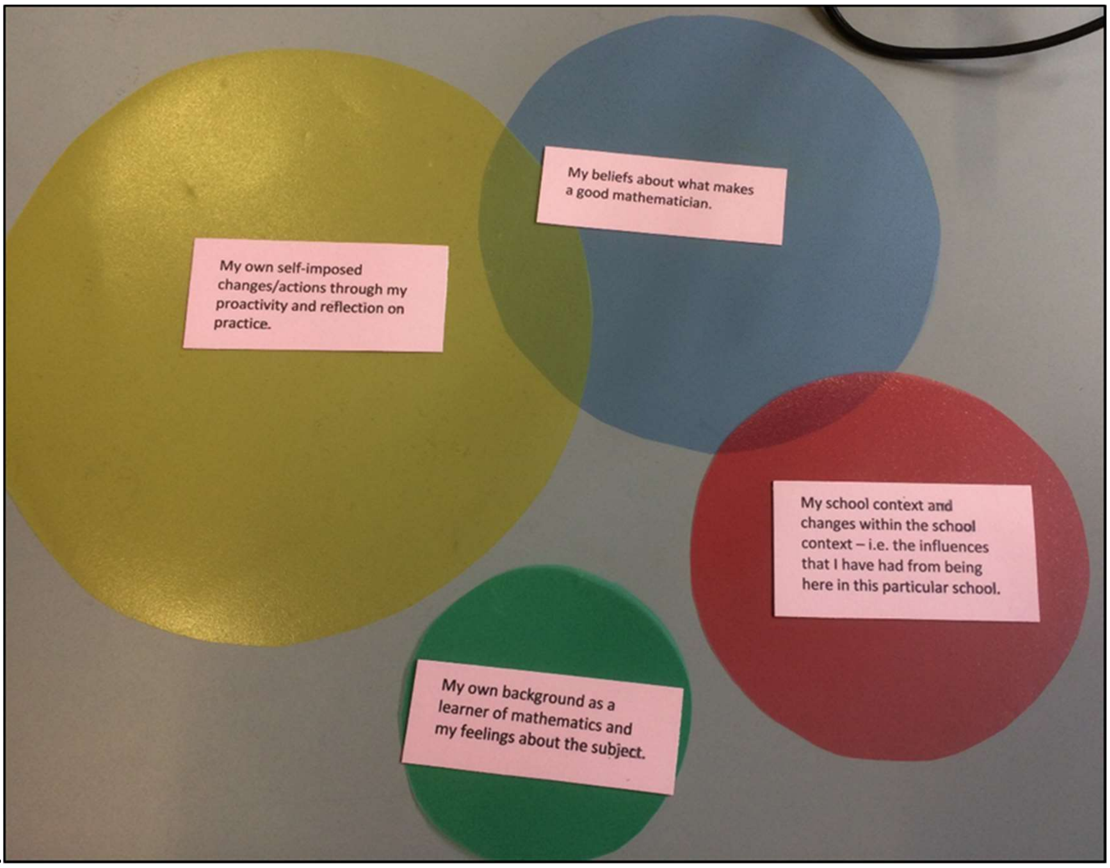


Figure 5-1 Rahma's influence map

Rahma's discussion as she created this map, alongside evidence from across her series of meetings, provides insight into her views of the influences on her over these first two years of her career. Some overarching themes are described below.

5.3 Self-imposed changes through proactivity and reflection on practice

Proactivity and reflection on practice were highlighted by Rahma at Meeting 5 as the overarching influence in her development to date. In Meeting 4 she had articulated her belief that reflection was a significant and positive aspect of her character: *"I tend to be reflective on my teaching all the time to be honest"*. In Meeting 5 she similarly commented: *"I always like to reflect on my lessons and try to make it better"* and went on to give the measure against which she reflects; *"was it right for my children"*. A year earlier she had articulated how reflecting against this measure was one lasting impact of her development as a pre-service teacher on the mathematics specialism route:

> *You're looking at what's best for the children and you're making sure that they understand it better and now I have that mind frame in my head.* (M3)

Rahma further elaborated on this mind frame as she created her influence map. She overlapped her two largest circles to indicate how her reflection was linked to her beliefs, but went beyond the prompt 'what makes a good mathematician' to link this with her beliefs about the teaching of mathematics:

> *I have my own thoughts of how to teach maths and what makes good maths and how to engage children and I want the children to have a deeper knowledge of maths; that's helped me to reflect on my lessons and drives me to make it better.* (M5)

Rahma's beliefs related to the teaching and learning of mathematics will be explored in more detail in 5.4.

Whilst at Meeting 5 Rahma specifically linked reflection and proactivity to her beliefs, connections are apparent in Rahma's narratives to both personal factors, in the form of confidence and a desire for children to enjoy mathematics, and her identified key factor related to her school context - her working relationship with Nadia.

5.3.1 *Reflection and proactivity – relationship with teaching partner*

During her first half year Rahma familiarised herself with school systems and resources, including the school's purchased scheme for planning and teaching mathematics lessons. Rahma quickly concluded that the suggested teaching approaches and children's workbooks were not in themselves sufficiently engaging, practical or creative for the type of lessons she wanted to deliver. She seemed to have persuaded Nadia that a more innovative and cross-curricular approach would be more beneficial:

> *We tend to stick to the* [scheme] *learning objective […] but we try to make it as creative as we can for our kids, so for example, we were learning about The Bear Who Couldn't Share book in English […] so we thought oh, the bear wants to […] get pairs of socks so we're trying to crosslink the two together, just to make it a bit more exciting.* (M2)

Through this approach Rahma's perception at Meeting 2 was that a shift had already occurred in the dynamics of her working relationship with Nadia:

> *I've had more of a voice of how I want to teach my lessons, whereas [...] she'd have that more at the start, she'd have that ownership of "we did this last year, so do you want to do this?" But now we've changed a lot of what we did last year.* (M2)

Rahma saw this development as mutually beneficial for the two teachers as well as for the children's learning. She quoted Nadia as saying, *"I even enjoy teaching it because it's exciting for us as well"* and she appreciated Nadia's flexibility and willingness to make changes and thus contribute to her professional development. At Meeting 3 she commented:

> *I'm still trying new things, that's what I really like about working with my Year 1 colleague because she's willing to try as well […] she's actually let me have my say and let me explore, let me have that opportunity, so I'm really grateful for her to help me develop as an NQT.* (M3)

Rahma's perception that she was in a fortunate position where she was allowed to develop her own ideas contrasts with most other participants who had less freedom within their school contexts. Her view of her relationship with Nadia also contrasts with that of other participants and their relationships with colleagues; whilst Rahma valued the opportunity to share her reflective approach, most of the others stressed how much they learnt from experienced colleagues. Rahma seemed to be a particularly proactive teacher, with the confidence that being proactive and reflective was for her an effective route to developing her practice.

5.3.2 *Reflection and proactivity – confidence and self-efficacy*

At Meeting 1 Rahma identified three key developments in her practice as a pre-service teacher of mathematics: *"adapting the lessons to suit different ages and ability in the classroom", "taking risks in teaching in different ways"* and *"much more thinking about making them* [children] *understand it*". Each of these suggest that at this early stage she was already seeking to adapt her teaching based on reflection and proactivity. Elaborating further on having the confidence to take risks she explained:

> *Sometimes it hasn't worked out the way I wanted it […] but I think because I have taken that risk and thought "let's just see how it goes" or "let's see if they are interested in this or if it works for them" [...] I have increased confidence.* (M1)

Confidence, and more specifically self-efficacy as a teacher of mathematics, was apparent in each of her meetings and was strikingly so at Meeting 1 in comparison with the other participants. As she summarised her thinking about how she learnt from both university and school-based parts of her ITE course, she gave a sense of self-efficacy in creating her own style:

> *I've learnt some bits from here, some bits from there, taken on everything and then I've adapted it to my way of teaching and understanding those children.* (M1)

In her final meeting, looking back over the previous two years Rahma talked about her confidence having further increased, here relating this to working with Nadia:

> *It's definitely been a journey where I feel more confident in myself, and I think I'm not shy to give my opinion or my ideas, which has benefitted both of us*. (M5)

5.3.3 *Reflection and proactivity – creativity and children's enjoyment*

Rahma's perception that she was positively influencing Nadia's practice was already apparent at Meeting 2. A key aspect of this stemmed from Rahma's desire to maximise children's enjoyment of mathematics.

By Meeting 2 Rahma considered that her approach had developed from *"ticking the boxes"* in terms of meeting National Curriculum objectives, to *"making it more enjoyable for the children".* Her elaboration of this approach again suggests confidence and a desire to do her best for the children, but alongside this a particular focus was engaging the children and developing their interest and excitement in mathematical contexts:

> *I think now my main priority is […] I want to make it fun for them, I want to make it a bit more exciting.* (M2)

The lesson she described as her best recent lesson at Meeting 2 illustrated this desire for children to enjoy learning mathematics. For this lesson she created a monkey character, linked to the English book the class were currently reading and their science work about animals. Illustrated with a PowerPoint presentation, she introduced doubling with her story of *"Double Trouble".* As he journeyed through the jungle, the monkey met various different animals; he asked each one for food, but being a naughty thief, took twice as much as he asked for! (Figure 5-2)

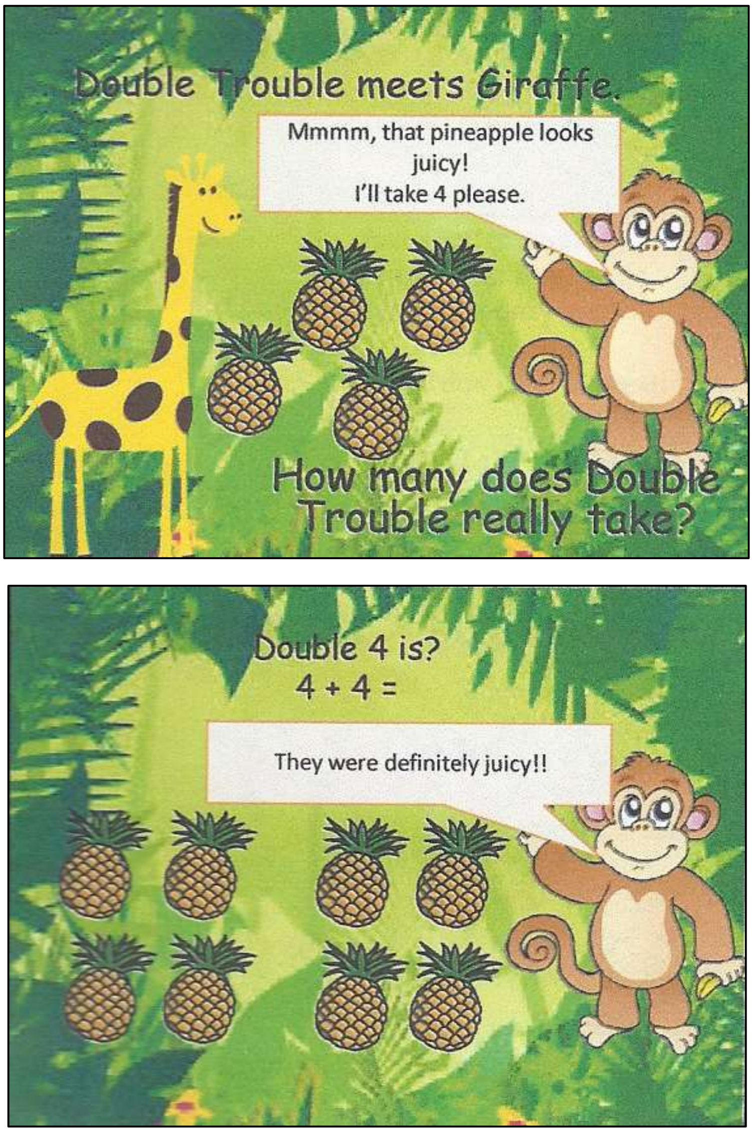


Figure 5-2 Example slides from the story of 'Double Trouble'

Rahma used a doubles bingo game after the story and then had different activities for different groups of children with the high attainers being challenged to add three numbers by spotting a double and adding the third number. Rahma's summary of why she had chosen this lesson as her best went beyond the enjoyment aspect and it seemed that she had retained the focus from Meeting 1 on securing children's understanding:

> *I think everyone was engaged and it challenged them enough for them to find that a bit difficult, but they could still do it […] everyone understood what doubling meant.* (M2)

This focus on enthusing the children in mathematics through interesting and fun contexts was one that continued throughout the series of meetings.

5.3.4 *Reflection and Proactivity - setting targets as an NQT*

During her first year of teaching, Rahma was working towards passing the required standards for a newly qualified teacher (Department for Education, 2011). In Meeting 2 she explained how as part of the support put in place by her school, she met regularly with her induction mentor, an experienced Year 2 teacher, and they agreed targets for her development. These targets are also illustrative of her reflective and proactive approach. Whilst other participants in the study presented their professional development in terms of events, Rahma's professional development record was written as a series of targets, most of which she set herself:

> *They are targets that I think for myself where I think I can improve on, just because I am always looking back at my lesson or thinking how well have I done or how can I improve and so on.* (M2)

She also identified that her targets had *"evolved"* since the start of the year, from being *"quite basic"* to becoming *"more about the children".* Rahma's professional development record gives evidence of this shift. Targets from the Autumn term included, for example, "To learn and develop an understanding of the maths scheme" and "To provide opportunities for cross-curricular links in maths", whilst later targets included: "To target specific children who have gaps in their learning" and "To ensure that I clearly show children how to use different strategies to aid their learning".

5.3.5 *Reflection and proactivity – seeking advice*

In addition to setting targets in discussion with her NQT mentor, Rahma proactively sought further advice and guidance to develop her practice and her professional position. For example, in her first year of teaching she had *"conversations all the time"* (M2) with her mentor to widen her understanding about how mathematics was taught in Year 2 and how they used the scheme resources, and in her second year she mentioned *"always"* asking the Foundation Stage leader who previously taught her class: *"Do you think this would be a good way to teach this? What ideas do you have?"* (M5). She also clarified teaching points with her deputy headteacher and the mathematics subject leader.

In her second year, weekly meetings for teachers in Years 1 and 2 were set up; Rahma valued sharing ideas with other teachers and considered this two way process *"helps all teachers to progress".* Rahma shared her ideas and sought advice, for example, *"to challenge my tops"* [higher attaining children] (M4), an area she was *"working on with my professional development"* following feedback from a formal observation.

Proactivity was especially apparent in the final term of her first year of teaching when it seemed likely she would move to Year 5 for her second year. Rahma met weekly with the subject coordinator

> *because I thought, let me prep into understanding what I need to know about Year 5 […] so I used to go to the maths coordinator and find out.* (M3)

This desire to develop professionally extended to making enquiries about potentially becoming a leader of mathematics in the school in the future, showing self-efficacy in her mathematics teaching and a desire to influence others. By Meeting 2 she had spoken to the Deputy Headteacher:

> *saying I would love to try and see what the maths coordinator's specific roles are […] just maybe it's one of those steps that I might want to go into.* (M2)

By her final meeting, Rahma had gone a step further towards this aim:

> *I mentioned it to the deputy head that if there was a chance of change or anything that I'll be happy to put my name forward […] I think I have that enthusiasm for it and I would love to help other years.* (M5)

5.4 Beliefs about what makes a good mathematician

Rahma's second largest perceived influence on her practice were her beliefs about what makes a good mathematician. Clues as to her views on what makes a good mathematician were apparent throughout her meetings and did indeed seem tightly linked to how she sought to develop her practice. Although not directly asked about what makes a good mathematician in earlier meetings, Rahma articulated her views on effective learning in mathematics.

5.4.1 *Effective learning*

During Meeting 2 Rahma defined 'effective learning' in mathematics as *"understanding the meaning of it"* and illustrated this by talking about the number five which the class were currently exploring:

> *We've done its name is five, let's tally it, let's count it, it looks like, one more than, one less than and so on […] is it odd? Even?* (M2)

She explained how she was aiming to give children *"a better understanding of that number five"* and *"broadening their knowledge".* For Rahma, effective learning was seen *"when children link everything together and apply it",* for example when responding to a question such as *"What can you tell me about this number?".*

A few months later, during Meeting 3, Rahma articulated her understanding of 'secure learning' in mathematics with the support of the concept cartoon shown in Figure 5-3.

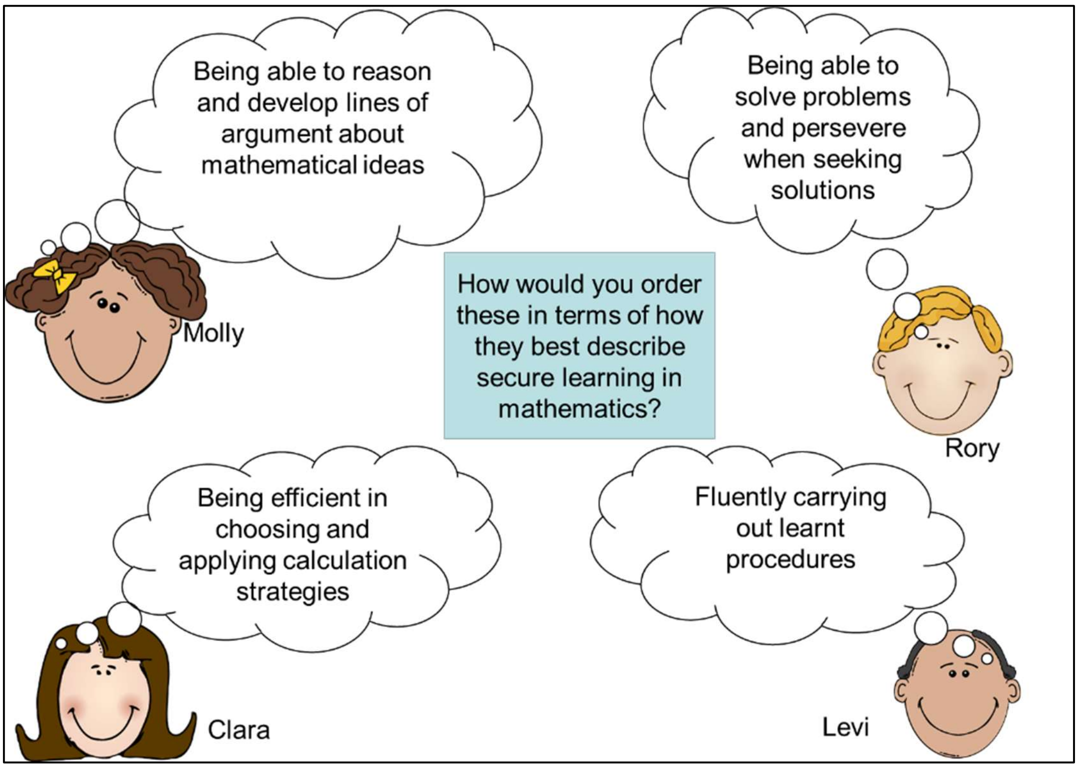


Figure 5-3 'Secure learning' concept cartoon

Rahma considered Molly's view as the best description of secure learning because:

> *That's mathematical thinking, the asking questions about it, their reasoning, why they've chosen this or why they've done this.* (M3)

She articulated how this is a precursor to Rory's idea:

> *With that I would feel they're able to, be able to solve problems and have that mindset where they're thinking, if I've not got it right, it's ok, I'm going to try again.* (M3)

Rahma's view on Levi's statement: *"There's no point in learning procedures if they've not got that understanding,* [if] *they are just following a pattern",* suggests she favours children developing conceptual understanding.

Rahma illustrated her thinking with examples of how she looked for and assessed 'secure learning' with open ended questions such as *"What can you tell me about the number sentence 3 + 4 = 7?"* She enthusiastically explained how she let the children *"go wild"* with their thinking as she looked for *"children really grasping, linking reasonable thoughts".* Other strategies she used included asking children to create their own word problems linked to their own experiences and the inclusion of games designed to develop mathematical thinking, such as *"Can you guess my […] shape, number?"*

5.4.2 ***Mastery***

Rahma's articulation of her thinking was further developed in later meetings. During Meeting 4, for example, she talked about the 'mastery' questions which had recently been introduced in the mathematics scheme and that she was using to assess the depth of understanding of her children. Rahma's definition of mastery matched closely with her exposition about Molly's definition of secure learning above:

> *Finding different ways where there is no <u>one</u> answer, it's different possibilities of their answer, but it's their reasoning of why they've said this.* (M4)

Rahma showed me an example of this 'mastery learning' from a child's book headed "What's the same and what's different about these shapes?" (Figure 5-4):

> *So, it's trying to think of the different ways so that they can explain their answers […] So this person's understood there's another way of actually finding an odd one out. So, I think for me it's more about their explaining why they think this.* (M4)

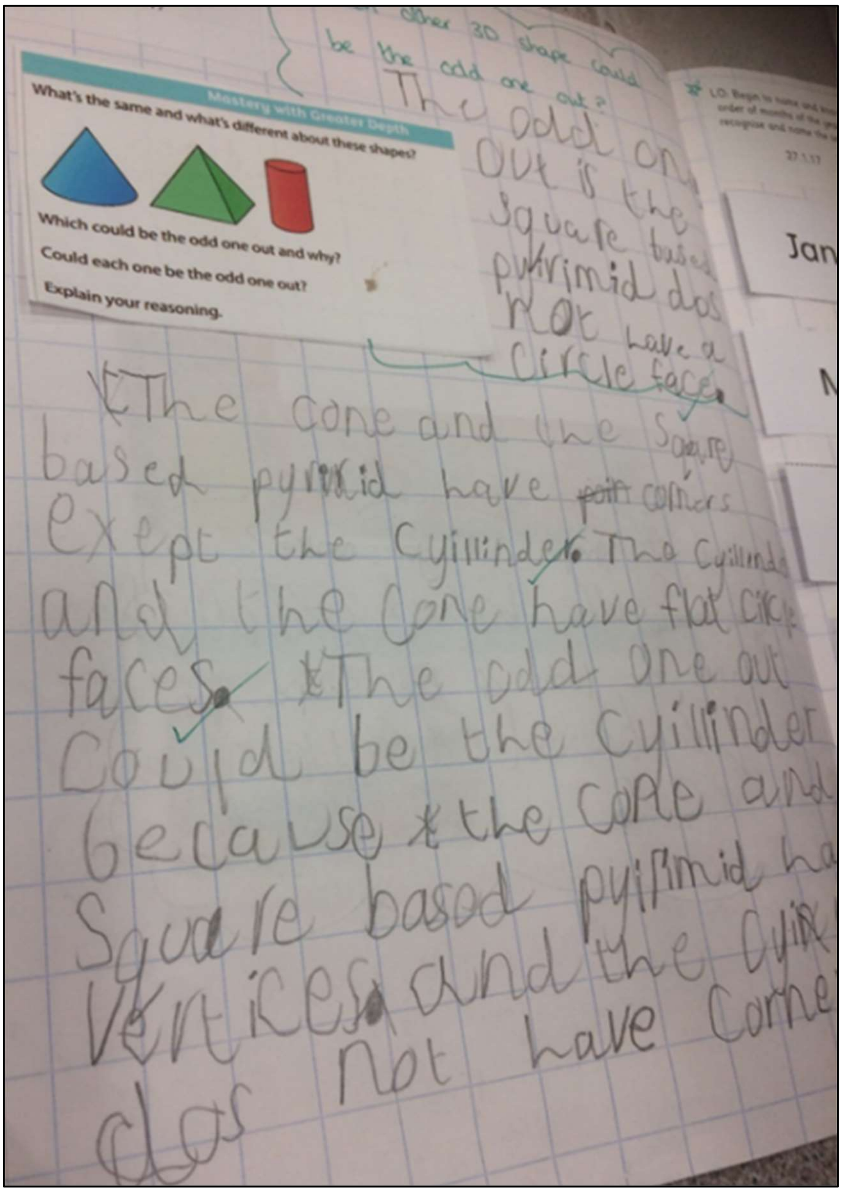


Figure 5-4 'Mastery learning' example

Rahma's inclusion of these types of questions within her lessons suggests that she agrees that the skills and understanding needed to solve them are aspects of what makes a good mathematician.

Reasoning and 'real life' application were particular features of discussion in her final meeting, along with increased emphasis on fluency, particularly of number bonds, so that children could fluently apply their knowledge of number facts to addition and subtraction. The lesson she described as both her best and her most challenging involved a creative approach to teaching capacity to address misconceptions that had been apparent when teaching the topic during the previous year. The context of Harry Potter making potions helped the children *"better understand the vocabulary"* of capacity and group discussions encouraged reasoning with each other as they made estimates:

> *When they thought* [about] *the estimate, when they had very contradicting answers, they themselves were thinking "How can it be 15 cups?" – they were asking the question to the other person.* (M5)

5.4.3 *Disposition*

In Rahma's final meeting there are also clues as to the dispositions she considered effective for a good mathematician. She talked about developing positivity and resilience as mathematicians – using creativity to *"engage the children"* and supporting their mindset in relation to right and wrong answers: *"It's ok to make mistakes and to be honest - with those mistakes you learn better".*

She also discussed encouraging the children to challenge themselves with questions designed to further extend their thinking, using the language of challenge:

> *The children will tell me "I want the challenge" or "I'm ready for this". It doesn't matter what ability they are, they all feel they can get that challenge.* (M5)

She talked too about children taking ownership by asking each other questions and that a good mathematician has a mindset where:

> *it is ok to make mistakes – you learn better and you can find out an easier way to work something out, or you can question why that worked and why that didn't.* (M5)

This resilience was an element of being a mathematician that Rahma herself developed during her later years at school and which she discussed in depth during her first meeting.

In summary, Rahma would recognise a good mathematician as a positive and resilient person with conceptual understanding of mathematics and well-developed reasoning and problem solving skills so that they can apply their understanding in different contexts. As Rahma explained when creating her influence map, it is this interpretation of what makes a good mathematician that formed the basis of her reflection and proactivity, and her discussions with her Year 1 colleague.

5.5 School context and changes within the school context

The particular element of school context Rahma mentioned when creating her influence map was that of working alongside Nadia in Year 1, as explored above. Also previously discussed are the influences of others in school who she worked with and approached for advice. Rahma *"definitely"* felt well supported by her school during these first two years of teaching.

Little change seems to have taken place in Rahma's school context in relation to the teaching of mathematics over the two years of research; in both years she taught mathematics to a mixed-attainment class in a school where almost all pupils learn English as an additional language, although in her second year she taught more children who were *"completely new to English"* and some who started school without having attended the Foundation Stage. Slight changes to the scheme used and the setting up of the weekly Key Stage 1 meetings were particular school developments mentioned. These limited changes contrast with the experience of other participants in the study, most of whom saw significant contextual changes.

Despite limited change, Rahma recognised an increased focus on mathematics in the school during her second year due to a drive to *"improve their maths scores because last year we did better in English"* (M4). Consequences of this school focus were that all teachers were observed teaching mathematics and teaching mathematics was a greater focus of discussion between teachers:

It makes you realise "Ok, how can I teach this better" or, you know, "What did you do in your lesson to teach this?" (M4)

Rahma seemed to view her school context as a community in which she had the opportunity to both learn from and influence others. The wider influence of the school context goes beyond Rahma's main point about the influence of working alongside Nadia, and although not as significant as for most participants, seems to clearly link back to the influence of proactivity and reflection on practice.

5.6 Background as a learner of mathematics and feelings about the subject

Whilst Rahma considered this to be the smallest of the four influences on her influence map because she felt she had *"grown as a person"* so much during her teaching years, she nevertheless stated this to be an *"important"* influence (M5). Unlike some of the other participants, most notably Gina, Rahma did not refer explicitly to how her background influenced her practice, but her background as a learner of mathematics and her feelings about the subject are possibly more significant than the map suggests.

5.6.1 *Love of teaching mathematics*

Rahma talked in some detail about her love of teaching mathematics and she came across as very enthusiastic and positive as both a teacher and a mathematician. In more than one meeting she explicitly stated that *"I love teaching"* (M4, M5) and, in particular, teaching mathematics. At Meeting 4 she explained how, because she finds mathematics *"easier personally"* than English, she found teaching mathematics easier than English. In further reflecting on her enjoyment she also hinted at her understanding of what mathematics is about:

In some questions there are so many possibilities and I love that, I love that openness about it. So that's probably why I enjoy maths. (M4)

At Meeting 5 she also articulated how she felt her enthusiasm and creativity impacted on the children she taught: *"I think teaching in creative ways they love it, they absolutely love it"*.

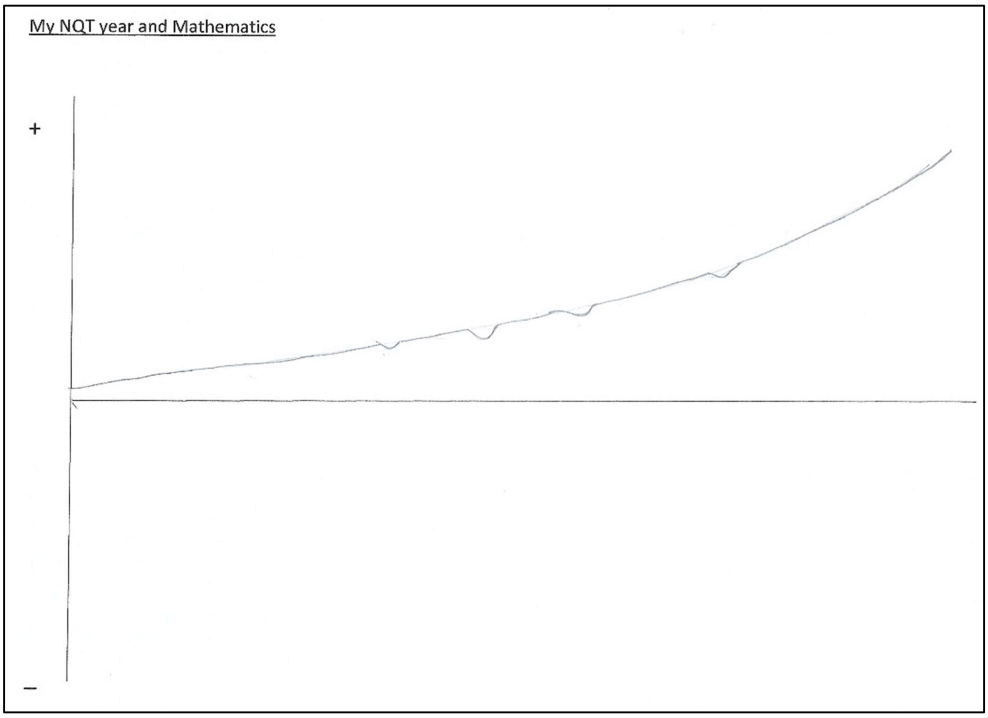
5.6.2 *Background as a learner herself at primary school*

Rahma's positivity about teaching mathematics contrasts with her experience of mathematics at primary school. Mathematics for Rahma was a subject that had been linked in the past with anxiety and negativity but, as detailed above, she particularly stressed the importance of positive experiences of mathematics for her pupils. She wanted her children to enjoy mathematics and recognised the importance of *"not being afraid of numbers"* but rather understanding that *"it's OK to make mistakes"* and *"have confidence to play with numbers"* (M1). It seems that she was keen that her pupils followed a smoother path to mathematical enjoyment than she had herself.

5.6.3 *Relationship with mathematics as a teacher*

Rahma's graphs of her relationship with mathematics over her first two years of teaching show for each year a strong and growing relationship with the subject as a teacher Figure 5-5. When drawing the final graph, she explained:

> *I think it's always progressing and there will be certain lessons where I feel like it didn't go as well as I wanted it to be, or maybe I should have taught it in a different way […] so consistently going up.* (M5)



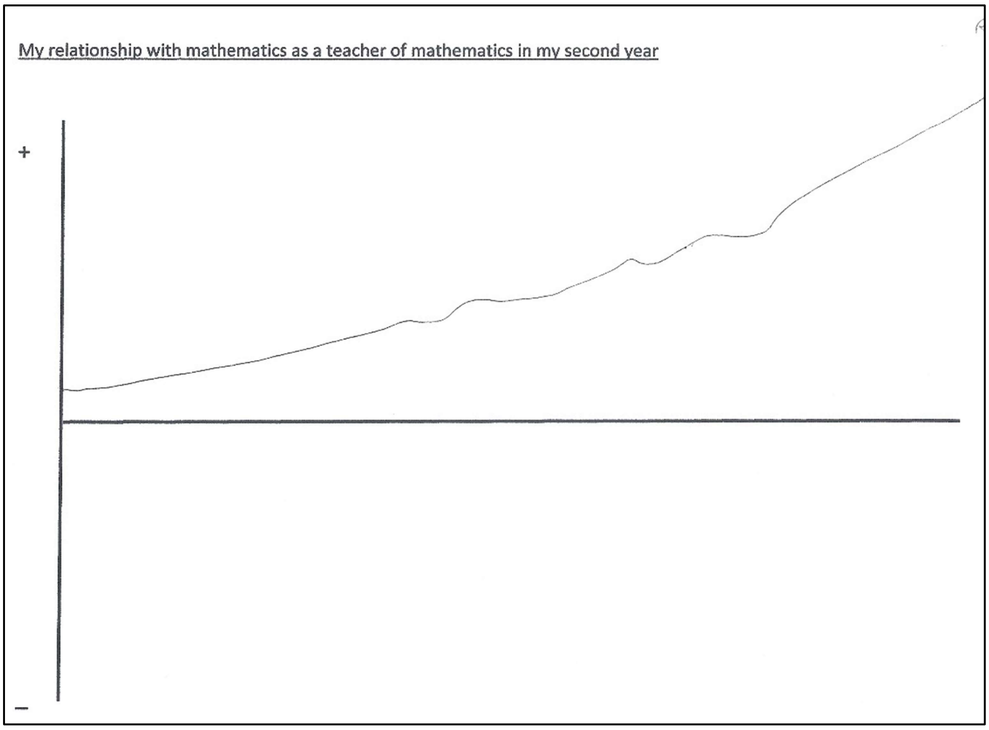


Figure 5-5 Graphs of Rahma's relationship with mathematics from her NQT year and subsequent year

5.6.4 *Subject knowledge*

Having studied the subject to A level, one would expect Rahma to be confident in her subject matter content knowledge. Rahma continued to develop her subject knowledge as a pre-service teacher, taking the mathematics specialism of the PGCE course and proactively looking to develop her subject knowledge more specifically for teaching. Her record of her subject knowledge development as a pre-service teacher evidences the conscientiousness with which she approached researching areas of the curriculum and appropriate teaching strategies and how she practised herself the questions she would use with the children she taught.

At Meeting 1 Rahma's views of what mathematics is suggest a breadth of awareness of the subject beyond that of most of the participants and, at this early stage in her teaching experience, reflect the views she later articulated about the qualities of a good mathematician: *"Mathematics is literally playing with numbers […] understand, reason with those numbers"*. At Meeting 2 she added: *"it applies to everything in some sense and it's allowing children to explore those ideas really"*.

Evidence of Rahma's perceptions of her own subject knowledge comes from her arrangement of cards related to her subject knowledge on a concentric circle board during Meeting 4. Asked to place cards with her particular strengths towards the centre and those she considered less strong towards the outer edge, Rahma placed all of the cards within the two central circles, suggesting confidence (Figure 5-6). The particular strengths she notes are ones that go beyond having strong subject matter content knowledge and suggest self-efficacy with planning and teaching mathematics: 'Choosing examples' is strong

> *because now that I know their expectations […] I can work backwards and think […] how to make that progress to reach that.* (M4)

'Responding appropriately mathematically to unplanned, unexpected questions and ideas from pupils' is strong because

> *in particular my more able, they tend to be the ones that ask the questions […] and then we discuss about a particular thing that's come about.* (M4)

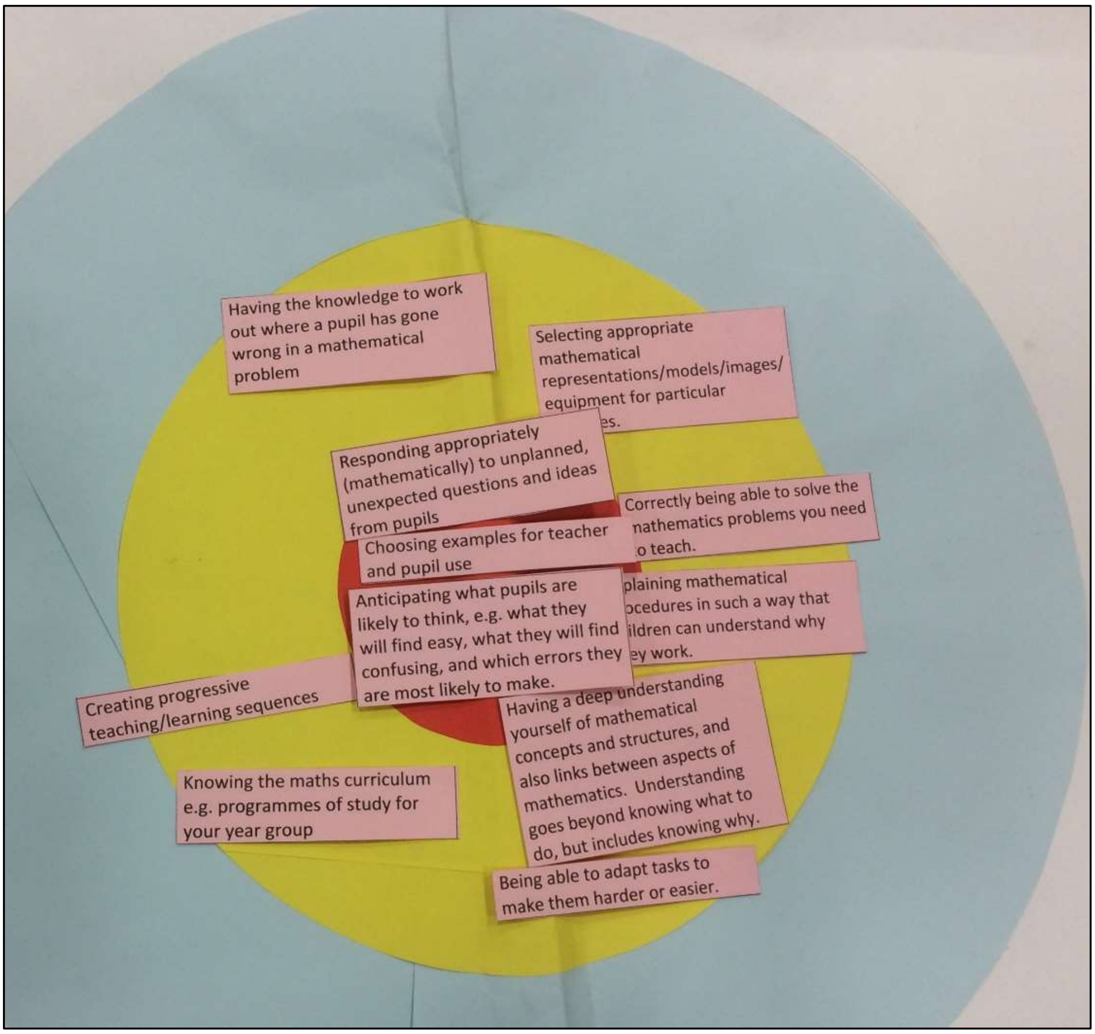


Figure 5-6 Rahma's subject knowledge statements organised by strengths

'Anticipating what pupils are likely to think':

> *That is something me and my colleague, we spend far too much time talking about […] so that's something that's one of our strengths.* (M4)

These aspects of subject knowledge strength fit closely with Rahma's summary of how the conceptual understanding she aimed at developing for all her children was a major influence on her thinking in the planning process:

> *I always try to think – will they really understand this? What's the basic? What's the root? I don't want them to learn the skill of just calculations or a routine of 'this is how it is' or just notice the pattern – get them to really understand why the pattern is like that.* (M5)

An example of this in practice is the doubling lesson described in 5.3.3 above where the context used complemented rather than distracted from the mathematical relationships involved. These relationships were depicted with the structured layout of the food items on the slides (Figure 5-2, page 131).

The lesson that Rahma described as her most challenging at Meeting 3 demonstrates the subject knowledge that enabled her to creatively adapt her teaching on an occasion when the children's responses took her by surprise. Teaching her class to halve odd numbers, Rahma demonstrated how to share an odd number of playdough balls between two people by cutting one in half. When children were subsequently carrying out this process themselves, *"they were halving correctly"* but counted each half-ball as one *"because they didn't see it as half".* Hence halving five, *"they were counting it as three things, but it's two and a half".* Thinking initially this was because their playdough balls were *"not formed correctly"* she turned to using grapes that happened to be in the classroom. Despite seeing the half-grapes, the children still made the same counting error. After deciding to switch to pictorial representations, she found the children were able to colour half of an odd number of circles, "*they could see it […] they got it".*

Throughout the series of meetings, Rahma's discussions of her lessons and documentation suggested overall strength in her subject knowledge.

5.7 Summary

In relation to Coffey and Atkinson (1996) categories of function, Rahma's narrative went significantly beyond the intended and explicit articulation of her immediate thoughts when asked to create her influence map. Although she articulated key points as she saw them in relation to each of the four suggested influences and explicitly focused on proactivity and the role of reflection, evidence from across her series of meetings deepens this initial perspective. It suggests a complexity and interaction between influences that hinged on her reflective nature, her desire for children to both deeply understand and enjoy mathematics and her desire to continue to develop as a teacher with a focus on children's learning. Implicit in her narrative is a sense of conscientiousness and of high and increasing confidence which combine with enthusiasm and a love of both teaching and mathematics. A strong set of beliefs about what makes a good mathematician and a drive to develop her teaching to facilitate these in the children she taught underpinned her desire to progress as a teacher within a supportive school context.

6 Gina

6.1 Introduction

Gina is introduced in detail in 4.3. Having completed the PGCE course with the English specialism, Gina taught a Year 1 class in a Catholic primary school, in her first year alongside Alan, a more experienced colleague in a parallel class, and in her second year alongside Annabel, a newly qualified teacher.

6.2 Influence map

In reflecting during her final meeting on what had influenced her during her first two years of teaching, Gina created the influence map shown in Figure 6-1.

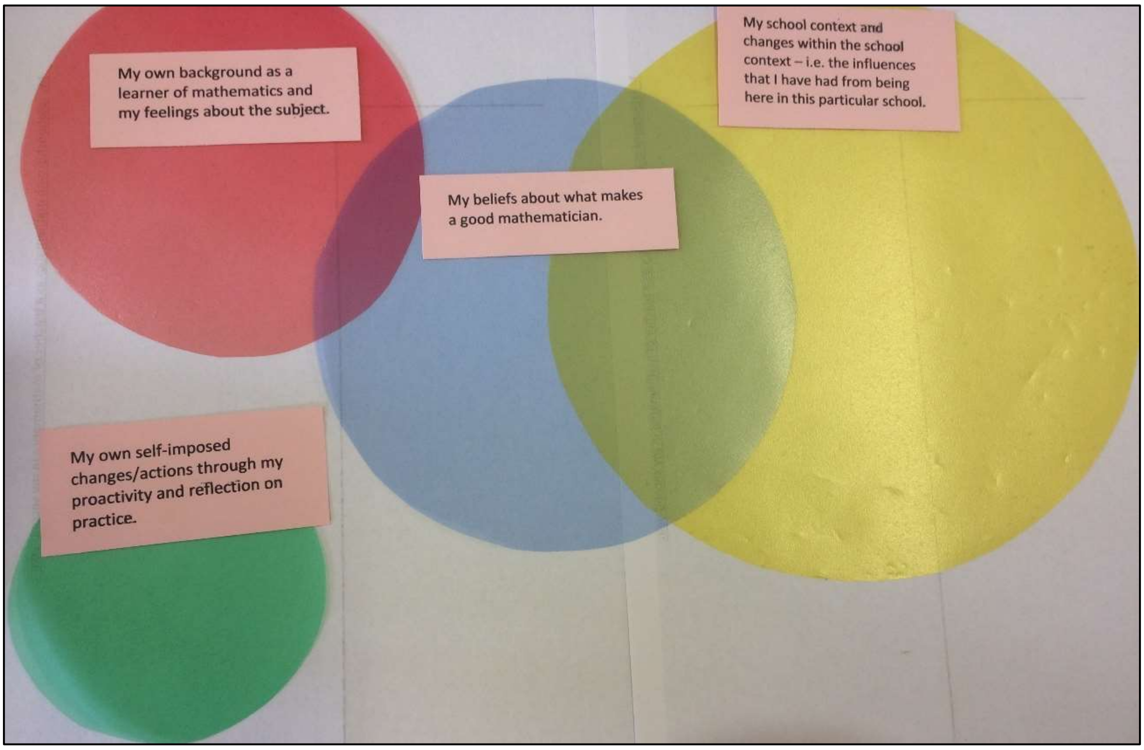


Figure 6-1 Gina's influence map

Gina chose 'My school context and changes within the school context' as the greatest influence on her development as a teacher of mathematics, overlapping this circle with her second influence – 'My beliefs about what makes a good mathematician'. These beliefs she also linked with the impact of her own background as a learner of mathematics and her feelings about the subject. Separated from these, Gina selected 'My own self-imposed changes/actions through my proactivity and reflection on practice background' as the smallest influence, stating this was *"because I haven't really thought about it".*

Gina's discussion as she created this map, alongside evidence from across her series of meetings, provides insight into her views of the influences on her over these first two years of her career. Some overarching themes are described below.

6.3 School context and changes within the school context

Her school context and changes within the school context were highlighted by Gina at Meeting 5 as the overarching influence in her development to date, with *"so many changes going on as an entire school".* These changes she *"had to follow"* and she *"couldn't really control"* them. The influence of the school is very apparent in Gina's dialogue and other influences interweave with this overarching one.

6.3.1 *School context and changes within this by Meeting 2 – whole-school training and learning from colleagues*

School-based training in teaching mathematics started for Gina on her very first day of employment with a training day for staff introducing "Strategies for ensuring mastery in mathematics across the school". From this training Gina implemented "more use of resources and children having the choice of level of work and resources they use" (NQT Record of Professional Development).

Two additional staff meetings and a session about 'mastery' at a conference for NQTs followed up this training, but at Meeting 2 she highlighted *"observing other people"* as the most significant influence on her development as a teacher of mathematics to date, particularly focusing on *"linking modelling on the whiteboard back to the task"* – Gina's explanation of her target set after a formal observation early in her first term: "Your modelling needs to be explicit and show the children exactly what they will complete in their books/independent activity" (Mathematics subject leader formal lesson observation feedback sheet). A willingness to learn from others and a desire to develop was evident in her discussion about what she learnt through this process:

> *That really, really helped and now I'm thinking about that every time I go to plan something or model it.* (M2)

and also through the way she described learning about planning from Alan, her partner Year 1 teacher at this time:

> *I compare my planning to my team member's and think, well that was good, maybe I should do some more of that.* (M2)

Gina's situation gave her the opportunity for both independence in planning and learning from Alan's plans. After an initial discussion one of them planned a topic for both classes, alternating consecutive topics. Acknowledging the need to *"prepare yourself before you teach it if you've not done it yourself",* she nevertheless welcomed the *"respite"* which resulted from not having to plan continuously (M2).

6.3.2 *School context and changes within this - impact of the "disaster" lesson*

In Meeting 3 Gina revealed the intense intervention of those within her school context following a second formal mathematics observation. This lesson was described as *"an absolute disaster"* by Gina and "not at all effective" by the observer (Mathematics subject leader formal lesson observation feedback sheet). Gina's narrative of the resulting *"rollercoaster"* second half of her first year of teaching dominated this meeting and revealed a crisis in her confidence, as shown in the graph she drew of her relationship with mathematics over this first year (Figure 6-2).

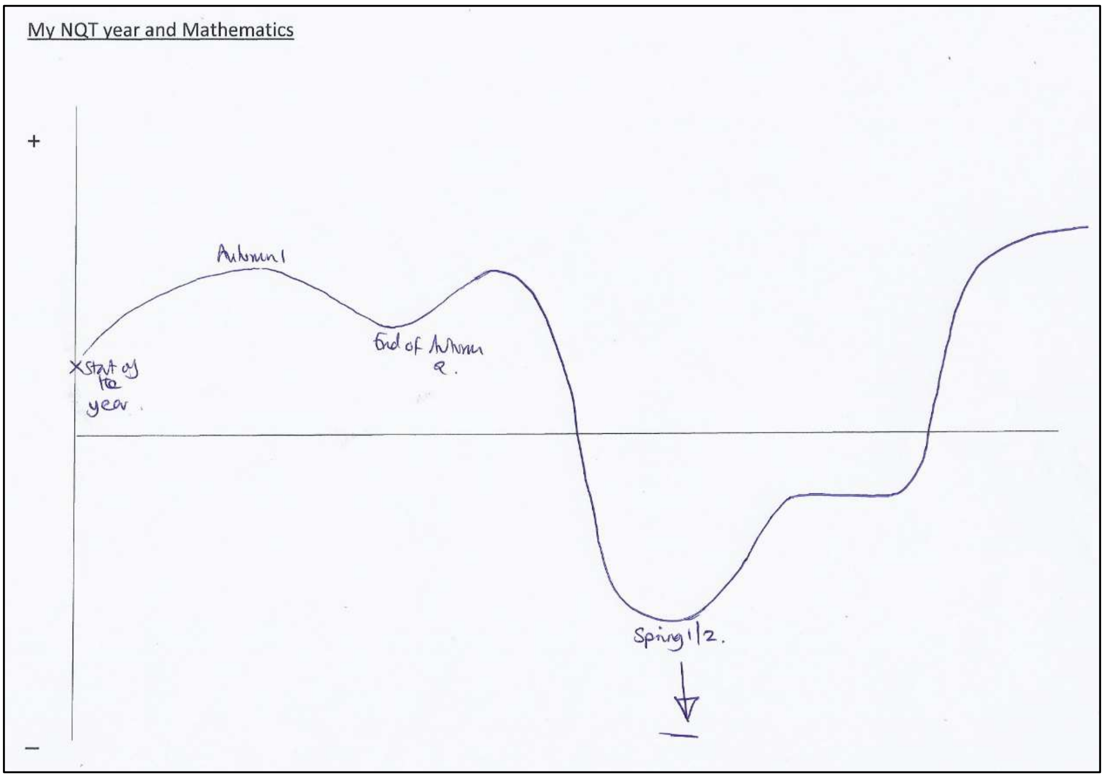


Figure 6-2 Gina's relationship with mathematics in her first year of teaching

A structural narrative analysis following Labov (1972) and Riessman (2008) is included in Appendix 6. This analysis highlights the impact on Gina of the series of events that followed on from the *"disaster"* lesson. The story unfolded in an emotional narrative, with particular emphasis on the impact of the process on her confidence and a sense of subsequently emerging from the other side of a traumatic experience:

> *There was a big period of time when I literally dreaded every single lesson, because you just think "What could happen? I don't know what I'm doing" and now it's just, it's your daily life.* (M3)

Gina needed prompting to be clear about the orientation of the story – what exactly had gone wrong in the *"disaster"* lesson, the timescale of subsequent events and the people involved - suggesting that, for her, these details were not particularly significant. However, she discussed some of the particulars of the disaster lesson and confirmed approximate dates, with the *"disaster"* lesson happening in March. The lesson had been planned by Alan, but Gina acknowledged that she was not as well prepared as she could have been and she made pedagogical mistakes:

> *Maybe I didn't know what he* [Alan] *wanted so much, so I needed to discuss that with him further. And there were silly things I did and I knew I - just in the pressure of a lesson - just didn't do. Things like counting backwards – easiest thing in the world to count backwards until you model it wrong in front of everyone and nobody's learning anything.* (M3)

As a result of this lesson, Gina had a number of further observations with formal feedback from a series of mentors, including an external mathematics consultant. The Year 1 planning was regularly scrutinised by the deputy headteacher and later the consultant, and she was given further opportunities to observe other teachers. However, Gina's dramatic account, alongside the drawing of the graph with an exaggerated dip in her relationship with mathematics and recovery period, gave evidence of Gina's thinking and perspective on her experiences as much as the actual experiences themselves:

> *I was really not very confident with it* [teaching mathematics] *at all and it seemed like no matter what I was doing to change this, I was still getting negative feedback and it was really disheartening. Really didn't enjoy that time; I was just thinking I can't do anything right, no matter what. I'm doing the things you asked me to do but I can't do any right here.* (M3)

Considering the narrative from the perspective of Coffey and Atkinson's (1996) categorisation of functions is helpful when considering the purpose of the narrative and a fuller version of this analysis is included in Appendix 7. Although the intended purpose was to answer my question about how she had developed as a teacher of mathematics, other functions are apparent in the analysis. Several aspects are identifiable relating to implicit function, and these link with the emotional emphasis identified in the structural analysis. A sample of transcript from the section of the interview where Gina drew her graph is annotated in Appendix 8 to show how implicit aspects of the narrative were identified. The selective phrases below are indicative of those building up the bigger picture of Gina's self-identity as a teacher of mathematics through the narrative and the narrative as a whole is powerful because of the combination of these phrases into a coherent overall story.

There is evidence of both a sustained negative impact on Gina's self-efficacy as a teacher of mathematics and feelings of a lack of control over events:

> *I had no sense of how well it had gone and I didn't like that feeling. I was like I'd followed the plan and done what I was meant to have done but it just wasn't what anyone wanted […] I wanted a little bit of an in between to say "but you're good at that".* (M3)

Gina's relationship with mathematics itself was affected: *"I was getting more and more, I suppose, hating maths, hating teaching it"* and she *"dreaded observations"* because *"every single time I felt like I was going to get negativity".*

However, Gina was able to look back at this period from the perspective of having recovered somewhat from the traumatic feelings. By Meeting 3 she had begun to see the value of the support she had been given: *"We* [Gina and Alan] *sort of plateaued while we were having the feedback, then I saw the benefit of it"* and end of year assessments in mathematics gave *"really nice"* data indicating that many of her class had *"made outstanding progress"* leading Gina to conclude *"I feel better about maths now".*

Gina also articulated a different perspective on teaching from Alan's planning, suggesting a growth in self-efficacy in this regard:

> *I think there's a risk in having someone more senior than you planning; you just think "well they know exactly what they're doing so I won't change this at all because this is going to be great". But it matches their style, not yours. So, this time I took it and I changed it.* (M3)

This was balanced with a feeling of still being inexperienced and knowing there is more to learn:

> *I'm just still very aware of the things I'm not so good at […] I feel like almost this year's been a trial run.* (M3)

Gina summed up the importance of her school context on her NQT year overall at the end of Meeting 3:

> *I think the school you're in, the support you have, just the things you do as a school have huge impact.* (M3)

Interestingly, despite the rollercoaster ride of her mathematics teaching, she spoke very positively about the school in general, notably relating to the Catholic ethos: *"I feel really happy here; I think that I do match the school".* (M3)

6.3.3 *School context and changes within this – changes of approach and pedagogical understanding within a collaborative learning community*

In Meetings 4 and 5 Gina detailed how the school focus on mathematics intensified during her second year with the introduction of a new whole-school approach using a purchased scheme based on a 'mastery' approach from Singapore. Continuing their focus for the previous year of *"maths mastery, greater depth and knowing what that means"* (M4), during this second year of teaching, Gina attended *"a lot of whole-school staff meetings, inset […] focused around mastery, pictorial things and resources appropriate to year groups".* Gina and her new Year 1 colleague, Annabel, an NQT who had previously spent time at the school as a pre-service teacher, *"started from scratch"* with their planning, using the scheme but also *"building in our own challenges"* and continuing with a style of differentiation where children chose from *"mild, spicy and extra hot"* levels of work. Gina described how she and Annabel had particularly valued a *"one on one session"* with the consultant about their practice: *"the most useful part – talking to someone who's not in Year 1, who's not in the school"* and by Meeting 5 they had further developed their planning style with more ideas for *"extra challenges"* with *"more time to reason, problem solve, using the bits they* [the children] *learnt* [from the scheme]*"*. At Meeting 4 Gina was very positive about the impact of the new scheme approach: *"It has been really good. Very new, lots of work, but a positive outcome."*

During Meeting 5 Gina reflected on the whole-school changes made during her second year. The sense of the school as a collaborative learning community is a stark comparison with the individualised nature of her professional development the previous year:

> *I do like when <u>everything</u> changes rather than one thing changing for one particular person. Because then at least you feel like you're all in that ship together […] Everyone's starting afresh.* (M5)

Gina felt well supported during these changes and she valued conversations with other members of staff giving an impression of collegiality:

> *We've had lots of conversations about how things are going and everyone's been pretty honest about it […] change is pretty scary because if it goes wrong, time is of the essence, but I think it's been nice that we've all talked about it.* (M5)

However, whilst drawing her graph of her relationship with mathematics in her second year of teaching, she also hinted at self-doubt and continuing lapses in confidence (Figure 6-3).

> *As we came into Spring it probably took a slight dip because we were having so many conversations […] and it was just hard to make sure you were doing the right thing […] Everyone's opinion's different on it, so it wasn't necessarily that I was not confident in my teaching of it, it was my understanding of what's expected had dropped.* (M5)

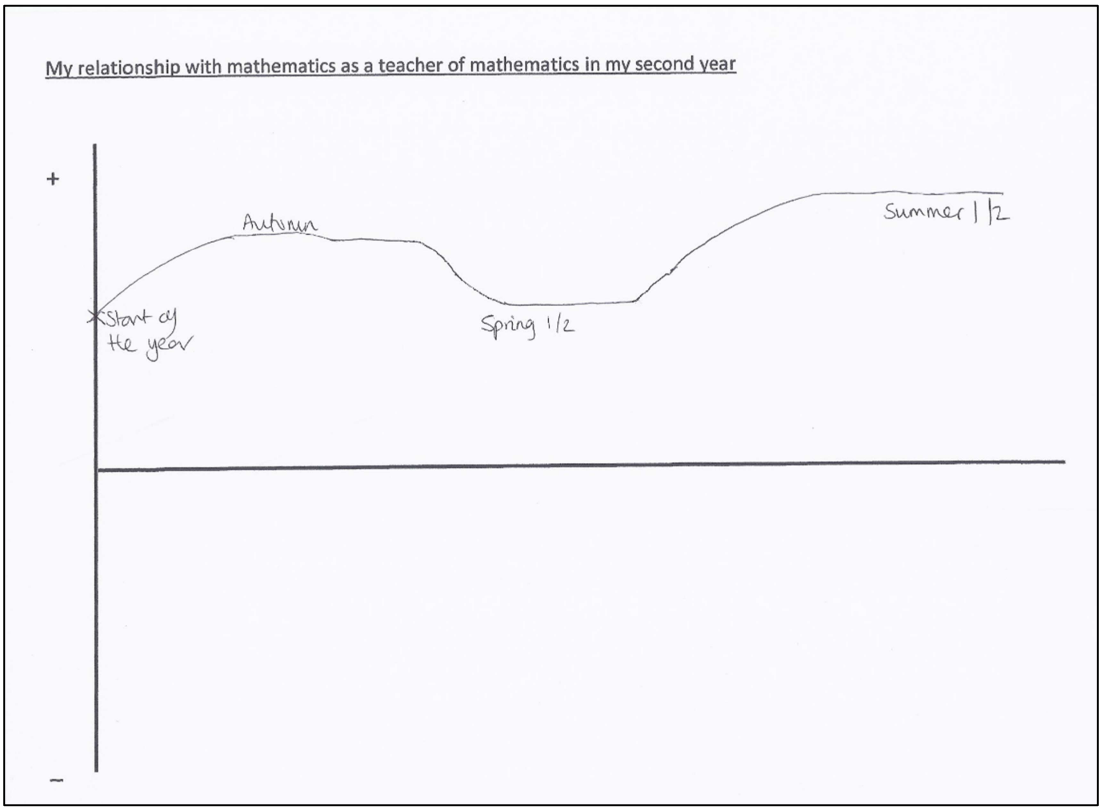


Figure 6-3 Gina's relationship with mathematics in her second year of teaching

Gina also hinted at a sense of irritation that these changes had negated some of the practice she had developed during the period of intense support the previous year:

> *There are some things that we did last year that were excellent and because we're doing things in a completely new way, it almost feels like you're reinventing the wheel.* (M5)

Nevertheless, the graph of her second year of teaching was solely on the positive side of the horizontal axis and was markedly more consistent than the graph of her first year (Figure 6-2).

Gina explicitly described the impact of the whole-school training on her pedagogical understanding and approaches in the classroom. For example, in Meeting 4 she said:

> *I've realised the importance of pictures, the importance of place value and stopping when* [the children] *don't understand because if you move on, you've lost a section.* (M4)

In Meeting 5 she explained how she expected the children to talk and reason about their mathematics:

> *I think that's probably one of the things we're strongest at actually – sometimes they haven't got the answer right but they can tell you all about why.* (M5)

6.4 Beliefs about what makes a good mathematician and background as a learner of mathematics

Gina's placed 'My beliefs about what makes a good mathematician' as the second largest influence on her practice, overlapping this circle with both her primary influence, the school context, and with 'My own background as a learner of mathematics and my feelings about the subject'. The evidence from her narratives suggests that the influence of her background intertwines with her beliefs possibly more than the influence map suggests and therefore these two influences are considered together.

When creating her influence map in Meeting 5, her own background was the influence Gina initially discussed:

> *I think my own background always sticks in my mind because I know there were things that I feel like I didn't learn well enough that really impacted me later on, so I'm very hyper aware that when children don't get something that we can't just leave them there […] Obviously it can't be the biggest* [influence] *because their experience is very different to my maths experiences […] I just got given a Letts book* [textbook] *and was like "well you've completed it so move on".* (M5)

6.4.1 ***Beliefs and background - purpose***

In more than one meeting Gina stressed the limitation she experienced of learning mathematics without understanding the purpose of tasks. *"When I was at school some people just said, "do this" and didn't tell me why; it was a case of you just did it that way.* In her view as a teacher, communicating *"why you are doing the things you are* *doing and then getting children to tell you why you are doing that"* was important to ensure that children do not just *"learn a rote method"* (M1).

In Meeting 2 Gina summarised 'effective learning' in mathematics as *"an opportunity to explore something, gain the skills and then start putting it in place"* rather than simply telling children *"we've got to do it like this",* suggesting the importance of a good mathematician not only understanding purpose but taking responsibility for their own learning; and in Meeting 3 she explained how she made up *"little 'we need to know because of this' type problems, so that the children feel it more invested"*. She discussed how children need to develop an awareness about the everyday use of mathematics: *"We are engaging with maths without knowing it the majority of the time".*

This sense of understanding purpose in mathematics parallels Gina's beliefs about the importance of children developing conceptual understanding.

6.4.2 ***Beliefs and background – the importance of conceptual understanding***

In Meeting 1 Gina explained how a particular issue with her own learning of mathematics at school was that she *"could do the methods but didn't understand them"* and throughout the series of meetings she intimated her belief that a good mathematician has understanding beyond this. For Gina, understanding mathematics conceptually was a breakthrough as a pre-service teacher – indeed she identified that *"actually understanding myself, my own subject knowledge"* (M1) was the most important aspect of her development as a teacher of mathematics during her ITE year. Especially useful were the subject knowledge support sessions she attended after weaknesses were identified through a PGCE course audit of her mathematics subject knowledge. In these sessions she was able to:

> *ask the silly questions that you've never been told the answer to, even when you should have known the answer when you were seven.* (M1)

A year later, during Meeting 3, Gina articulated her understanding of 'secure learning' in mathematics with the support of the concept cartoon shown in Figure 6-4. Her responses suggest that, for her, conceptual understanding is particularly important for a 'good mathematician'.

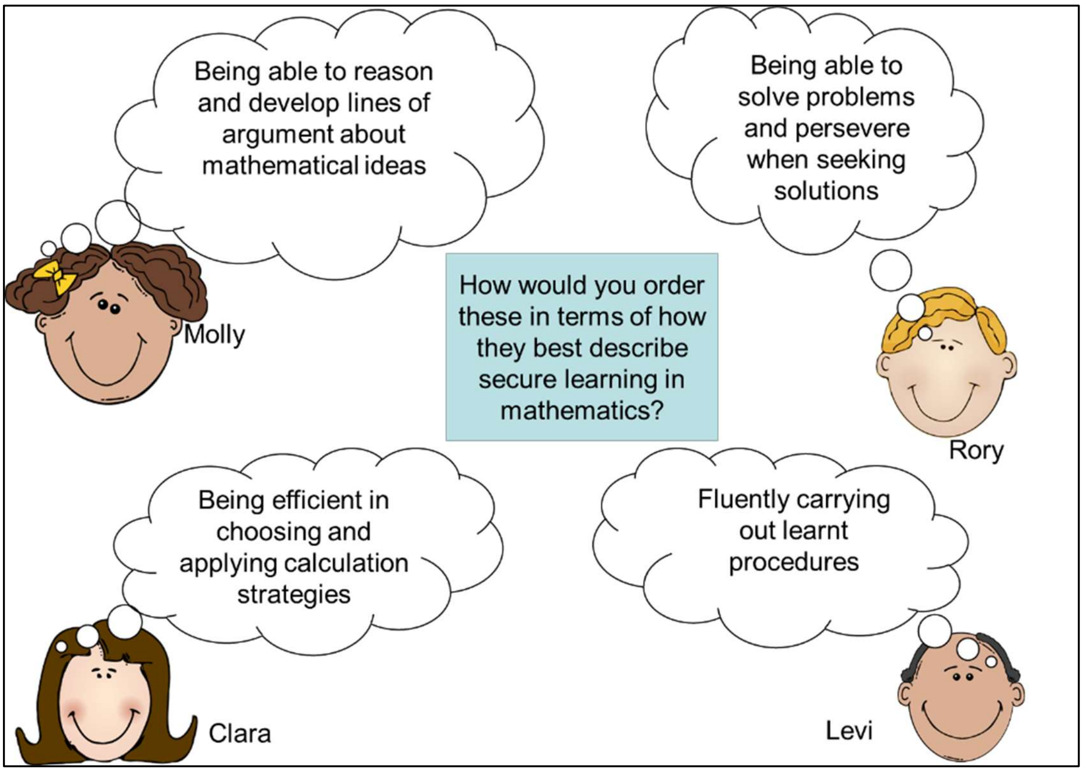


Figure 6-4 'Secure learning' concept cartoon

Gina immediately saw a connection to her own learning and established that Levi's answer was *"least secure"* because:

> *I know myself that I can carry out a procedure on something I don't understand and get it right.* (M3)

Rory's answer was *"the next level up"* because

> *They're solving problems and persevering but they're not necessarily understanding the mathematical idea behind it.* (M3)

Linking again to her own experiences as a learner, the importance Gina placed on conceptual understanding is clear in her explanation of why Molly and Clara have, in her opinion, the best descriptions of secure learning. Her comment on Molly's description was *"a line of argument so they clearly understand the concept"* and for Clara:

> *You need to be able to understand the mathematical idea in order to choose and apply a strategy most effectively and most efficiently. I know lots of ways of carrying out procedures but, unless I really understood the concept, I don't think I could choose the most efficient way.* (M3)

This emphasis on conceptual understanding is a recurring theme throughout Gina's narratives, and seemed to be the highest priority in her teaching.

6.4.3 *Beliefs and background - characteristics of effective teachers*

In Meeting 4 Gina created a visual representation of her ideas from Meetings 1-3 about the characteristics of effective teachers of mathematics (Figure 6-5) with the elements she considered most important closest to the centre of the board.

The statements overall seem reflective of Gina's desire for children to develop conceptual understanding and are teaching strategies that she considered would facilitate this aim, but her positioning of the statements gives further insight into specific elements of this process. Gina placed particular emphasis on strategies which she considered necessary *"<u>in order</u> to* [help children] *understand",* positioning these at the centre. Of lesser significance were elements which were only important *"once you understand"*, for example 'higher order questioning to develop reasoning' is *"important but useless if you don't already understand at a basic level".*

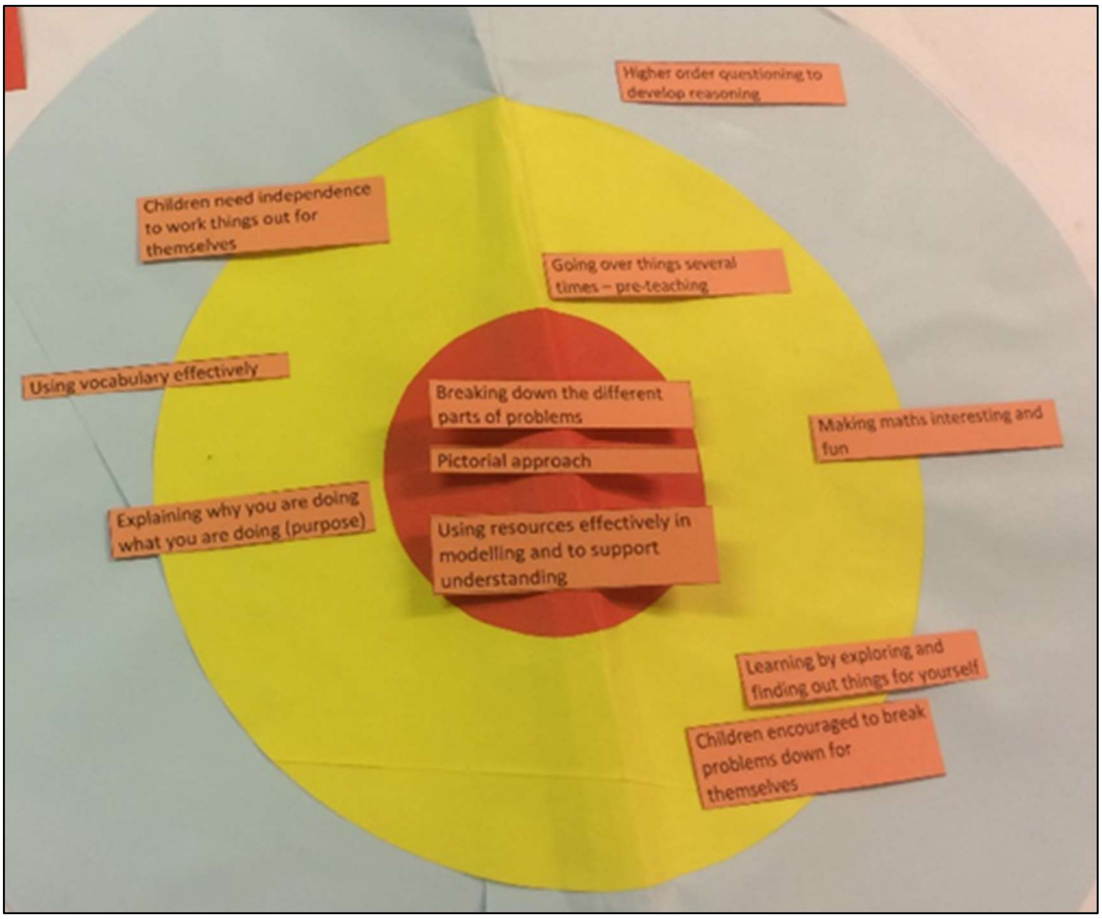


Figure 6-5 Gina Meeting 4: Characteristics of effective teachers of mathematics arranged by importance

Rearranging the statements to show her perceived strengths (Figure 6-6), gave Gina the opportunity to discuss her feelings about using these characteristics. Her comments indicated that her desire to ensure children conceptually understand was so strong that she feared using strategies where she was *"letting children do things on their own"* even though she considered these characteristics of effective teachers.

Commenting on the three statements which she placed together on the left of the board, she said:

> *I think the reason I'm not so great at them is because it's fear that they* [the children] *will not understand. I want them to be able to do that and I know they need the independence, but I don't want to give them free reign and them not understand at all.* (M4)

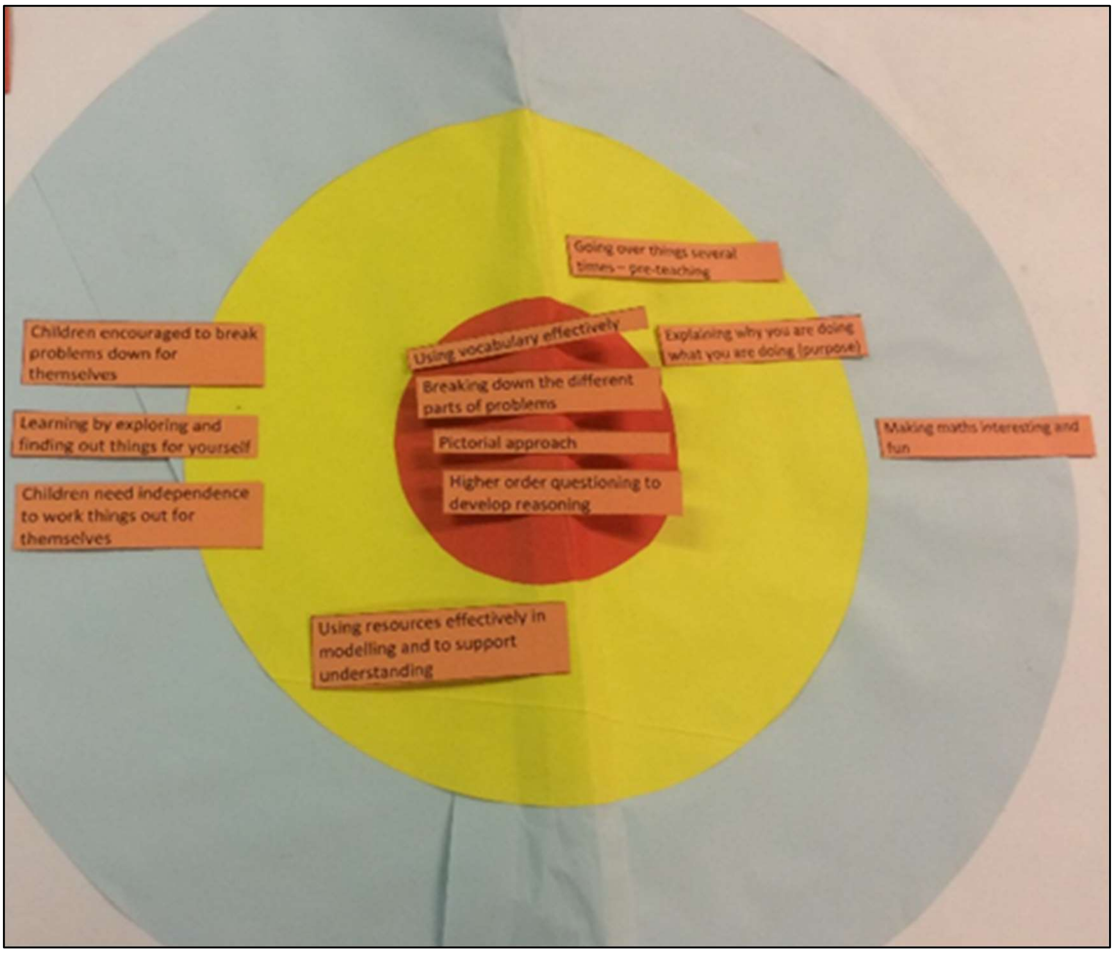


Figure 6-6 Gina Meeting 4: Characteristics of effective teachers of mathematics arranged by strengths. The strongest elements are at the centre.

Reflecting on a photograph of her concentric circles of strengths (Figure 6-6) during Meeting 5, Gina reiterated her fears:

> *I just want them to understand something. I don't want it to be that they've had that independence, they've gone and tried to find it out and they've learnt nothing. I want them to feel that they've achieved and I want to feel like they've understood.* (M5)

Following this explanation, she then reflected *"so maybe I need to give them a bit more freedom with that",* suggesting that she realised this could be beneficial.

All the participants in the study valued conceptual understanding, but Gina's views were particularly stark in the focus she gave to this at the expense of some potentially effective teaching strategies, including giving children opportunities to explore mathematics and attempting to make mathematics enjoyable for the children she taught.

6.4.4 *Beliefs and background - feelings about mathematics*

Gina's personal relationship with mathematics seemed complex. During Meeting 1 she stated, *"I've always enjoyed maths"*, despite there having been "*times when I have no idea what I'm doing with it."* As discussed in 6.3.2 she *"hated"* mathematics when she was closely scrutinised teaching it, and at Meeting 4 when comparing herself to colleagues who showed a fear of mathematics at their whole-school training, she said both *"I've never hated maths really"* and *"I did at a time when I hadn't done it for a long time – I had that same fear factor."*

Gina did not specifically discuss any attempts to enthuse children as mathematicians or explicitly state a belief that enjoying mathematics is a characteristic of a good mathematician. She did, though, include *"making it interesting and fun"* in her ideas about the characteristics of effective teachers at Meeting 1 because:

> *A lot of children really hate it, understandably* [because] *if you are not told why you are doing something it's quite confusing.* (M1)

Her views on *"Making maths interesting and fun"* evolved over the series of meetings. Gina did not mention fun specifically during Meeting 2, but she did note that she planned practical work into lessons *"exploring things, before we try and do anything written"* and that the children *"enjoy that, so they're much more happy to get involved".*

In Meeting 3 she suggested that as children's formal understanding of mathematics develops, the fun aspect needs to decline:

> *As much as it's fun to do everything physically, at some point it needs to be less fun and a bit more formal, so you know why you are doing things.* (M3)

In Meeting 4, with thinking that contradicted this statement, she reasoned that at Year 1, the priority of ensuring children's understanding of basic skills meant that *"it can become more fun in the future if you've got the ground work"*.

In Meetings 4 and 5 she reflected on her seeming inability to make mathematics interesting and fun:

> *I think I'm probably weakest at making things fun. We really have fun* [learning] *other things just not really maths.* (M5)

It was only in Meeting 5 that she gave examples of children enjoying their mathematics and in these cases she stated this was a benefit to children's learning but she was concerned about the lack of written evidence of the learning. The best lesson she described during this meeting involved taking the children outside to do some practical work to help their understanding of volume and capacity. Gina commented:

> *They really enjoyed it and we all know when we enjoy something we're more likely to remember it.* (M5)

Later she described teaching the concept of time:

> *Time they absolutely loved because we were getting up and we were clapping and estimating time and practically doing things and I realise that is a much better way to learn.* (M5)

Gina's mixed feelings about mathematics seem to have impacted on her approach to teaching the subject. She did not seem to have communicated an enthusiasm for the subject to her learners and making lessons fun was not considered a priority.

6.4.5 *Beliefs about what makes a good mathematician linked to school context*

Whilst Gina recognised the influence of her background on her beliefs about what makes a good mathematician, in particular in terms of a good mathematician having conceptual understanding and an awareness of the purpose of mathematics, she suggested in the creation of her influence map that the influence of the school context linked even more strongly with her beliefs:

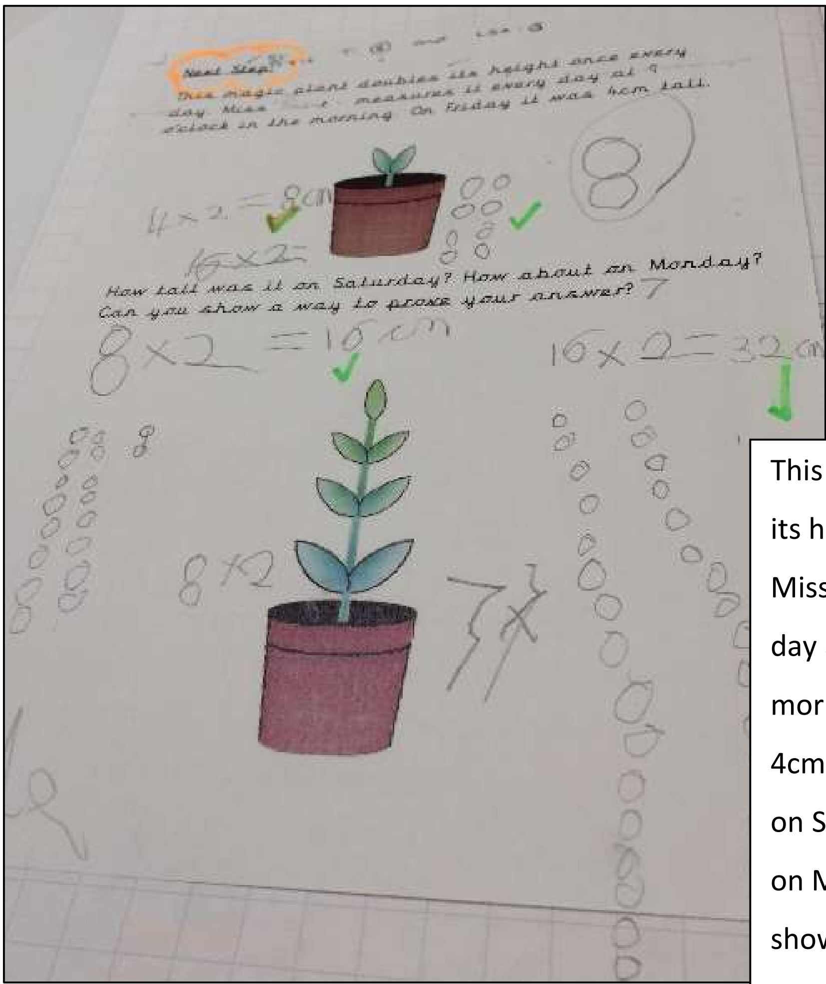
> *I am constantly believing that you need to have those problem solving skills and have your fluency embedded before you can move on, which is a big part of what we've changed as a school anyway. And that sort of links into my own beliefs anyway.* (M5)

6.4.5.1 ***Problem solving***

Gina exemplified a belief in the importance of problem solving skills most strongly during Meeting 3 at the end of her NQT year. She mentioned how she was becoming more *"fond"* of problem solving and that her practice had developed from earlier in the year when she was less confident. Her thinking then was: *"I don't want to make this hard for myself, I don't want them to not understand"* (M2). At Meeting 3 she discussed applying a problem solving approach to assessment, showing examples of using *"next steps"* to assess children's learning which tended *"to involve a problem or proving".* She explained that she gave these problems to give her better evidence of children's attainment:

> *I just found it's very easy to have lots of ticks everywhere where you encourage them to get things right and actually it doesn't tell you anything about what they can or can't do.* (M3)

Figure 6-7 shows an example of one of these problems. This problem was given to the whole class *"to gauge their understanding of depth".*



This magic plant doubles its height once very day. Miss J measures it every day at 8 o'clock in the morning. On Friday it was 4cm tall. How tall was it on Saturday? How about on Monday? Can you show a way to prove your answer?

Figure 6-7 Example of a problem used for assessment

This focus on problem solving was also highlighted when Gina first mentioned the new scheme at the start of Meeting 4. *"It's very fluency based, although there are some problem solving elements within it".* Critiquing the scheme, she stated:

> *For us, it* [problem solving] *wasn't explicit enough, so we* [Gina and Annabel] *do have extra challenges where they are using things in a different context.* (M4)

She also explained how they were advised by a consultant to include more investigations to supplement the scheme: *"we do try and use those […] even if it's once a unit just to get it in".*

6.4.5.2 ***Mastery***

Gina's statement that her beliefs about what makes a good mathematician closely link with the changes made as a school suggests that she endorsed the view that a good mathematician has achieved 'mastery':

> *Our focus for last year and this year has been maths mastery, greater depth and knowing what it means.* (M4)

When asked for her definition of mastery at this stage, Gina gave a very similar definition to her description of 'secure learning' during Meeting 3 (6.4.2), saying:

> *I think mastery is being able to unpick a problem, use a strategy that is efficient and understand why you've done it.* (M4)

She went on to compare this to rote learning, again with a sense of comparison with her own learning of mathematics:

> *You could be amazing at rote methods but if you can't establish which method you need there's no point.* (M4)

and concluded that:

> *Knowing why you're doing things, being efficient and being able to apply in a different scenario are the things that make you a master of maths really.* (M4)

However, in Meeting 4 Gina also showed some doubt in her clarity of understanding of the approach she was being trained to implement in her classroom:

> *Sometimes I'm like "Yes, I know what it* [mastery] *means" and at other times I'm "No, I still haven't got a clue what mastery means, don't know what it means".* (M4)

However, in the final meeting when asked to sum up her understanding of mastery Gina's response went beyond her previous definitions by including examples of reasoning self-prompts:

It's being able to apply the knowledge you have of maths and the fluency skills you have to a problem that's unrelated, I would say, picking up that piece of information and going "hang on, what do I need to know? What's the important thing and can I do the mathematical calculation to support it?" But it's having to understand what is this, why is it related to maths, and can I physically solve it? Once they've got that and they can tell me why, then I feel like they're moving into that mastery element. (M5)

This final statement seems to capture Gina's beliefs about what makes a good mathematician and having very rarely mentioned reasoning during the series of meetings, at Meeting 5 she considered this to now be a strength of her practice:

We do an awful lot of talking and a lot of the talk time at the start of the lesson is focused around proving things and explaining yourself rather than just answers. (M5)

Comparing Gina's statements about mastery with her diagram of characteristics of effective teachers arranged by importance from Meeting 5 (Figure 6-8) suggests that, for her, 'mastery' learning builds on the central importance of children developing a conceptual understanding of mathematics. 'Higher order questioning to develop reasoning' and 'Children encouraged to break problems down for themselves', for example, remain distant from statements of central importance.

The lessons described by Gina as her best lessons throughout the sequence illustrate this focus on securing the overriding desire that the children understand mathematics with conceptual understanding. It seems likely that Gina's articulation of her understanding about mastery is based on what she has been repeatedly told and is what she would consider appropriate for particularly good mathematicians.

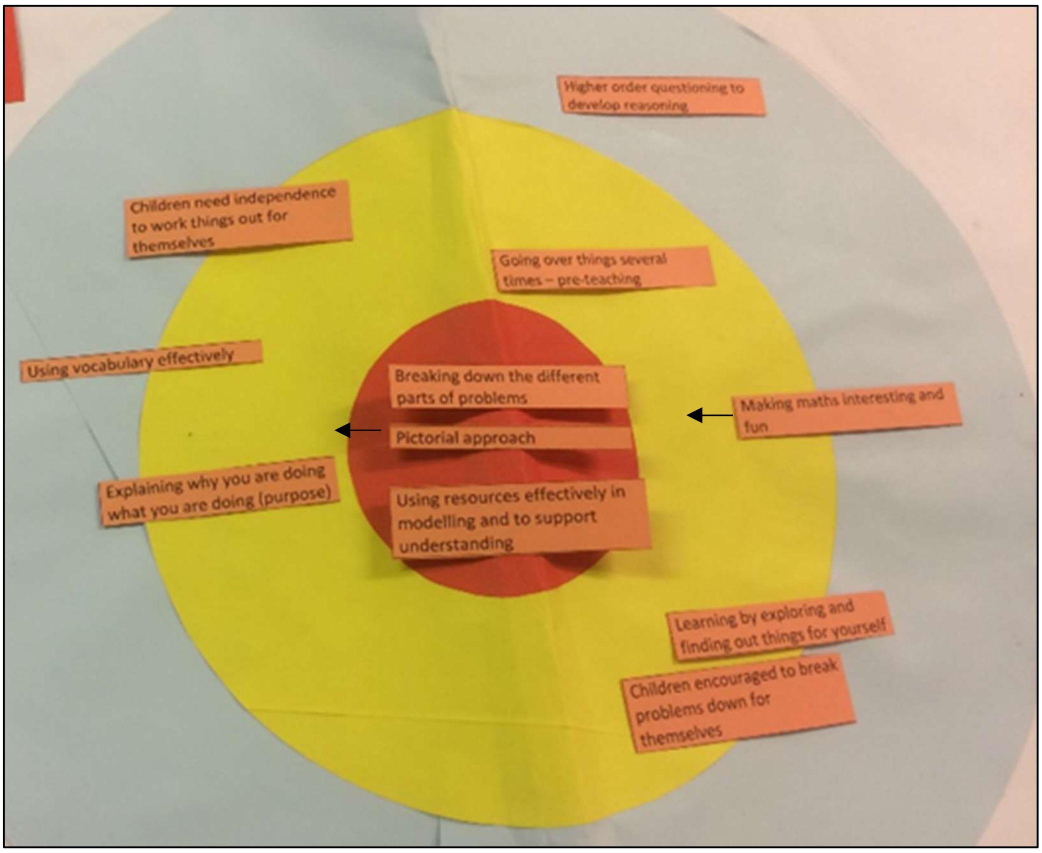


Figure 6-8 Gina Meeting 5: Characteristics of effective teachers of mathematics (photograph is from Meeting 4 with arrows showing the slight changes she suggested in Meeting 5)

6.5 Self-imposed changes through proactivity and reflection on practice

Gina placed this as the smallest of the four influences on her influence map because:

> *There's been so many other things that have to be put in place that I've had to just go by the wayside with those.* (M5)

She preceded this with the words *"This sounds really bad",* suggesting that she felt this should have been a more important influence and indeed, when discussing how taking part in my research caused her to reflect, she stated *"all the time when you are training and when you are teaching you are told to reflect".*

Although Gina suggested that she was not able to make self-imposed changes because so many changes were imposed on her, there is evidence of her developing her practice in this way, especially at the level of making changes during a lesson. In Meeting 4 Gina said:

> *As a teacher of maths, my understanding of 'you've got to do it at their own pace' has definitely improved because before, it was "we need to do this lesson, this is the objective we're doing today" and actually, Friday, I just went "No we are not even doing this, we are not even entertaining this idea […] we need to do something else because otherwise you're not going to understand, I'm going to be frustrated, I'm not going to know what you do and don't understand and this is just a waste of our time".* (M4)

Similarly in Meeting 5 she said the most important way she had developed as a teacher of mathematics over the preceding few months was *"not being afraid to throw things out", "judging how well things are going" and "seeing "Ok, let's stop – we've all got this wrong" and going over things."* She compared this approach to her previous year when, *"especially on observations"* she would *"plough on"* when the children were not learning as expected.

This change in practice is illustrated by Gina's contrasting response to her most challenging lesson described at Meetings 2 and 4. Without realising, Gina actually described the same scheme lesson on both occasions. At the time of Meeting 2 she and Adam were dipping into the 'Singapore' scheme and taught a lesson where children had to carrying out addition of a single digit number to a teens number, using a new pictorial approach (Figure 6-9).

The method used involved partitioning a teens number into tens and one, adding the ones to the single digit number and then then recombining. Gina described this lesson at Meeting 2 as *"horribly bad":*

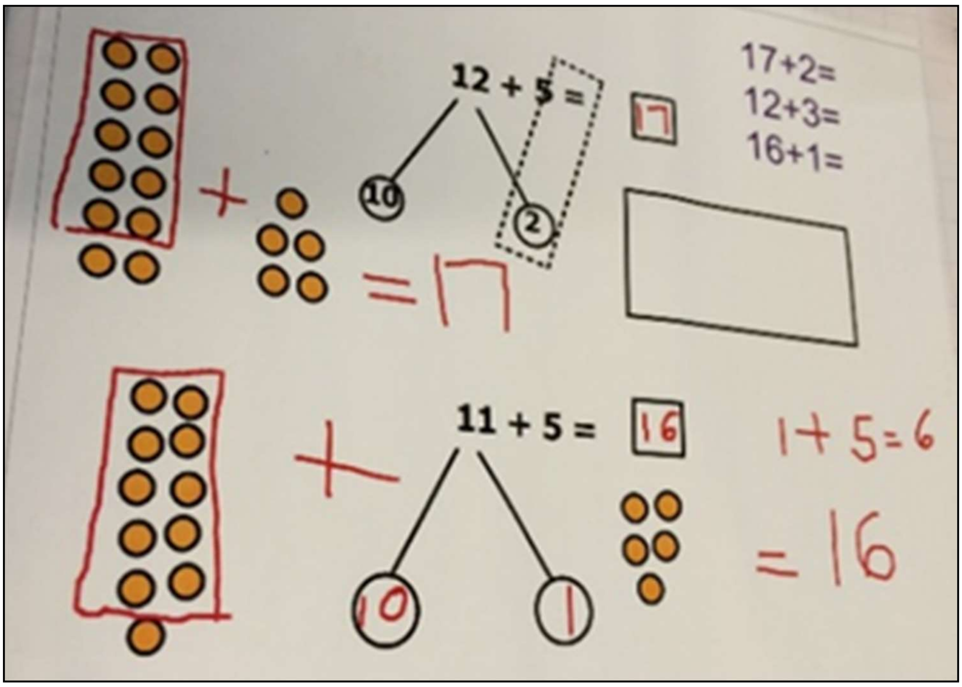


Figure 6-9 Visual representation used by Gina in a 'challenging' lesson

> *It just wasn't successful, basically, at all. And it was definitely challenging in terms of my understanding of their understanding – I thought "How do we not understand?" because to me the pictures were making it so simple.* (M2)

Despite the children's difficulties Gina had continued with her lesson plan because *"that's what they* [the children] *should be doing".*

When describing the same lesson a year later, Gina diagnosed:

> *They couldn't understand that they had - "This is ten – I'm putting it to the side for the moment but I'm bringing it back to use it later".* (M4)

This time Gina decided to:

> *abandon the lesson completely and literally focus on seventeen – how many tens, how many ones, with all the resources in the room out.* (M4)

During our meetings Gina often talked through various points before coming to a conclusion, suggesting she is someone who reflects through this discussion process. At

Meeting 5 she suggested that although she recognised the value of reflection, she did not give herself the time to think or talk things through in this way:

> *Sometimes you get to 4 o'clock and you go "I've got a stack of books" and you don't reflect on anything that's happened. You just think "I've got another thing to do".* (M5)

The only time she mentioned reflecting on a lesson with her partner teacher was after the first challenging lesson described above.

Gina was the only participant who placed 'self-imposed changes through proactivity and reflection on practice' as their smallest influence and her perspective about proactivity and reflection contrasts markedly with Rahma's passion for using these for self-development.

6.6 Summary

Gina was very clear as to the overriding significance of her school context on her development as a teacher of mathematics. This influence dominated her series of interviews, generally articulated in a pragmatic way, but with considerable emphasis on the emotional impact of the series of events following her *"disaster"* lesson observation. Evidence from across her series of meetings suggests that Gina's own background as a learner of mathematics was the context within which she attempted to make sense of the changes imposed on her and her developing beliefs about what makes a good mathematician. Although able to articulate the philosophy of the 'mastery' approach she was trained in, Gina's overriding priority seemed to be to ensure that the children she taught were not learning mathematics in the way that she did. Explicit in her narrative was an urgency for children to develop conceptual understanding of mathematics and implicitly, this urgency suppressed additional desirable factors. Also implicit in her narrative was a sense of conscientiousness, of variable but generally increasing confidence and a sense of achievement at successfully reaching a level of equilibrium in her teaching of mathematics.

7 Penny

7.1 Introduction

Penny is introduced in detail in 4.4. Having completed the PGCE course with the mathematics specialism, Penny taught in a village primary school. For mathematics she taught the higher of two sets of Year 1 children from three Year 1/2 classes in her first year and all the Year 1 children together in her second year.

Lesson observation feedback forms from school senior leaders during her NQT year show that Penny was recognised as a teacher who "responded to feedback" and "improved" her practice (Formal lesson observation feedback). Being chosen to mentor a PGCE pre-service teacher in her second year and then being appointed to the role of Special Educational Needs Coordinator for her third year illustrate the high regard that Penny was held in by senior leaders in the school.

7.2 Influence map

In reflecting during her final Meeting on what had influenced her during her first two years of teaching, Penny created the influence map shown in Figure 7-1.

When Penny first saw my labels she asked, referring to the 'school context' label, *"Could that include courses or not courses?"* She was very keen to stress that the impact of her school context was very small other than being sent on courses and, in particular, one specific course. I suggested writing a new label: 'Courses'. She later talked about the impact of being involved in my research and said: *"You should have had a circle for you".* Again, we improvised and created a new label. Using the full range of labels, she then created the influence map.

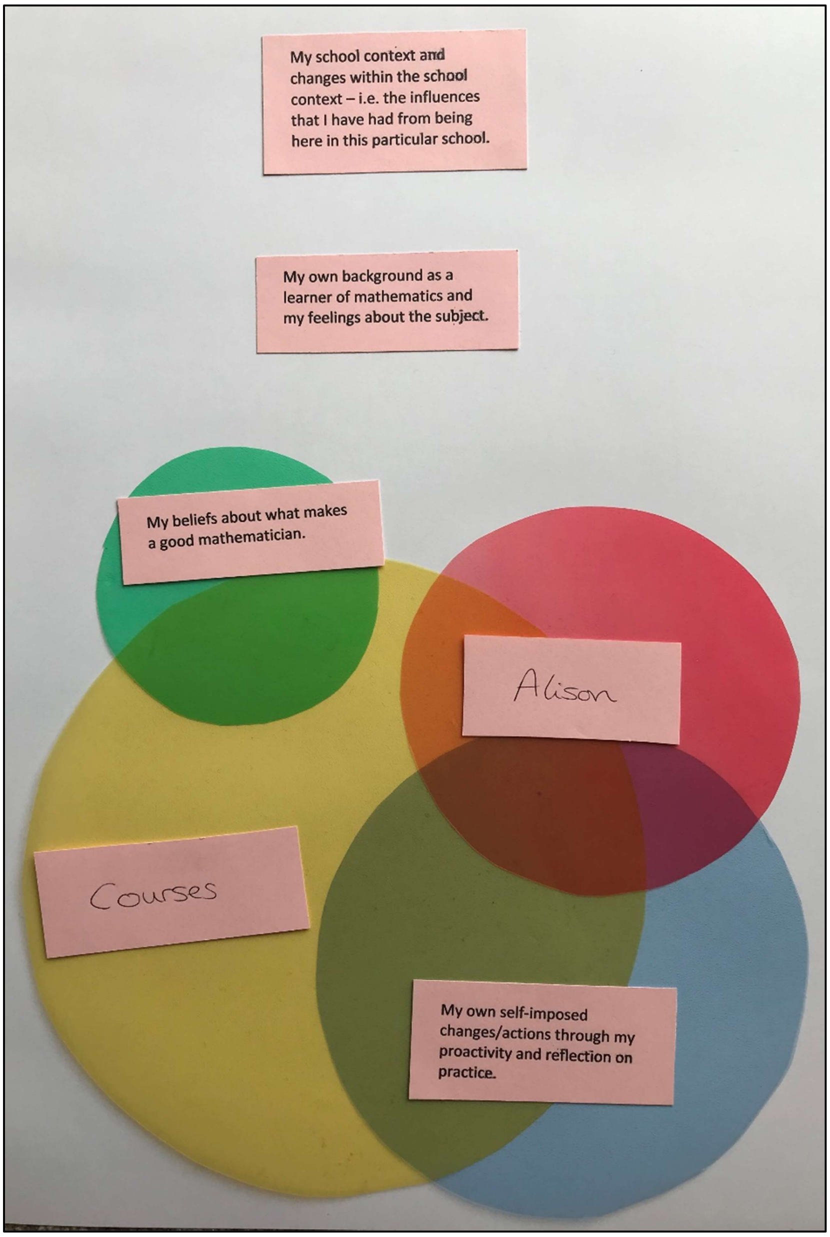


Figure 7-1 Penny's influence map

Penny chose ‘Courses’ as the greatest influence on her development as a teacher of mathematics, overlapping this circle with her second influence; ‘My own self-imposed changes/actions through my proactivity and reflection on practice’. Her third influence, that of taking part in my research, overlapped with both of these first two, because she reflected as a result of the research visits. ‘My beliefs about what makes a good mathematician’, overlapped with ‘Courses’, suggesting that the courses impacted on or at least matched her beliefs. Penny placed her own mathematical background as a separate and smaller influence because although she *“loves maths”* her teaching of the subject would *"just happen regardless".* She placed the influence of her school context as the smallest influence whilst asking *"Is that awful?",* suggesting that she thought a school's influence should be greater than she felt in her case it was.

Penny's discussion as she created this map, alongside evidence from across her series of meetings, provides insight into her views of the influences on her over these first two years of her career. This chapter focuses on some distinctive elements of Penny's narrative: the separate influences she discussed and included on her map, the interconnection of background and beliefs impacting on the way she viewed children as mathematicians, and her impact on others in her school context.

7.3 Separate influence - Courses

Penny's narrative is distinctive firstly because of the way she wanted to separate out elements within the given categories of the influence map.

In January of her NQT year, Penny attended the University of Leicester NQT conference where she attended a one hour mathematics session on 'Mastery in Primary Mathematics' given by a consultant. She referred back to this course in each of Meetings 2-5, each time stating the significance of this course on her practice. The day after the conference she emailed me to explain how she had already used an idea from the *"brilliant"* session with her class that morning:

> *We are revisiting number bonds to ten and I asked the children to write a number on their white board between 0-10 and got them to walk around the classroom swapping boards etc. and then with a partner first tell them the number bond which goes with their number and after a few goes I asked them to tell their partner what they know about their number. Well it was brilliant - without any prompting I heard, "This is nine and nine plus one equals ten" and "two plus eight equals ten", "they are the same" and one child said, "My number is odd!" I was so pleased with them all; great activity to hear what they know and understand and one which will be added to over time.*

During Meeting 2, two weeks later, she followed this up, stating:

> *I love that activity […] it's just been really good […] I'll use it weekly to see what they've understood, what they are incorporating in the lesson.* (M2)

At Meeting 3, when drawing a graph of her relationship with mathematics during her NQT year, she said this course *"gave me that lift"* with *"lots of ideas"* (Figure 7-2), and she increased the gradient of the line at that point (labelling this 'NQT').

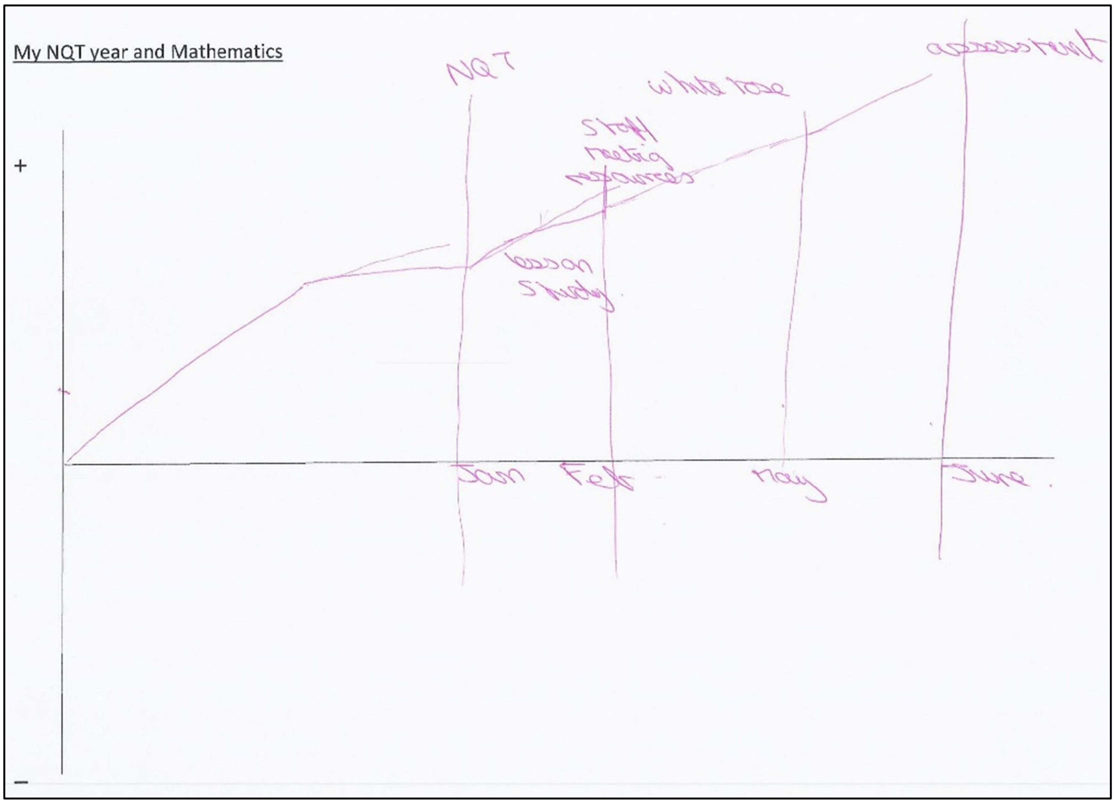


Figure 7-2 Penny's relationship with mathematics in her first year of teaching

Reflecting back at Meeting 5, Penny commented:

> *The course was brilliant – just gave you that impetus to carry on, gave you ideas to do, spot on.* (M5)

Although this course had a markedly strong impact, she mentioned other courses and staff meetings during the series of meetings, some related to mathematics and some to other subjects or roles, for example, staff meetings on *"Mastery in mathematics"*

(M3) and *"Questioning and growth mindset"* across curriculum areas (M2), a course on *"EYFS profiling" (M5)* and training for mentoring a pre-service teacher. The way Penny talked about professional development events showed an attitude of keenness to develop her practice and make the most of the opportunities given to her:

> *As soon as you go on a course, I always try to use what I've learnt, and you can see the impact straight away […] Courses definitely have an impact on me, without any shape or form. Some people go on courses and don't do anything about it do they, which I think is really odd.* (M4)

> *It just makes you stop and think, doesn't it; whenever you go on a course, you think, I'll have another look.* (M5)

Although other participants talked positively about courses they attended and what they learnt from them, Penny stood out as markedly proactive in reflecting on what she learnt and seeking to immediately implement this in her practice.

Penny expressed disappointment that whole-school development in mathematics was relatively low profile in her school, particularly in her second year. In Meeting 5 she commented: *"Maths has been left alone this year […] a shame really",* and referring to the formal observation schedule she commented:

> *The big push is questioning.* [The school senior leadership team] *said they didn't want to do maths and I was like "No, but there's so much questioning you can get in a maths lesson!" So, you can either do topic or literacy. So, that's a bit of a shame. We're hoping to do lesson study for maths […] because we did English last year.* (M4)

Penny came across as a teacher who was actively seeking to develop her practice. She valued opportunities to learn from more experienced and expert practitioners and reflectively and proactively implemented new ideas in her classroom. This seemed to include the impact of talking with me.

7.4 Separate influences – talking with me

Although all the participants responded positively to my question in Meeting 5: *'Do you think taking part in my research influenced your practice at all?'* and mentioned the benefits of reflection (see 9.5.4 for a detailed discussion of this), Penny stood out in her response to my research: firstly in the thoroughness of her preparation, secondly in the extent to which she used each meeting as an opportunity for reflection and thirdly in the extent to which the meetings were a springboard for further developing her practice. It did not occur to any of the other participants to label a circle on the influence map specifically for the influence of being involved in my research.

Several of the participants wrote notes in preparation for some of my visits, but Penny did this most thoroughly and consistently, and for Meetings 2 – 5 gave me between one and two pages of notes she had typed up (see Appendix 9 for an example). Penny showed a keen interest in my research, asking me each time how the research was going and was particularly interested in my experiences at conferences. She showed a very strong commitment to her participation.

Penny talked at Meeting 5 about reflecting before, during and after my visits:

> *You reflect after every lesson to get ready for the next lesson, but with you coming in, it's looking at – "oh what have I done over the last couple of months" […] you want to do it just to check you've got everything ready for you to come – so you look through everything. And it's also after the discussions I've gone off and then done, oh yeah, let's make those changes now, let's try it and see if it's going to work. So just make changes to your classroom practice type thing, which I definitely wouldn't have done – I definitely wouldn't have had these mild and spicy ones […] if you hadn't have come in.* (M5)

The reference to 'mild and spicy' linked specifically to an idea I shared with her at the end of Meeting 4. After answering my final question, she asked me whether I had any other participants in Year 1 and how they were getting on. I responded by briefly describing some contrasts between Rahma and Gina's teaching strategies and mentioned Gina's school strategy for differentiation (see 6.3.3). Although in hindsight this was a compromise in my role as a researcher, I did not see a reason at the time not to do so and spoke without mentioning names.

Penny picked up on the idea of 'mild, hot and spicy' and, demonstrating her reflective and proactive approach to developing her practice, she adapted this, using it not as Gina did for children's independent work, but as a way of differentiating *"the starter"* to her lessons. She showed me examples of starter activities where children chose from a mild or spicy question at the start of their mathematics lessons (Figure 7-3).

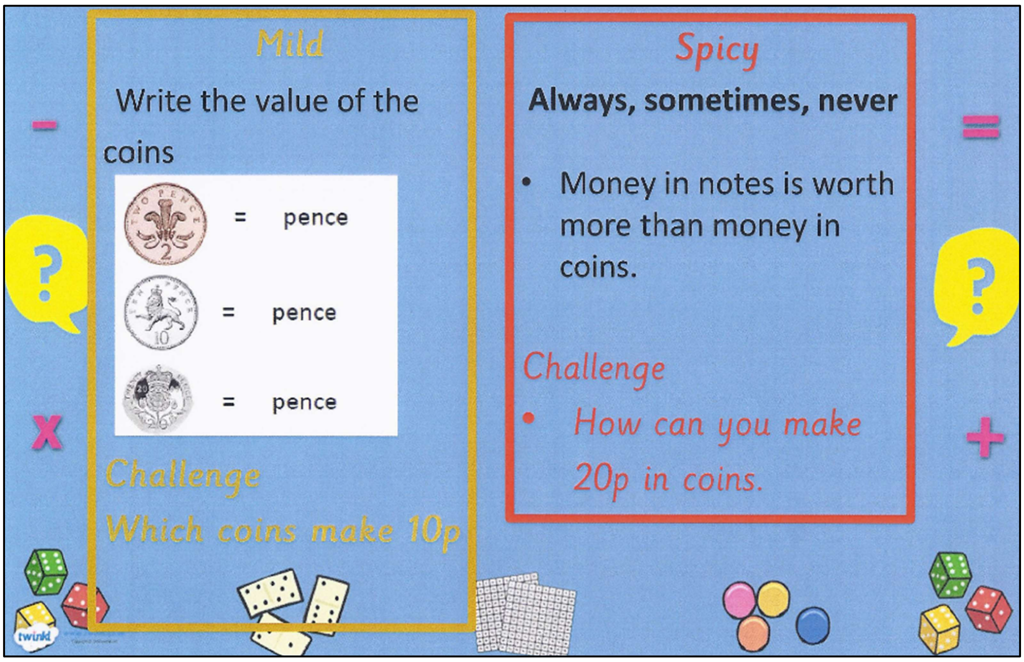


Figure 7-3 Example of Penny's use of mild and spicy starter questions

Although she specifically mentioned this development, Penny also stated *"I reassessed everything"* after our fourth meeting:

> *I relooked at everything. I hadn't been happy with the format of the lesson […]* [I gave] *more thought as to how it would all fit together.* (M5)

Both her overlapping of the circles for ‘Alison’ and ‘proactivity and reflection’, and her graph of her second year of teaching indicate that my visit at Meeting 4 seemed to be particularly significant for her (Figure 7-4).

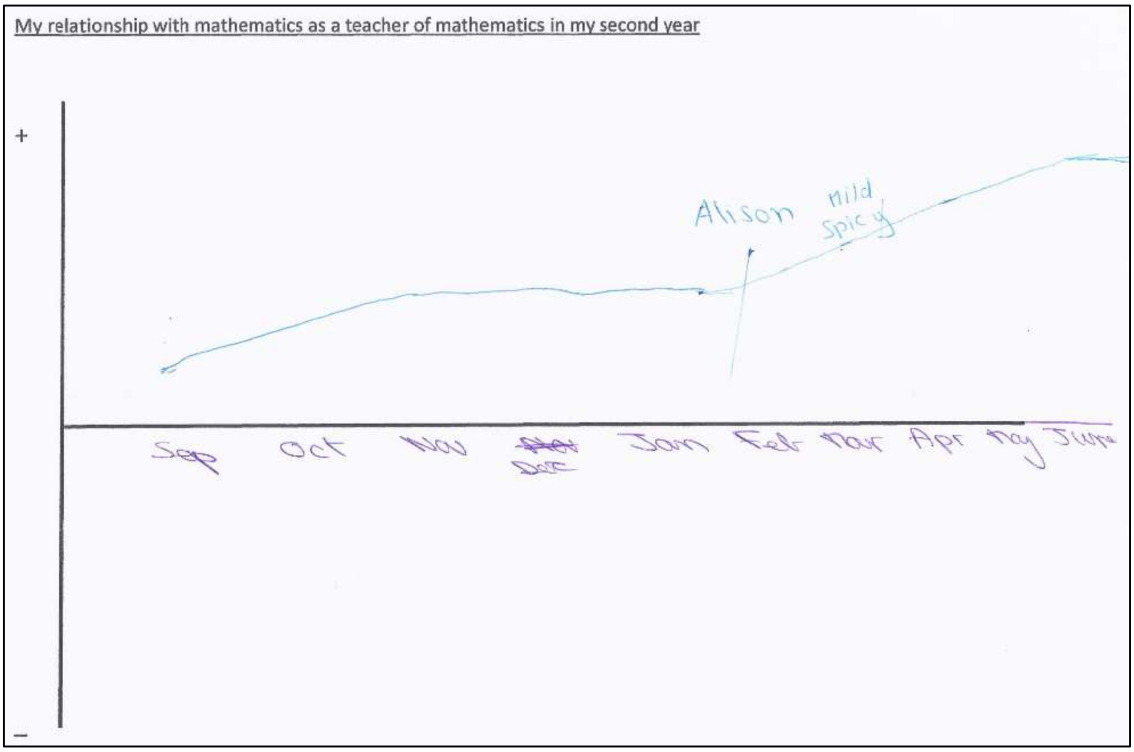


Figure 7-4 Penny’s relationship with mathematics in her second year of teaching

Penny thus justified the use of additional categories in her influence map which was the only one identifying six influences.

7.5 Background and beliefs about what makes a good mathematician – seeing children as mathematicians

Penny was also distinctive as the participant with the strongest mathematical background, both in terms of her qualifications and her experience as a mathematician in business prior to her teaching career. However, when creating her influence map, Penny placed her background and feelings about mathematics as a relatively small influence on her development as a teacher of the subject and did not mention any overlap between this and her beliefs about what makes a good mathematician. These influences are possibly more significant and intertwined than the map suggests.

Although Penny felt the influence of her school context was small, it was apparent that she was free to teach mathematics according to her beliefs about what makes a good mathematician. The school used a purchased scheme for planning and teaching mathematics lessons, coincidentally the same one as Rahma's school, but teachers were free to use their own activities in lessons to supplement or replace those from the scheme. Over the series of meetings, Penny described how she increasingly used her own ideas rather than those from the scheme. In Meeting 2 she described her approach:

> *We take the content but sometimes you change what the activity is if you don't like that, move it around, so I do that quite a bit […] I find it* [the scheme] *restricting in some ways but then at least you know you are going to cover all the work because it's all set out for you.* (M2)

By Meeting 3 she had *"more confidence"* not to rely on the scheme. Although she dipped into it, she stated:

> *I definitely now do what's best for the children […] I'll make my own resources or use different websites, so that's definitely changed.* (M3)

This approach continued into her second year, and by Meeting 5 she described how:

> *I print it* [the scheme plan] *off religiously, put the date that I'm going to do it and then just cross things off and then just do whatever I want to do.* (M5)

Throughout the sequence of interviews Penny gave insights into her beliefs about what makes a good mathematician. At Meeting 1 she talked about the importance of *"giving time for children to see problems in different ways"* and ensuring children have a range of strategies with which they can *"tackle different problems in different ways".* This links to her belief that mathematics is *"a logical way of solving problems"* (M1) and her own love and experience of solving mathematical problems and puzzles.

Penny seemed to view the children she taught as mathematicians despite their young age. Whilst Gina was hesitant to give children independence and freedom in their mathematics, Penny embraced the freedom she had to develop in the children she taught the characteristics she felt were those of a good mathematician. These particularly related to children developing a *"deeper understanding"* of the mathematics they were learning, using appropriate language and mathematical vocabulary for reasoning and problem solving, and developing their disposition as mathematicians with resilience and independence. These characteristics were expressed in Meeting 2 and further developed as Penny gained new ideas and tried these out in her classroom.

At Meeting 2 Penny talked about the importance of developing children's understanding of the language of problem solving and reasoning:

> *You need to give them the language […] the odd one out and stuff like that.* (M2)

She explained how the children's reasoning had developed using this approach:

> *When I started doing 'which one's the odd one out?' it was hysterical, the things they came up with were just lovely, it was just – "it's just number 4"* (laughing) – *"That one's the odd one out because the other two are 10 and 5" […] But now the reasoning and what they're saying is much more what I want them to say […] rather than just seeing it as a number, they are now seeing it as a number that can do something.* (M2)

By Meeting 3 she had widened the range of strategies she used to further develop children's understanding through reasoning, with questioning and an emphasis on mathematical vocabulary identified as particular areas of development:

> *Making sure it's much more deeper, the questions I'm asking,* [for example:] *How else can you do that? Is there another way? […] If you know that answer what else do you know?* (M3)

In order to get the children to do that deeper understanding, I've introduced the vocab cards, I've introduced different types of questioning […] true or false questions. (M3)

I'll have key words around the classroom so they know the words I want them to use when they're talking to their partners […] having prompt cards for children to know which questions to ask. (M3)

However, as is clear from her description of her best lesson from Meeting 3, it was very important to her that children had a thorough understanding of the vocabulary. Realising mid-lesson that although the children could sort odd and even numbers, they were only able to state *"cause it is, cause it is"* when asked why a number was odd or even, she deviated from her planning to get the children investigating which numbers of objects they could share equally.

By Meeting 4 she was including such mathematical vocabulary on PowerPoint slides and "*making sure the children use mathematical language in the lesson"* (Figure 7-5).

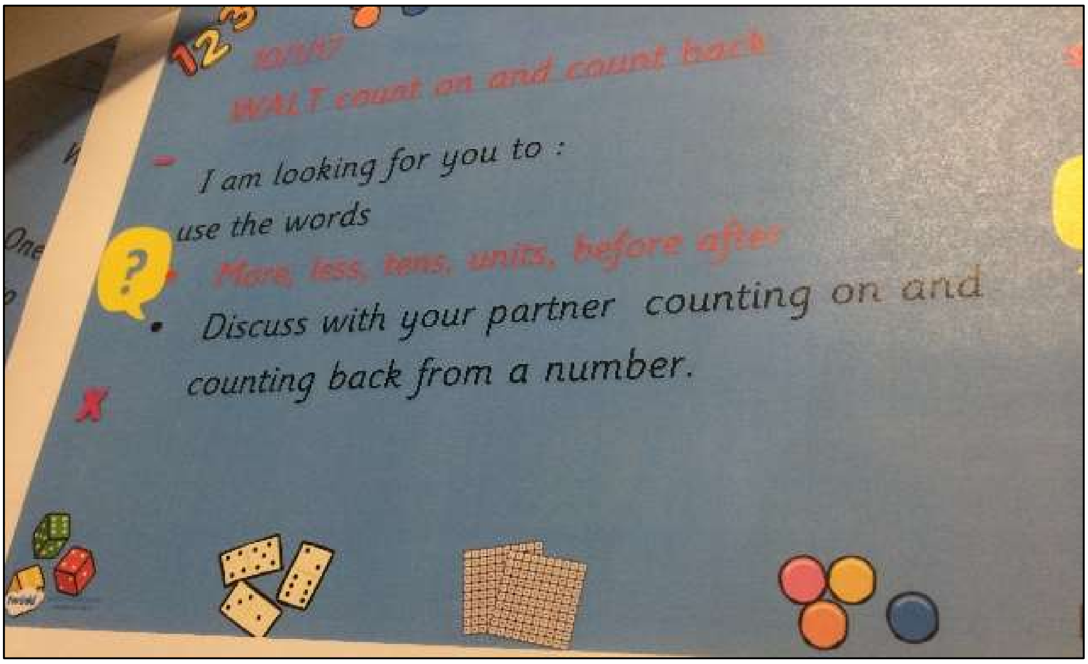


Figure 7-5 Example of Penny's PowerPoint slides emphasising vocabulary

At Meeting 3 Penny mentioned the importance of resilience as a desirable characteristic of a child working on mathematical problems: "*You should be able to keep going at the problem",* although at this stage she did not discuss this in relation to her pupils.

By Meeting 5 Penny had clearly focused on developing her pupils' resilience in problem solving and their demonstration of this resilience was her reason for choosing a problem solving lesson on the addition of three single-digit numbers as her recent best lesson. The previous day the children had worked on set examples practising the strategy of looking for pairs totalling ten, and then created their own questions (Figure 7-6).

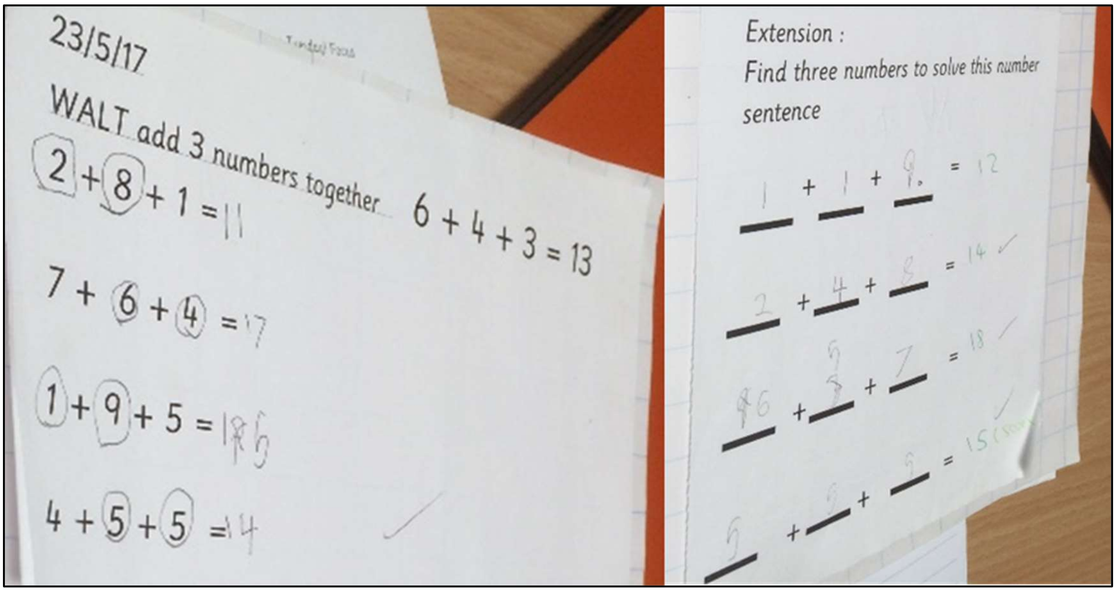


Figure 7-6 Example of child's work adding three numbers

The best lesson involved the children working in groups to apply their understanding when solving addition puzzles such as the one in Figure 7-7.

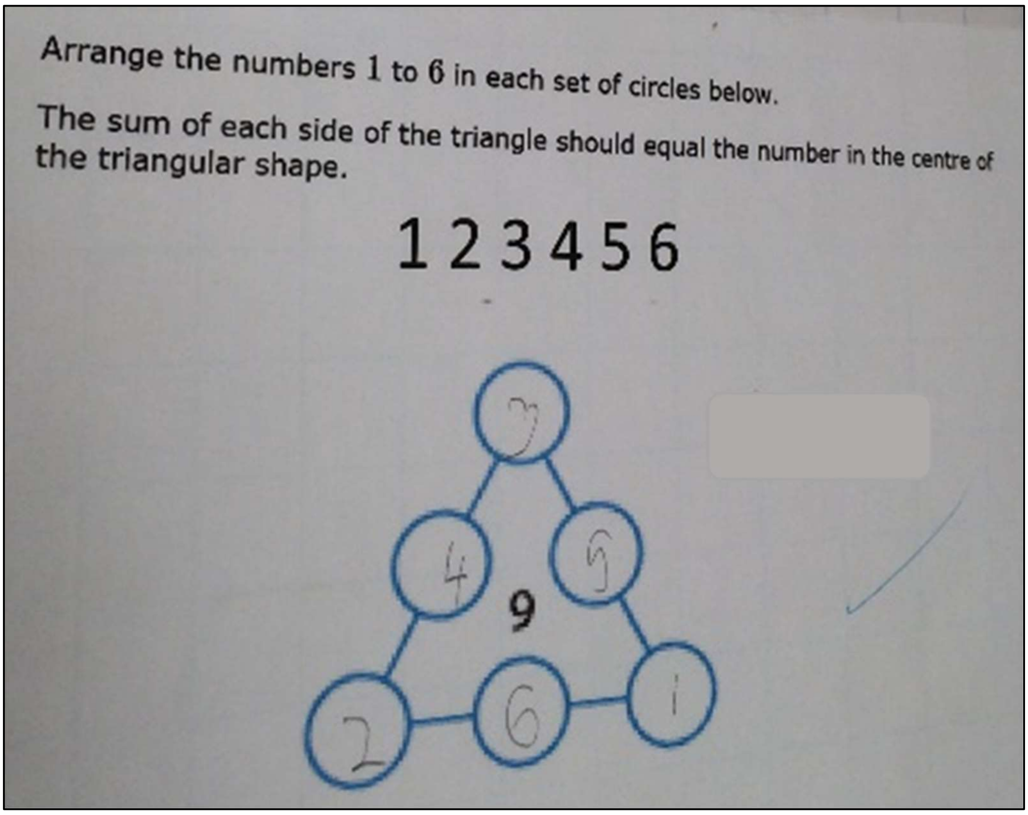


Figure 7-7 Example of child's work problem solving with addition of three numbers

Penny explained:

> *It's quite a leap isn't it from that to that* [the previous day's tasks to that day's number puzzles], *to realise there's a plus in the middle. We worked in groups […] and it was just lovely to watch.* (M5)

In response to my question "Did they have the resilience for dealing with it?" Penny enthusiastically continued:

> *That's why I really loved it […] They kept crossing it out – they were like "that's not going to work, I'll have another look" and they just kept going back – the way the lesson worked was just fantastic – you know that spark you get, you could tell the determination in their little heads. Once one got it, that was it then, they've all got to get it.* (M5)

Penny also considered it important to develop children's independence as learners. One way she encouraged this was through children choosing resources to support their learning. She had already established this by Meeting 2 and was clear that she felt this was beneficial:

> *I've got big mats on the table now like 100 square grids, number lines, and I've got whiteboard pens on there and they can just go and get counters, go and get dice. They just get whatever they want and it's interesting to see how different children work differently and it helps you then to support them in their learning.* (M2)

In Meeting 4 she further explained her reason for adopting this approach:

> *because otherwise you will not get the outcome you want […] What can be really beneficial to one child is useless to the other.* (M4)

As seen in Figure 7-8 Penny also believed in the value of children creating their own questions.

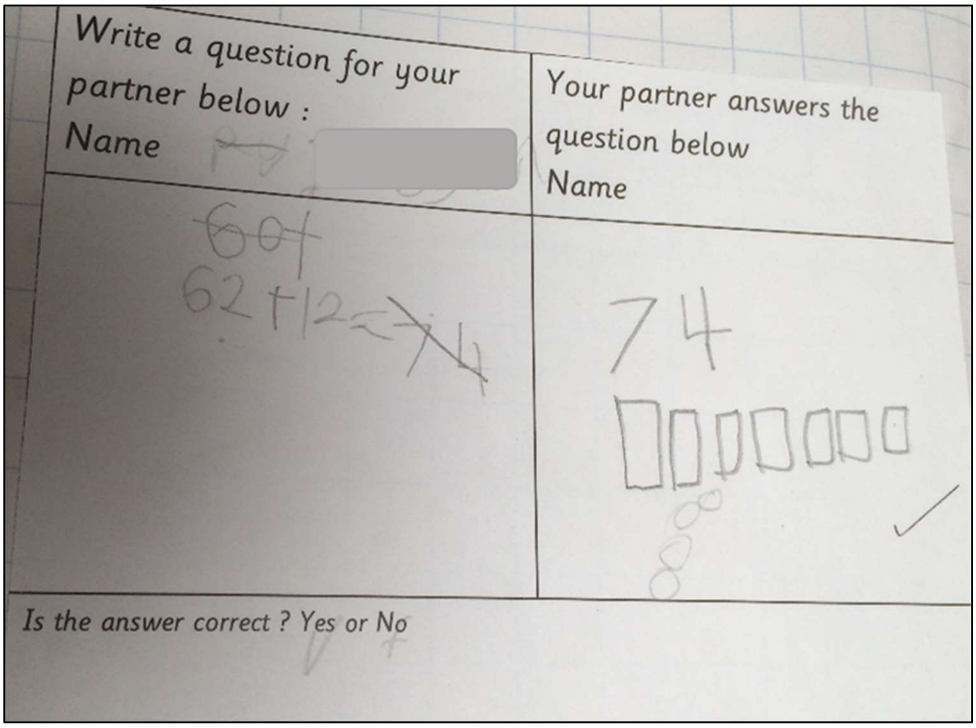


Figure 7-8 Example of children creating their own questions

In this example, not only are children showing independence in writing questions, they are also able to choose their own methods and recording:

> *So, they could have answered it however they wanted to, but they answered it in chips and beans which is quite nice.* ['Chips and beans' is how Penny's children describe drawings of tens and ones equipment.] (M5)

By Meeting 5 Penny had established a routine where she often gave children questions to start their independent practice *"so that I know that they're ok"* and then:

> *They can just go and write their own questions – they've got free reign then to do whatever they want to do. So this is the bit I like doing* [their own questions] *– I don't really like doing this bit* [the part where she has given questions] *but in order to get to that bit I think it's like a stepping stone for them. Some of them just go mad, which is great […] As long as they tell me what they've done and how they've done it, they can do what they want.* (M5)

Penny stood out as a participant who independently developed her teaching in line with her beliefs about what makes a good mathematician within the context of flexibility allowed by her school.

7.6 Impact on the school context

Penny and Orna were the participants who seemed to have the most influence on others in their school context. Whilst Orna did so in the context of a formal role alongside the mathematics subject leader (8.6.1), Penny's influence was distinctive in its longevity, variety and mix of formal and informal roles. In each meeting she spoke about how she was influencing others in a mathematics context beyond her own classroom, speaking pragmatically about her support of others and treating this as a normal part of whole-school practice.

Penny had formal responsibility for assessment and analysing pupil data across the school, resuming this role from her days as a teaching assistant in the school. Even prior to starting her first term as a qualified teacher, she had advised and worked with the mathematics subject leader. Penny recorded in her Professional Development Record that she "explained" to her that the assessment software the school used had recently been updated and they "discussed the best format" for children's targets. In her first month of her NQT year she "set up templates" for all Key Stage 1 teachers for children's targets in mathematics and her role continued throughout the research period with regular analysis of whole-school data.

Other formal roles included running mathematics intervention groups in assembly times for Year 2 children prior to their end of year national tests and mentoring a pre-service teacher, a role which she spoke very enthusiastically about. Penny valued the opportunity to observe her children being taught by the pre-service teacher:

> *You sit and watch the lesson - you think, OK - What is it they enjoy? What is it that's grabbing their attention? What is it they really enjoy doing? And trying to do more of that.* (M4)

There was also an impact on her teaching as she sought to demonstrate good practice:

> *Making sure when he sees a lesson that it's trying to make sure you've got everything covered.* (M4)

Penny was also confident enough in her subject knowledge to make suggestions to the mathematics subject leader. This included purchasing new rulers to replace those labelled with centimetres and millimetres which her Year 1 children were struggling to use:

> *I've got some really lovely funky rulers now that I've managed to order - they are lovely, really colourful, little smiley faces on them, literally has centimetres 1- 30, but they're lovely, they're just lovely.* (M2)

Informally, Penny seemed to be viewed as a teacher who was willing to share her mathematical expertise. In Meeting 2, for example, she recalled a *"little chat"* with an NQT teaching in Year 6, advising her about strategies to support a child who was struggling mathematically. In Meeting 3 she revealed that for the weekly problem solving lesson that was taught by both the Year 1 teachers

> *It’s usually me who comes up with what lesson we’re going to teach, so I’ll produce all the resources and just pass them across to the other group to do.* (M3)

She also organised the activities for Key Stage 1 teachers for the whole-school mathematics *“Puzzle Day”,* choosing *“ones I thought were the most appropriate for us all to use.”* (M3)

By Meeting 5 she was supporting the Year 2 teachers *“and also some of Year 5 as well”* with *“informal support”* in mathematics teaching. She anticipated supporting a teacher new to the school the following year *“with the Year 1 maths”*.

7.7 Summary

Penny’s discussion as she created her influence map was distinctive in the way she was keen to create additional categories, emphasising a specific professional development event and the impact of being involved in my research. Penny’s mathematical background seemed to have more of an influence than she acknowledged; it seemed to impact strongly on her beliefs about what makes a good mathematician and consequently on her practice, and she was acknowledged by other teachers as someone they could go to for support.

In some ways, Penny showed similar priorities in her teaching of mathematics to Rahma. She had strong beliefs about what makes a good mathematician and, with a reflective and proactive approach, was able to develop her practice according to these. Her teaching approaches contrasted greatly with Gina’s; Penny aimed to develop the children as independent mathematicians in a way that Gina did not yet have the confidence to do.

8 Findings from other participants

8.1 Introduction

In this chapter findings are presented from the five participants for whom it is not possible to include detailed individual narratives. The main focus is the influence of the school context because most participants considered this to be the strongest influence on their development as a teacher of mathematics. The dominance of the school context can be seen in Figure 8-1 where representations of all participants' influence maps from Meeting 5 are shown using one colour for each influence and summary labels. Five of the eight participants placed the school context as their most important influence whilst Penny's largest influence, 'Courses', came from school leadership decisions to provide her with learning and development opportunities. The influence maps also indicate though that other influences interlink with the school context and, throughout the chapter, evidence of these overlaps is also included.

The chapter is sub-divided into the main aspects of the school context discussed by participants. Firstly Orna's perspective on the importance of the school context is described as shown through her influence maps from Meetings 3 and 5. Adding a different dimension to the perspectives of the school context outlined in Chapters 5-7, Orna used the maps innovatively to represent firstly the school context as a *"day to day"* rather than *"overarching"* influence and secondly to separate out the specific influence of her class context.

Section 8.3 follows up Orna's thoughts on the influence of the children she taught, with contributions from other participants who taught children learning English as an additional language. Section 8.4 explores the influence of the year group taught: for Chloe a mixed aged class had particular influence and for Rakesh and Emily, teaching the final year of primary education significantly impacted on their development as teachers of mathematics.

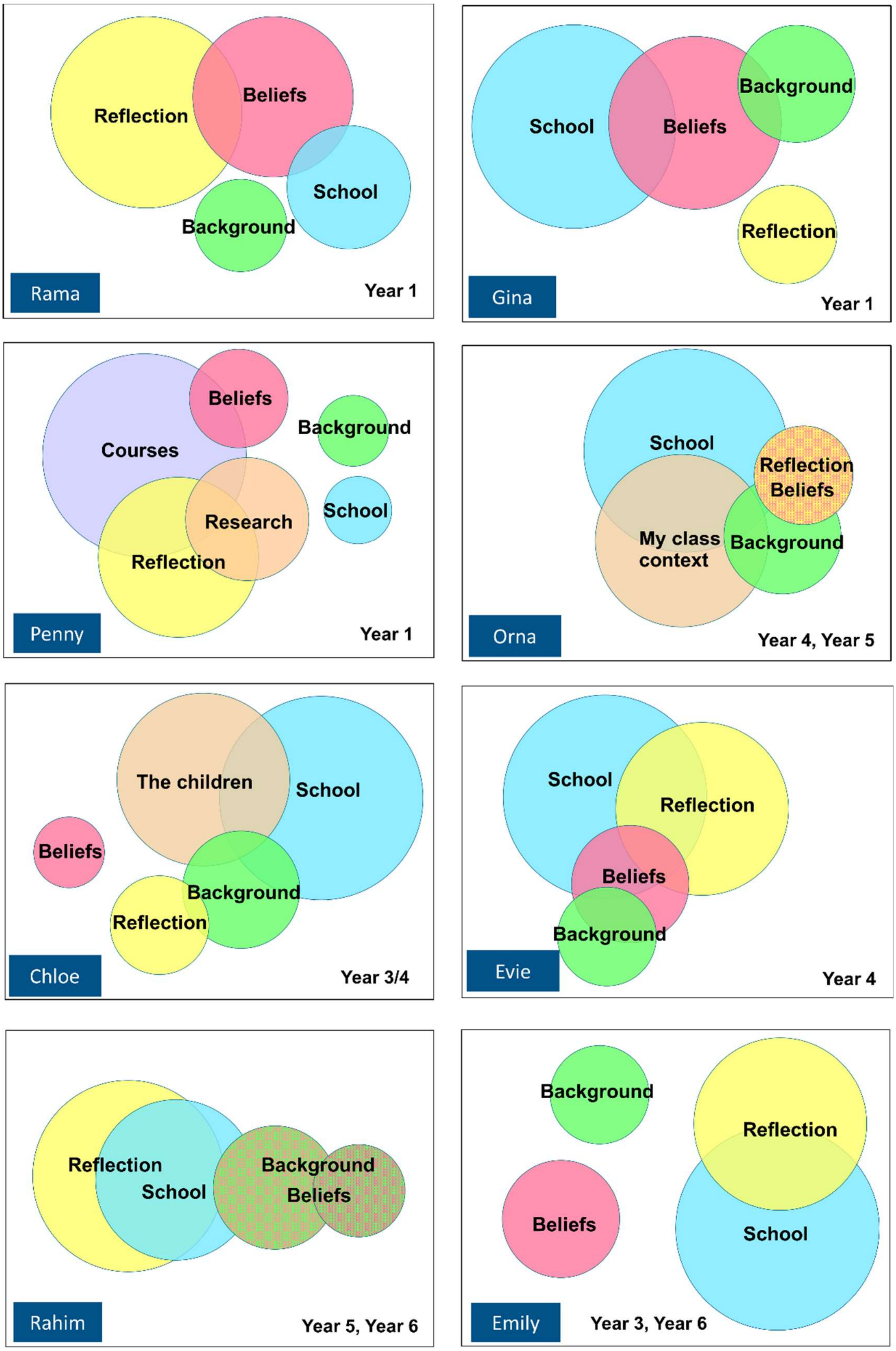


Figure 8-1 Representations of Meeting 5 influence maps using summary labels and year groups taught

Schools provided participants with a range of learning and development opportunities and Section 8.5 gives the perspectives of Evie and Orna on the influence of these. Finally, in Section 8.6 the subject leadership responsibilities given to Orna and Rakesh in their second year are explored.

8.2 The importance of the school context - Orna's influence maps

Orna is introduced in detail in 4.4. Having completed the Primary with Mathematics PGCE course, in her first year Orna taught a Year 4 class (children aged 8-9 years) in a large multi-ethnic primary school alongside Liam, the mathematics subject leader and another experienced colleague. For her second year Orna taught children aged 9-10 years in Year 5.

Orna's influence maps are discussed as an example of a participant who perceived her school context to be important in a number of ways. She was in Cohort 2 of the study and therefore created influence maps in Meetings 3 and 5. Although contrasting in appearance, in both maps the importance of the school and class contexts on Orna's development as a teacher of mathematics stand out, despite her strong mathematical background and related beliefs about what makes a good mathematician. In reflecting during her final meeting on what had influenced her during her first two years of teaching, Orna created the influence map shown in Figure 8-2.

Orna decided to separate out the influence of her class context from that of the school and chose these as her most significant influences over the previous two years. The other three influences all overlap with the school context. She felt her passion for mathematics enthused her class, *"they love maths, it's their favourite thing",* and by Meeting 5 the whole-school practice in mathematics was *"coming in line"* with her beliefs. Using an explanation similar to Gina's as to why changes through proactivity and reflection were of relatively low importance, Orna commented:

Given that there's been so many external changes, I don't feel like I've been particularly proactive. (M5)

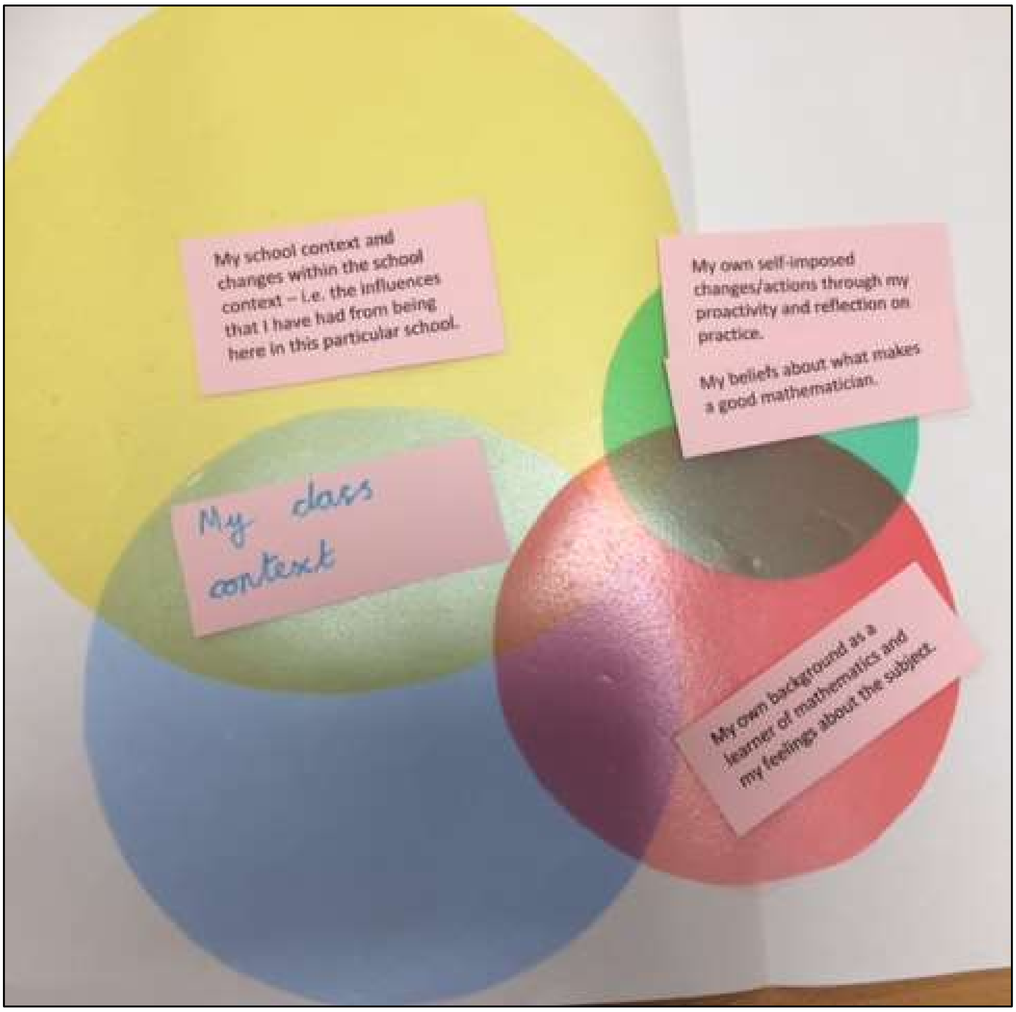


Figure 8-2 Orna's influence map Meeting 5

This map contrasts in structure with that from Meeting 3 where she discussed having two *"day to day"* influences and two that were *"more of an overarching influence".* When I suggested she could adapt the structure of the map to show this, she created the map shown in Figure 8-3.

Her day to day practice was, she felt, very much influenced by the school context, both in terms of the children she taught and working to school procedures, and she engaged in *"reflective discussion pretty much after every new topic or every lesson"* with Liam, considering *"What did they get? What did they not get? What can we change?"*. Orna linked the cards relating to beliefs about what makes a good mathematician and her background as influences *"on a more long term basis":*

> *I think my thoughts about what makes a good mathematician come a lot from my learning of maths and actually doing it at uni; the reality that it's not what a lot of people think it is and the problem solving and the importance of that and the importance of reasoning and the importance of justification comes a lot from there.* (M3)

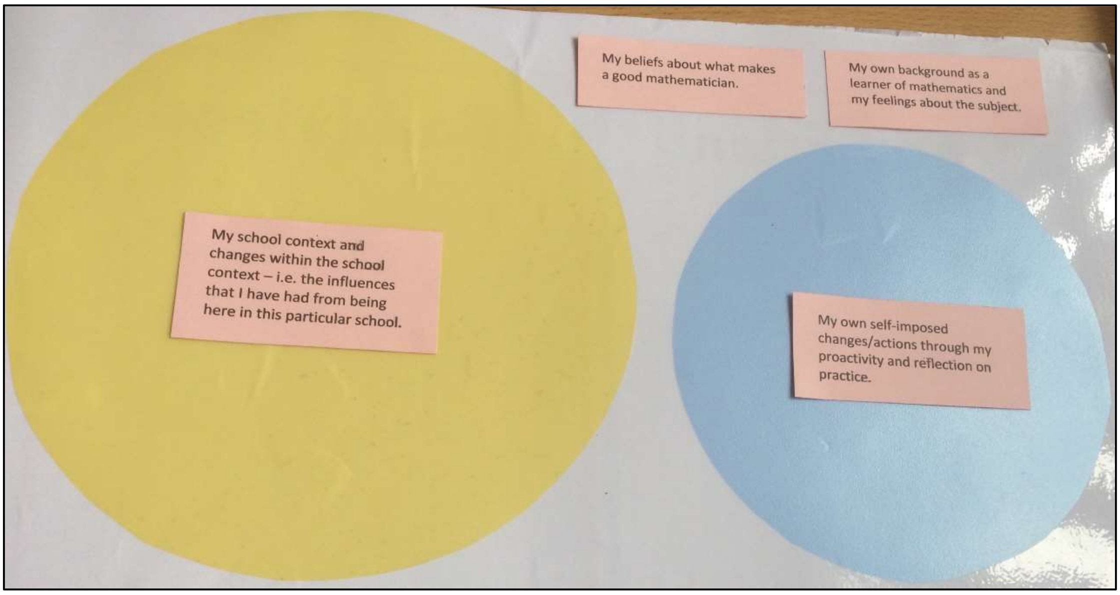


Figure 8-3 Orna's influence map Meeting 3

Whilst for Orna the influence of her school context was strong due to a combination of factors - particularly the background of the children, the new initiatives that were being introduced in her school and the opportunity she had to influence the practice of others - the "overarching" influences of her own background and beliefs about what makes a good mathematician formed the benchmark for her narratives discussed in 8.3 and 8.6 below.

With the exception of Penny, the other participants also overlapped the influence of the school context with at least one other influence (Figure 8-1), showing that they also did not view the influence of the school in isolation. In the other sections of this chapter these links are further explored.

8.3 The children

All participants talked about the children they worked with. However, Chloe and Orna considered their specific class context so significant that they added an additional, overlapping circle and label when creating their influence maps at Meeting 5. For Chloe this particularly related to teaching children with a wide spread of attainment from two year groups within the context of a year group specific curriculum and her narrative is considered in 8.4.1.

This section focuses on Orna for whom the spread of attainment in the class was also a concern, but for whom the influence of the background of the children and the nature of individuals she taught was most prominent. Orna was one of four participants who taught classes with a high proportion of children learning English as an additional language. Her perspective on the influence of this is outlined in detail and then compared with the perspectives of Rakesh, Evie and Rahma. Orna's distinctive emphasis on the influence of teaching individual children provides the final narrative of this section.

8.3.1 *The influence of the background of the children – Orna's perspective*

Orna gave two specific reasons at Meeting 5 for the class context being an important category of its own. Firstly, she mentioned the academic nature of the children she taught, particularly teaching a wider spread of attainment in her second year and so needing to teach with *"high expectations"* and *"a lot more challenge"* whilst having a "*working group at the other end*".

> *I really worry about my low children in maths […] the fact that it's Year 5 and I've still got children who can't really add one to a number.* (M5)

This was especially difficult when she was the only adult in the classroom:

> *I don't know where to put myself [..] I normally start them off and then go to the others and then, when I check back on them, sometimes I'm like, "You know what, I'd have to devote my whole time to you for the rest of this lesson to get you achieving something that's not even close to Year 5" and I never really know how to balance it out.* (M5)

However, the influence of the background of the children she taught was the more prominent reason throughout the sequence of meetings for considering the class context as an important category of its own.

The influence of teaching children with English as an additional language (EAL) was a major consideration for Orna:

> *It is a really EAL heavy school – that's really changed from the basis of my placements* [as a pre-service teacher]- *that changed how I teach because there's so much more vocabulary emphasis and so much more going into them learning that and being able to use it competently and confidently.* (M5)

This links with Orna's emphasis when creating her influence map at Meeting 3 when she immediately mentioned the influence of the children she taught. Although at this stage including it within the broader school context category, she said:

> *The school context is probably the biggest because that explains the children and where they're coming from and why I've had to adapt things a lot based on the children that I have. […] They've probably had the most significant influence on what I've taught and how I've taught it.* (M3)

Orna mentioned at Meeting 2 that she had applied to work in her school because she was *"quite keen to work in a more diverse school"*. Her class at Meeting 2 had 17 children with EAL out of 23, with *"lots of different languages"*; *"I've had to think about how to teach them maths"*. Although at this time all her class had been in the country for at least a year, she had experienced trying to teach a child mathematics who did not speak English. Revealing her beliefs about the importance of mathematical reasoning skills, Orna expressed concern that her teaching was not adequate to cater for this child:

> *I had a boy come who was gifted and talented in maths in Turkey and didn't speak any English whatsoever and he would just get everything right that I gave him and it's like, "What you need is reasoning problems, but I have no idea how to give it to you when you have no English whatsoever", so he's solving all these complicated addition, subtraction, multiplications and I didn't know how to challenge him. But then he left, so that worry has gone. But if I get another one like that, I still haven't solved that problem.* (M2)

Orna identified other challenges she faced with the generally high turnover in the class population:

> *It's difficult with a lot of them coming in new, even from other schools in Leicester - I don't know what they've done before […] All of them have got some slight variation on the methods from whatever school they've been at or whatever country they've been in.* (M2)

As a consequence, she was very aware of the importance of *"trying to get as much consistency as possible"* with the way she was teaching, in line with others in the school. Showing proactivity in addressing this concern, she talked with the Year 3 teachers *"quite a lot"* and sought to closely follow the school calculation policy. When creating her influence map at Meeting 3, Orna was clear that this was a significant aspect of why the school context was her biggest influence:

> *Liam's got a really clear calculation policy and so learning that and sticking to that and just having that to hand all the time just to make sure we're following that properly.* (M3)

At Meeting 3, again linking to her beliefs about what makes a good mathematician, Orna talked about the challenge of getting children problem solving in mathematics *"when their language is so poor"* and discussed trying to get children talking more about their mathematics to develop their reasoning. By then she had also started using 'Google Translate', *"trying to make sure they are getting the right level of challenge in maths from the beginning"* to avoid *"patronising"* children by giving them basic mathematical tasks simply because of their lack of English. This concern was also voiced at Meeting 4 when Orna talked in detail about *"trying to teach maths effectively to EAL children"* as her *"biggest learning curve"* in her teaching of mathematics. Reflecting on why she found it harder to teach them mathematics than English, she reiterated the importance of trying to teach mathematics at an appropriate level:

> *You know how to teach the beginnings of English, because I've done phonics training – with English it's the same as teaching Year 1/2 English and I did a Year 1/2 placement, so that's fine, but with maths they're not Year 1/2 in maths, but they are lower than that in language.* (M4)

Orna linked this with a parallel concern - the difficulty of *"getting the children to show you exactly what they can do":*

> *They'll see you doing a method of something and you want them to show you how they would do it and they worry – well it's not what they've seen the person out of the corner of their eye do, because they are often very, very anxious when they first start […] – they don't always show you, and you'll find weeks later when they've settled in, you'll suddenly realise "oh, they're actually really good at that".* (M4)

By this stage Orna had developed some strategies to support these children:

> *Teaching what you'd think of as very basic vocabulary very explicitly and planning exactly how you are going to phrase things and repeating it […] When I was doing division I just wrote down how I was phrasing it each time to just make sure I was consistent with it.* (M4)

She was also trying to make sure all her children used reasoning in their mathematics:

> *even if they can't speak English, that they're somehow showing me how they worked it out, […] I'm like "Why did that happen?" and "How did that work?"* (M4)

8.3.2 ***Other perspectives on the influence of teaching children with EAL***

Rahma, Evie and Rakesh also taught classes with the majority of children having EAL. Evie, who is introduced in detail in 4.6, and Rakesh, who is introduced in detail in 4.7, both taught in large multi-ethnic city primary schools. Evie taught Year 4 children; Rakesh taught in Year 5 for his first year, and then Year 6.

Whilst all mentioned the impact of this on their teaching, only Rakesh specifically talked about it when creating his influence maps. In contrast to Orna, Rakesh considered mathematics *"an easier subject to teach"* to EAL learners than English because they "*find maths a lot easier, particularly arithmetic skills"* (M3) and this impacted positively on his feelings about mathematics: "*a lot more enjoyable to teach than English*" which was "*much more of a struggle across the whole school; a massive issue.*" (M3)

All found challenges in teaching mathematics to children with EAL, with Rahma having a particular challenge with new arrivals who had not previously attended school. Evie, who taught in Year 4, emphasised, like Orna, difficulties with children not understanding language in word problems. In addition, she mentioned the issue with formally assessing the children's mathematical understanding using such problems:

> *They actually might be able to do the maths and it's more the language barrier that's inhibiting them, so I don't think testing on its own is really a fair way because sometimes it's more that they don't understand what they're being asked to do, not necessarily that they can't do the maths behind it.* (M2)

Rakesh stated similar challenges in relation to preparing his Year 6 children for national testing and discussed the extra lessons deemed necessary:

to ensure that the children are practising reasoning as much as possible, because that is one of the biggest difficulties for our children, particularly because most of them are EAL learners, the reasoning, language behind some of the word problems is particularly challenging for them. (M4)

The influence on Rakesh of preparing children for the national tests is considered further in 8.4.3.

Like Orna, Rakesh and Evie discussed strategies to help children access mathematical problems and to show their understanding:

At least if they could use resources or diagrams, they could at least show you what they mean so that you could see that they understand it. (Evie, M5)

[Before national testing] *we did lots of practising of bar models and looking at different strategies for reasoning to help them visualise the problem […] working pictorially was really helpful to them.* (Rakesh, M5)

Rakesh also talked about using *"real life experiences":*

so they understand why they're having to perform these calculations, in what context these calculations would need to be performed. (M4)

Whilst finding teaching EAL learners challenging, all were positive about having chosen to work in a diverse school. Evie commented on how *"interesting"* her class were: "*It's so nice, there's so many children from all over the world*" (M2), Rahma enthused about the "*huge progress*" her children with little English had made (M5) and Rakesh relished the challenges he faced in his school context:

It's been a really good place to start my career, because I'm experiencing so many different things – almost a third of my class are SEND [having 'Special Educational Needs and Disability' (Department for Education and Department of Health, 2015)], a third of my class weren't at this school until Year 3 or 4, I've had one child join my class in October who's completely new to English and he's

> *illiterate in his first language, so there's lots of challenges there in trying to figure out how best to meet their different needs*. (M3)

Orna, however, was distinctive in the emphasis she placed on developing in these children the characteristics she believed would make them good mathematicians and therefore in the influence on her practice of teaching them.

8.3.3 *The influence of individuals – Orna's perspective*

An additional and related element of Orna's approach was the way she viewed her class as individuals and her concern to help those with difficulties to learn mathematics. As she said at Meeting 4:

> *I think you do need to know your children really well and know what they can do and also find out where their errors are coming from.* (M4)

Short anecdotes about particular children were shared by most participants, but Orna was the one who spoke most specifically about the individuals she taught, their needs and how she aimed to teach all of them according to her beliefs about what makes a good mathematician.

Orna was very open about the struggles she had to help some children progress in their mathematics, especially in her first year. These included one child who really enjoyed lessons, but needed a lot of support to *"see maths":*

> *He adds everything […] before you've even told him what you are doing that day, he's added everything up within sight […] getting him to do something else can be really tricky.* (M2)

Another child had a recognised fear of mathematics

> *and just freezes every maths lesson and just doesn't do anything […] I don't know how to crack that.* (M2)

And a selective mute was challenging to teach:

I don't know how to work out where he's gone wrong when he won't speak to me. (M2)

By Meeting 3 Orna felt she had made some progress in supporting these children. She recalled acting out a problem which the selective mute not only solved, but also told her his answers, giving her an opportunity to not only gain insight into his understanding, but also to share his success with her class:

> *I was like "Oh my goodness that's totally right" and I told all the kids he'd found a solution and they were all flabbergasted and all started working really, really hard because actually it was a really good way. The fact that it was acted out and he got to see it and be involved with the problem rather than just reading it or just hearing it, meant that he could access it and understood what was happening and then he got to actually show that he does have really good skills.* (M3)

The child with mathematics anxiety was *"still really struggling",* but Orna took opportunities to try to develop a more positive attitude to mathematics through praising her efforts in non-numeric mathematics:

> *She's had moments when I'm like – "You're being so good, you are doing so well" – when we were doing symmetry which was a bit different, she was really getting into it. I was like, "This is still maths, this is still maths – this thing that you are enjoying now is still maths, believe it or not."* (M3)

These two instances are illustrative of Orna's encouragement of resilience in the children she taught, a characteristic of effective teachers that she recognised and considered a strength of her practice:

> *The resilience thing has been the biggest thing this year in terms of so many just gave up and that is one thing they have really improved at actually – they persevere so much more than they did at the beginning of the year*. (M3)

Orna's graph of her relationship with mathematics during her NQT year, while positive throughout, has *"lots of little spikes"* reflecting the challenges she faced, particularly with supporting individuals (Figure 8-4).

> *I'll have lessons where I'm like "This is so great" and then "Oh my goodness, I can't deal with this […] It does make such a difference when they go into negativity in terms of how they do it […] It is when we are doing the more reasoningy stuff that I do enjoy it more.* (M3)

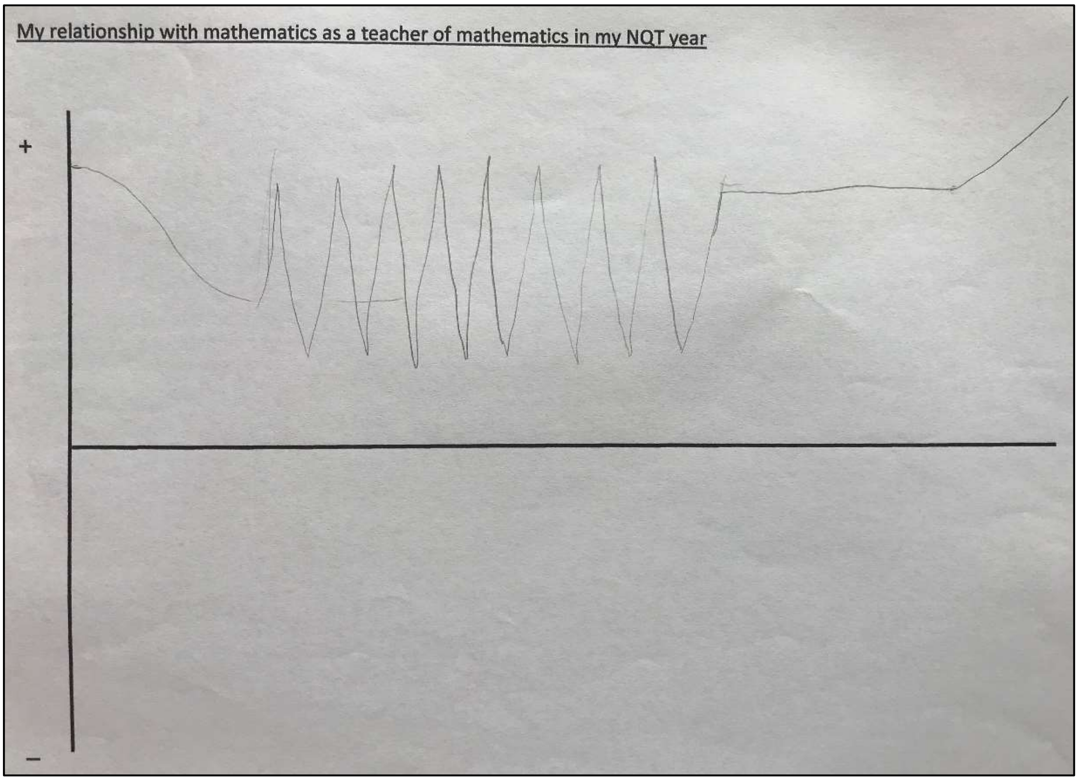


Figure 8-4 Orna's relationship with mathematics in her first year of teaching

The influence of the children taught was apparent to some extent in the narratives of all the participants but was highlighted distinctively by Orna. The expression of her commitment to get to know her pupils as individuals in order to best develop their learning in line with her beliefs about what makes a good mathematician, in turn derived from her background as a learner of mathematics. In relation to Coffey and Atkinson's (1996) categories of function, the intended and explicit articulation of her thoughts about the influence of the class and school sit within the context of the more implicit but nevertheless significant influences of her background and beliefs.

8.4 The age group taught

When selecting pre-service teachers as potential participants for the study it was not possible to take into consideration the year group they would be teaching as this, for most, had not been decided upon at that stage. This section firstly presents Chloe's experience of teaching a mixed-aged class and then highlights the influence of the age group taught on Emily and Rakesh, the two participants who taught in Year 6, with children aged 10-11. These two had the lowest mathematics qualifications of all the participants and both were challenged by the mathematics content knowledge required. Emily and Rakesh also talked at length about the influence on their teaching of preparing children for the national Standard Assessment Tests (SATs) - tests taken in English and Mathematics towards the end of the academic year by Year 6 children in England.

8.4.1 *The influence of teaching a mixed-year class – Chloe's perspective*

Chloe is introduced in detail in 4.5. Having completed the Primary with Mathematics PGCE course, she taught in a primary school with a large majority of white British children on the outskirts of a small town. She was the only participant who taught mathematics to children from more than one year group together. She saw this as a specific influence on her development as a teacher of mathematics, creating the influence map shown in Figure 8-5 at Meeting 5.

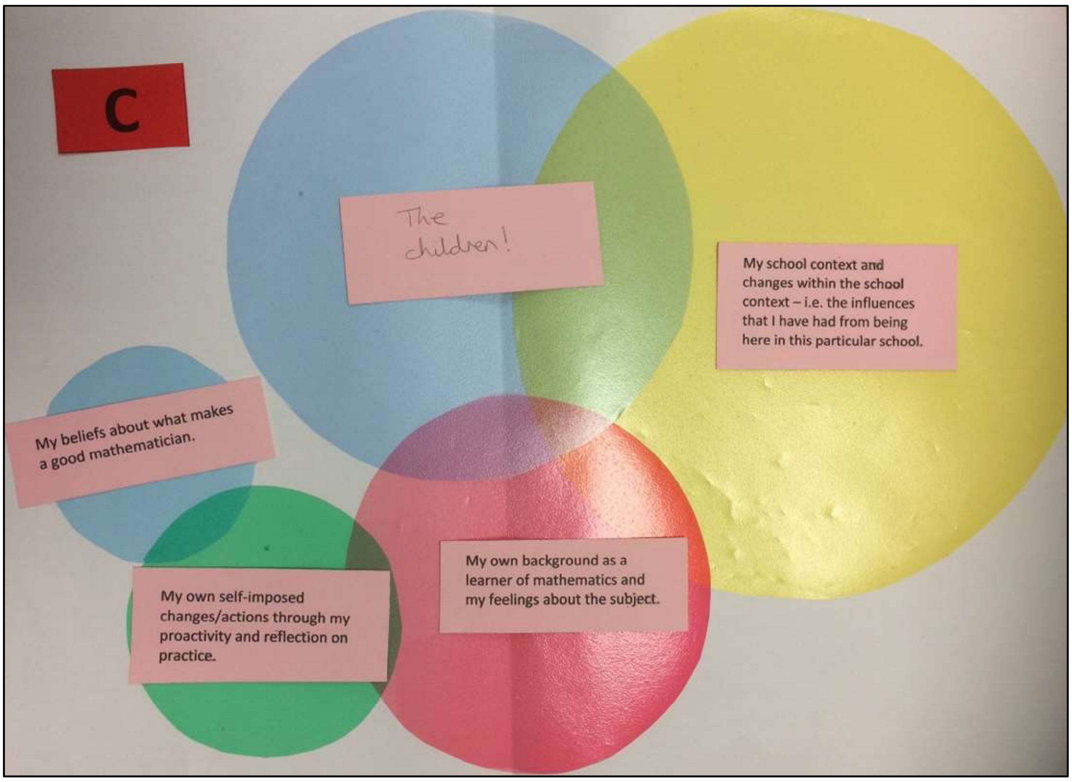


Figure 8-5 Chloe's influence map Meeting 5

In both of her first two years of teaching Chloe taught a Year 3/4 mixed age class (children aged 7-9), alongside two parallel classes. However, for mathematics lessons the children were set by attainment. In her first year, Chloe taught a *"challenging"* Year 4 set of *"lower/middle"* children while the highest attaining children in the year group were taught in a separate *"lovely class"* (M2). At this stage, challenges particularly related to the attitude and behaviour of *"quite a big group of boys":*

> *getting them to actually listen and be on task and want to do tasks - I guess partly them seeing the importance of maths,* (M2)

with a consequent impact on her teaching:

> *I want it always to be fun and I try to say to them sometimes, "I really wanted to do a fun activity but you're not making that possible". So that's a difficulty I guess when you've got the behaviour.* (M2)

Chloe also perceived an impact of these challenges on her beliefs about what makes a good mathematician, reinforcing the importance of a *"positive attitude towards maths itself":*

> *You can try and try and you will get there eventually if you have the attitude where you want to.* (M5)

In her second year, the setting arrangements changed and Chloe taught a "*mixed Year 3/4s lower ability*" set (M4). This brought a welcomed change to planning, teaching and reflecting on lessons alongside a colleague teaching a parallel set, with a sense of shared responsibility:

> *You know that you're on the right track […] When you've had a really bad lesson, a really bad week* (laughing) *and you think 'was it just my class?' – no it wasn't, ok, right, this is just a really difficult topic – how can we try it again next time? […] I think I'd always like to have some kind of sharing of planning.* (M4)

However, when creating her influence map at Meeting 5, the point that Chloe stressed was how the children had "*influenced my teaching massively because of the spread of children, their ability level."*

Elsewhere in Meeting 5 she elaborated on how "*challenging*" she found this: "*there's so much differentiation*". By this time, she had a child of "*very high ability*" join her set because there was insufficient room for him in the higher set. She found it *"very difficult to teach all abilities"*.

Chloe talked about how she organised her teaching to accommodate children working on the National Curriculum from Year 2 to Year 4 and her concern that this organisation did not lead to the best outcomes:

> *I often have my TA* [teaching assistant] *with the three children who are Year 2 level go off at the start, but I still have to talk about all of the Year 3 work first and then send off Year 3s and then talk about Year 4 […] If I just had the one*

year group it would be a lot easier – I would be able to set them off sooner, they would be able to probably get more work done, I would be able to give them more examples than having to do a bit of both levels of work. (M5)

Chloe found a particular problem when the number of curriculum "*targets*" differed for a particular topic, meaning that her strategy of teaching the class as different year groups together became disjointed:

For example, we did position and direction - shape - but there's loads of objectives for Year 4 for that, there's about three for Year 2, there's none for Year 3, so I used that week for Year 3 for testing shape topics from the previous term and then revising some topics that they found a bit tricky. (M5)

The practicalities of teaching this range of attainment required much organisation:

I just find that there are so many sheets […] At the start of the week you've got three objectives but by the end of the week […] I've got about five objectives and so I've got five different piles of sheets and then there's extensions for those sheets and it's just – there's so much going on. (M5)

Chloe worried that the following year would be "*even more challenging"* as the setting arrangements were ending and she would teach all her Year 3/4 class for mathematics. This resulted in Chloe's graph of her relationship with mathematics in this year being the only graph of all the participants that had a net decline (Figure 8-6). Although *"always in the positive side of maths because I've always liked maths",* her summing up of the graph neatly sums up her feelings from the year:

Some wobbles with the stress and the level of input needed and then maybe ending a little lower because of the worry of next year. (M5)

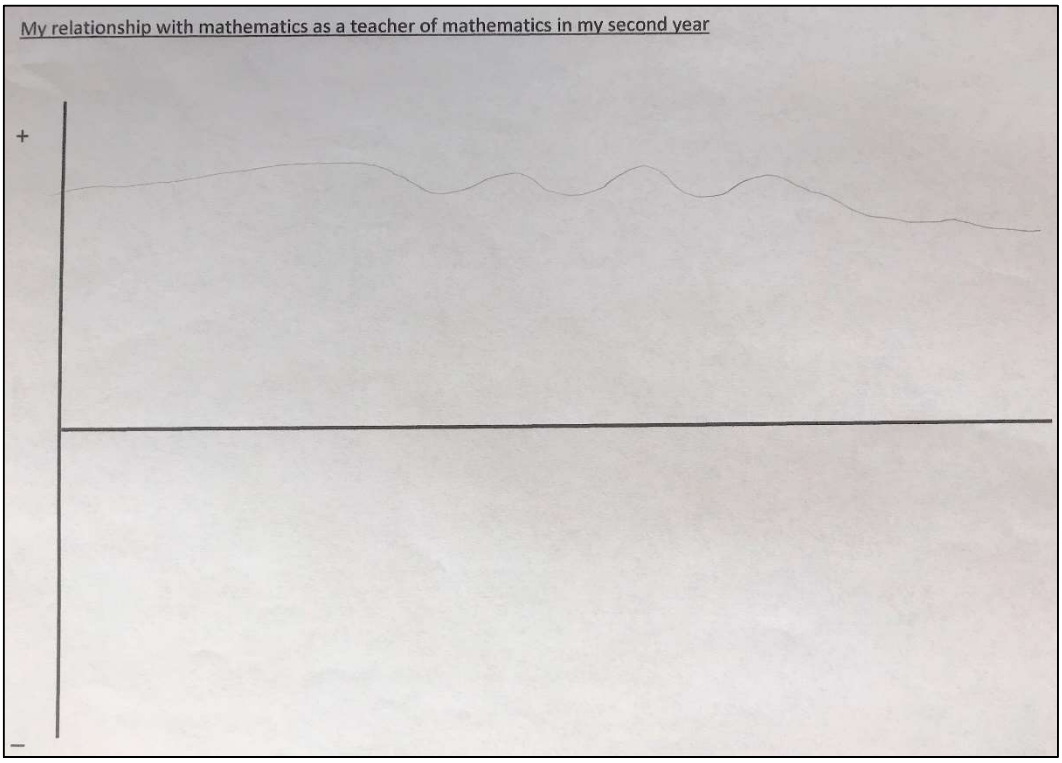


Figure 8-6 Chloe's relationship with mathematics in her second year of teaching

8.4.2 *The influence of teaching in Year 6 – subject knowledge development*

Emily and Rakesh, the two participants with the lowest mathematics qualifications taught for their second year in Year 6. Despite Emily's statement when creating her influence map that her background in mathematics was *"quite good"* and therefore she had *"not really thought about"* its influence on her teaching (M5), the subject knowledge required for Year 6 was a challenge for her.

Emily is introduced in detail in 4.8. She taught Year 3 and then Year 6 children in a large village primary school. Emily's influence map created in Meeting 5 shows the school context as the largest influence, overlapping with her own self-imposed changes through her proactivity and reflection on practice (Figure 8-7). In explaining this she stated:

> *I think* [the two largest circles] *are very, very closely linked because the changes within your school have a big influence on you because you have to follow the*

school's ethos and way in which they want things to be implemented […] I will always try to fit what they're expecting by reflecting on my own way of practice.

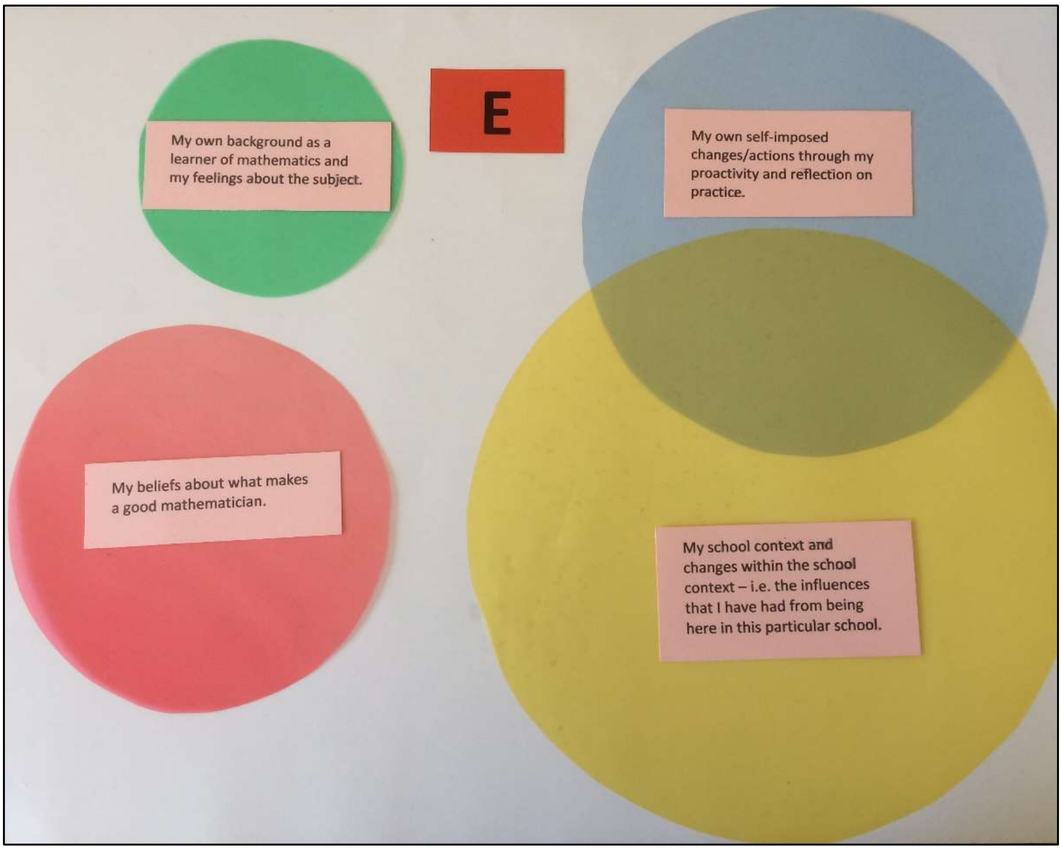


Figure 8-7 Emily's influence map Meeting 5

Insights into these influences come from a list Emily made in preparation for Meeting 4 and suggest these relate closely to the development of her subject knowledge. She set out what had influenced her development since starting teaching in Year 6; "mimicking good practice" from her phase leader, "My LSA – previous Year 6 teacher" and "SATS!". Implementing changes in line with others in her school context through reflection and proactivity too are apparent as she elaborated on the list during Meeting 4:

The Year 5/6 phase leader […] I've mimicked a lot of her good practice which I think has helped no end […] I was looking at her books and she was saying how she would teach the skill of something and then there would be an applying *section* [on a worksheet] *where you've just got to apply the basic skill you've learnt, a problem solving section and then a reasoning so you've actually got to explain how you've got something. So, seeing that in practice has made me feel more confident and I feel better in knowing where I'm taking the children and where I need to get them to.* (M4)

The Learning Support Assistant (LSA) working with Emily happened to be a qualified teacher who had previously taught in Year 6. Although initially *"a little bit intimidated"* by this, Emily stressed in Meetings 4 and 5 how much she had benefitted from working with her:

She comes in every morning and we talk about what I'm going to teach and she'll recommend tips and things, suggest misconceptions that she has previously experienced which is good, so I can be ready for anything that comes along. I found that really helpful […] I couldn't do without her now. (M4)

I do feel like my maths subject knowledge and just understanding of the approaches to maths and understanding children's misconceptions and everything seems to have developed hugely this year, which I think is down to the support I've had from my LSA. (M5)

This support from the LSA included her occasionally teaching the class when the subject knowledge was particularly challenging for Emily:

If there is something that I don't feel particularly confident teaching, she will do it and I can watch and learn from her, especially as the maths is much harder than it was in Year 3. (M4)

Rakesh also spoke of the additional preparation required for teaching in Year 6:

In terms of subject knowledge, this year has been a challenge in the fact that the textbooks throw some questions in there that even I'm thinking "How do I approach this? How do I model this?" […] It's a case of going through them *before the lesson and practising modelling by myself before I teach the lesson, which I didn't have to do last year as much*. (M4)

Thus, as he explained when creating his influence map in Meeting 5, Rakesh thought *"a lot about what I don't know […] plugging those gaps as I go along".* By Meeting 5 he considered the changes he had made meant *"my background from before is almost irrelevant now"* and he enjoyed teaching mathematics *"which wasn't the case when I was a learner".*

8.4.3 ***The influence of teaching in Year 6 – SATs***

In addition to the more advanced subject knowledge required, the pressure of preparing children for SATs was a major theme of both Emily and Rakesh's meetings in their second year. Emily found that although knowing *"exactly where I need to get them to"* was making her *"much more efficient with my time, making sure everything gets covered",* she was also *"starting to panic a little bit"* at Meeting 4 about how much more the children needed to learn. Rakesh too, whilst considering his year to have been *"very positive"* overall, acknowledged that he entered Year 6 with *"some anxiety"* related to the SATs (M5). Rakesh talked about SATs being *"really important for the school"* (M4) but for him the long-term impact of children's success in the SATs was particularly important:

Mainly for me it's just making sure that these children don't have to do that catch up work next year and the years after and making sure that their education isn't something that would hold them back. (M4)

Rakesh's anxieties about SATs are indicated on his graph of his relationship with mathematics drawn at M5 (Figure 8-8). The graph includes:

A few wavy moments where we've had difficulties with getting our children to understand different concepts, and just general anxiety about the SATs and how prepared they are going to be for it. (M5)

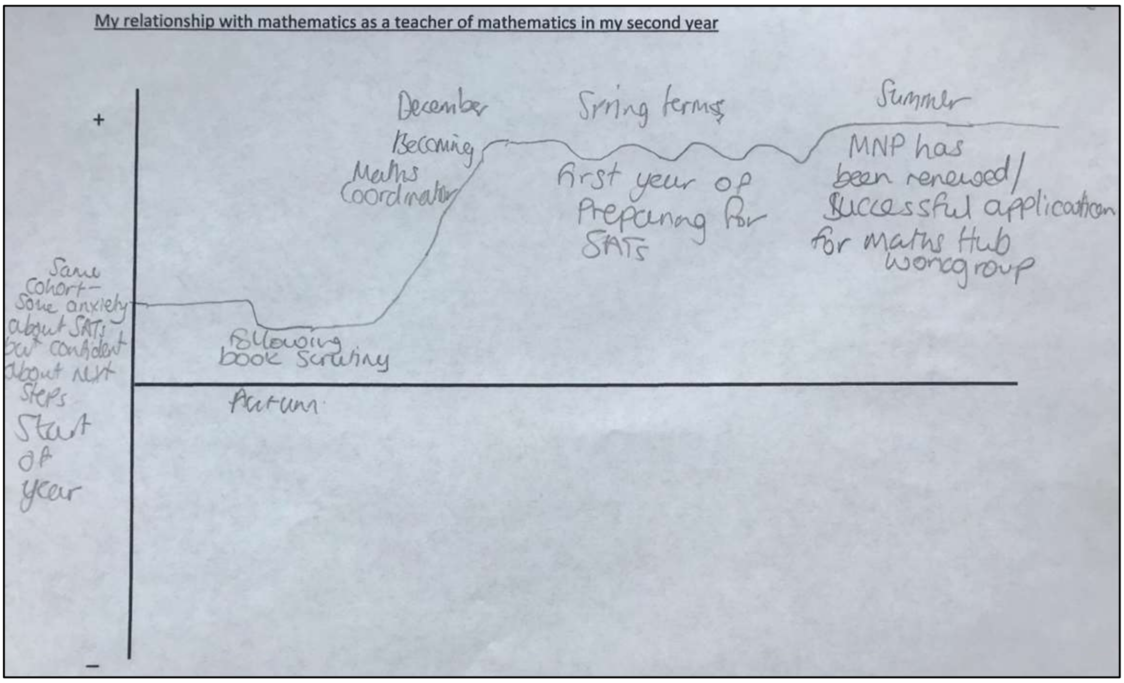


Figure 8-8 Rakesh's relationship with mathematics in his second year of teaching

As both Emily and Rakesh focused on preparing their children for SATs, they changed the structure of their lessons, taught extra mathematics lessons in the afternoons, revised topics and looked at SATs style questions with their children. Emily, for example, taught several weeks of lessons in the Spring term where children worked on solving past SATs questions with a focus on *"reasoning and problem solving, because that was an area all of them were struggling with"* (M5). Rakesh similarly focused on looking at specific mathematics skills *"within a reasoning context",* using past SATs questions and teaching strategies including *"lots of practising of bar models and looking at different strategies for reasoning to help them visualise the problem because mainly it's an EAL issue."* (M5) His children also practised weekly arithmetic tests

> *because that's something that our children should be strong at because it's straight forward calculations, so if we practise enough and they understand what they need to do with those questions, they have a real chance of success.* (M4)

Both Rakesh and Emily felt their teaching of mathematics had improved over the year, for example:

Ensuring reasoning is part of my teaching and understanding the importance of children being able to apply skills to real life problems. (Emma, preparation notes for M4)

Trying to make sure that I add that extra element in, that next connection, or thinking about how to deepen that learning further – identifying the right point to do that. (Rakesh, M5)

Rakesh, however, expressed pragmatically at both Meeting 3 and Meeting 5 that he was not able to teach according to his beliefs about what makes a good mathematician. Referring to the influence of these beliefs as he created his influence map he said:

I'd say that's quite irrelevant now because I think I a lot of what I believe makes a good mathematician isn't necessarily what is reflected in the tests […] We have to reflect what we're told to do, basically by the government, through the curriculum and things like that but also school priorities as well. (M5)

When prompted, Rakesh summarised these beliefs and contrasted these with his views on the constraints that were imposed on him:

I think a child that always questions things is always usually a good mathematician […] they are problem seekers rather than problem solvers – well they are a bit of both, but they see that real value on the problem seeking as well. (M5)

We work within a system that values the right answer and the importance of getting to the right answer quickly and efficiently as well. (M5)

Even a year earlier, whilst teaching Year 5, Rakesh had expressed the same concerns:

Ultimately, I don't think it really matters what I think makes a good mathematician because that's not how they are assessed at the end of Key Stage 2. […] My own beliefs about what makes a good mathematician and the

> *best way of producing good mathematicians doesn't really matter because unfortunately we work in a system and that system dictates how we approach things.* (M3)

The influence of SATs was therefore prominent for both Rakesh and Emily and contributed to their positioning of the school context and self-imposed changes through proactivity and reflection on practice as large and overlapping influences on their influence maps. Emily's acknowledgement that *"we've not done any maths"* since the SATs because *"we've had enough for the year"* (M5) possibly sums up the impact of the SATs on her and the children.

8.5 Learning and development opportunities

Chapters 5-7 provide evidence of the differing learning and development opportunities Rahma, Gina and Penny received within their school context, with Gina receiving particular support. Evie and Orna, like Gina, taught within the context of a specific whole-school focus on change and development in the teaching of mathematics. Their perspectives provide contrasts to Gina's in both the approaches taken by the school leaders and how the learning and development opportunities were perceived by the participants. Set out in this section are Evie's developing perspectives about the value of concrete and pictorial approaches linked to whole-school and individual support from her mathematics subject leader, and Orna's perspectives on her development as a teacher in her first year linked to whole-school priorities. In talking about these learning and development experiences, both participants reflected on links with their beliefs about what makes a good mathematician.

8.5.1 *Changing practice and beliefs – Evie's perspective*

In reflecting during her final Meeting on what had influenced her during her first two years of teaching, Evie created the influence map shown in Figure 8-9. Explaining why the school context was the largest influence she said:

Because our maths coordinator is brilliant […] she's introduced so many things this year, so using more resources, the different types of resources, Problem Solving Friday, Method Monday, and they've made such a huge impact on my teaching of maths. (M5)

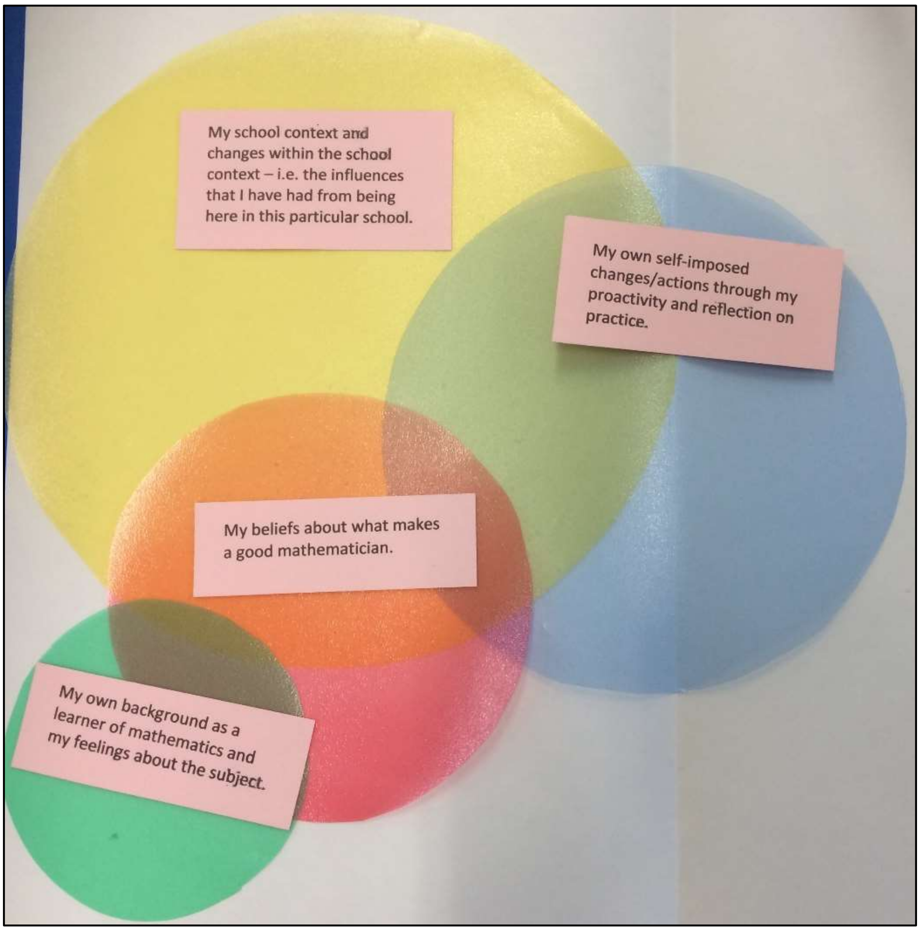


Figure 8-9 Evie's influence map Meeting 5

A distinctive feature of Evie's narrative was the evolution in her ideas about strategies to successfully teach children the conceptual understanding they need, in her opinion, to be good mathematicians. She overlapped the influence of the 'Beliefs' circle with each of the other circles, mentioning, for example, the *"value"* she placed on mathematics and her high confidence teaching it while overlapping 'Background' and 'Beliefs':

I really like maths, I'm confident with maths, I'm confident teaching it, I think it's really important – I can see the real value of it. (M5)

However, she particularly linked her beliefs about what makes a good mathematician, *"being able to reason in different contexts, spot patterns, make links, show it in different ways",* to the emphasis placed by the mathematics coordinator on the use of concrete resources and the support this coordinator gave her over the two year period while teaching a lower set in the same year group.

Throughout her series of meetings, Evie stressed her belief that children should understand the mathematics they learn conceptually. In Meeting 1, for example, when discussing the concept cartoon about the nature of mathematics and learning in mathematics (Figure 8-10), she stated:

> *I disagree completely with Molly. […] There is always a reason behind things and why we do them […] that's the procedural learning rather than the conceptual understanding. […] I agree with Clara completely, it's definitely the key, so like the commutative law, if you can understand things like that it makes it so much easier. […] Maths is abstract, I do think it is in some instances, so we do have to help children think abstractly but there is that stage beforehand where it's all concrete and they can physically move things […] I wouldn't say maths is all abstract because you can physically see it, so measuring out volume, measuring distances, it's not abstract.* (M1)

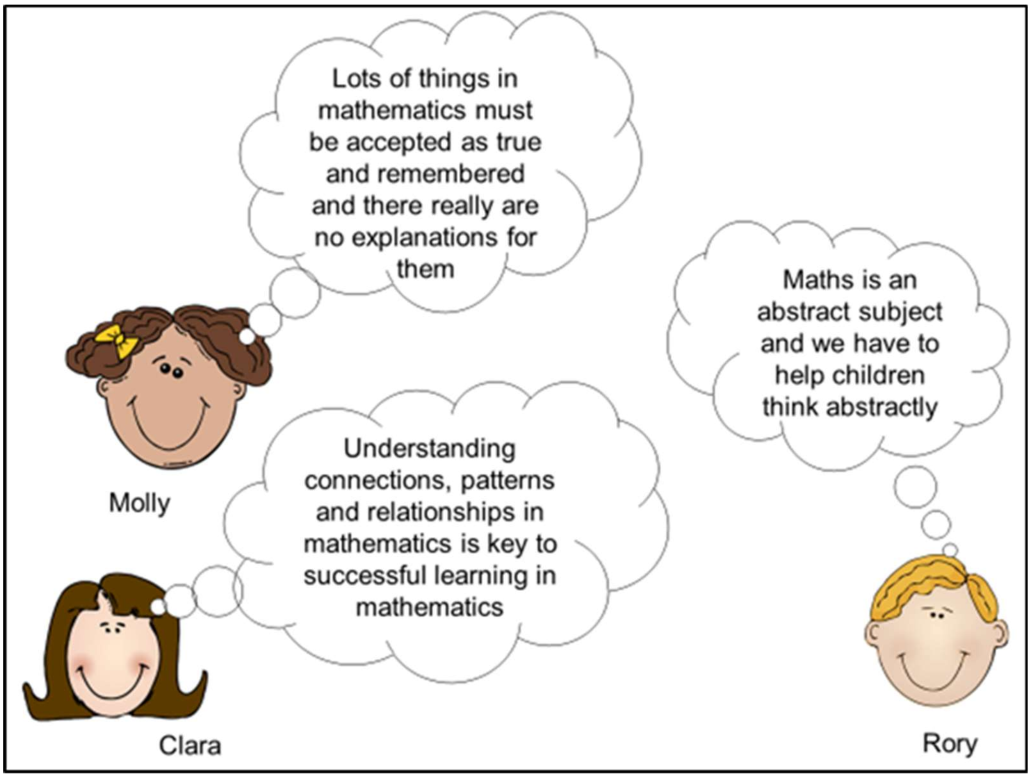


Figure 8-10 Concept cartoon used by participants in Cohort 2 to discuss their ideas about the nature of learning in mathematics

However, at Meeting 2 Evie expressed doubts about the value of children using concrete resources:

> *I think what I've really found is that concrete can actually make it more complicated for the children, so sometimes actually if they're ok enough, visual is ok, but taking that visual away is then the next step.* (M2)

By Meeting 3 Evie had increased her use of visual representations and concrete resources to support children's understanding. She had accessed support from the mathematics coordinator who was *"really, really helpful"* in giving advice when Evie found children were struggling to understand concepts. Looking at the coordinator's planning for the teaching of fractions, for example, and considering her use of *"pictorial, bar models, […] Dienes"* had informed Evie's teaching; Evie used Dienes equipment (blocks in which cubes represent ones, rods equivalent to ten cubes represent tens, flats equivalent to ten rods represent hundreds and cubes equivalent to ten flats represent thousands) for calculation when children did not understand a more abstract approach and had children physically organising themselves into groups to understand fractions of quantities.

However, Evie found that the use of concrete and pictorial approaches did not necessarily lead to the deep understanding she was seeking. Although stating

> *They like being able to see it. They do because I think it's too abstract if they can't see it or they can't actually physically move it.* (M3)

in relation to the children's understanding of fractions she commented:

> *They were ok with the 'show it' and 'write it' bit with the bar model but explaining it and proving it, particularly the explaining bit they did find difficult to understand. Even with resources they struggled to manipulate them properly.* (M3)

Despite this, Evie seemed convinced that greater use of concrete resources from the start of the following year might enhance the children's learning:

> *I think next year I probably will try and use more concrete materials than I have this year, particularly at the beginning of the year and with the introduction of fractions.* (M3)

At Meeting 4 Evie talked about further support as she sought to adopt this approach:

> *Our calculation policy's changed and that again has really helped – that's very much – this is how you do the concrete, this is the pictorial, this is the abstract.* (M4)

There was also a greater emphasis in the school on problem solving with the introduction of Problem Solving Friday and some whole-school training on problem solving.

By the end of her second year of teaching, the use of a concrete and pictorial approach seemed embedded in Evie's teaching. There was a distinct change in the way Evie talked about how the children used resources and diagrams – a move from securing a basic conceptual understanding to children using these to support reasoning and problem solving:

> *I definitely use more problem solving and more reasoning and more getting them to explain it but not just explaining it verbally, but we've really gone for a push on give me a written explanation, showing me with a resource, showing me with a diagram – they have to prove it to me, they can't just tell me, they've got to do something more […] I think my uses of resources have gotten better and I'm hoping that they will continue to get better as I develop.* (M5)

Evie's influence map places 'My own self-imposed changes through my proactivity and reflection on practice' as her second largest influence. The narrative above is illustrative of Evie's reflective and proactive approach as she sought to develop the effectiveness of her teaching.

8.5.2 *Developing practice in line with whole-school priorities – Orna's perspective*

Mathematics was a whole-school focus throughout both of Orna's first two years of teaching, contributing to her rating the school context as her largest influence in both years. In her NQT year, a staff meeting early on gave input on scheme resources to use in planning and ideas to *"promote maths language"* which was *"quite necessary in this school"* given the number of children with EAL. The school calculation policy was highlighted by the subject leader and initiatives were put in place to share this with parents:

> *I think this is the first year they made a big thing out of it* [the calculation policy] *[…] We got the parents in and had a session going through it with them and we've just pushed it in terms of using it with homework.* (M2)

Reasoning was promoted, with the subject leader observing lessons and scrutinising children's books *"looking for reasoning".* To increase the amount of reasoning, teachers were asked to *"draw a little thinking bubble"* on pages where children had *"done reasoning".* Orna saw benefits to this new system, *"it makes you think "we need to get some reasoning in""* and she related this to negative experiences she had as a learner when her teachers were *"always on at me for presentation"* (M1):

> *I'm trying to get my kids whenever they have that* [reasoning] *that they can just kind of go a bit free range on their presentation, which I know I would have really liked when I was a kid, because then you can see a bit more how they're actually working it out rather than desperately trying to fit with your pattern.* (M2)

Reasoning for Orna was an important characteristic of a good mathematician, but she reflected too on how the children she taught had different beliefs, considering that tables knowledge, another school priority, was most important. This was *"stressing"* Orna although she also appreciated the value of children knowing these facts:

> *I've got one kid who thinks he's amazing at maths because he knows his times tables, but actually can't reason at all. And then I've got others who think they are terrible at maths because they can't do their times tables, but are actually really good […] Times tables are like a big part of their personal belief about how good at maths they are. I don't know what I've done to make that a thing because I was very - didn't want it to be a thing, but then at the same time I do want them to learn their times tables because it would make everything so much easier.* (M2)

Whilst *"the way things are done"* (M3) at her school was a particular influence on her practice in her first year of teaching, Orna had the opportunity herself to influence the practice of others in her second year.

8.6 Subject leadership responsibilities

Two of the participants were given mathematics subject leadership responsibilities during their second year of teaching. Orna's experiences supporting Liam, the subject leader, are presented in detail below and illustrate the breadth of experience gained by an enthusiastic early career teacher with a very strong mathematics background working in a school where mathematics was a particular whole-school focus. Rakesh's experience as temporary subject leader was much more limited but was nevertheless seen as a valuable learning and development experience.

8.6.1 *Orna's experience of leadership - "Helping with the maths coordination"*

Lesson observation feedback forms from senior leaders in her school showed that Orna was regarded in her school as a high-quality teacher of mathematics; in June of Orna's NQT year the headteacher made comments such as "a wonderful atmosphere of everyone experiencing new learning", "outstanding subject knowledge" and "highly effective questioning". Like Penny, Orna was also seen by other teachers as an expert in mathematics resulting in them asking her for advice. Orna described this as "*a bit stressful*" at Meeting 2, feeling she did not necessarily have answers, but it was also "*kind of nice to be asked*".

At Meeting 3, at the end of her NQT year, Orna explained that she had been given the role of "*helping with the maths coordination*" the following year, anticipating "*it will be good*".

Orna fully embraced the role, describing it as *"really fun"* (M4), and appreciated Liam's approach:

> *letting me do stuff because he's still the subject coordinator, so the pressure's still on him but he still lets me do things, so that's nice.* (M4)

She shared with enthusiasm the range of initiatives she and Liam implemented and the extra training they had received through attending a multi-day *"maths leadership course"* focused on *"maths moderation", "evidencing reasoning"* and *"providing* [children] *with opportunities to show what they can do"*. One initiative they implemented in school from this was a lesson structure where "*They do their fluency and then they go on to their reasoning and their problem solving"*. (M4)

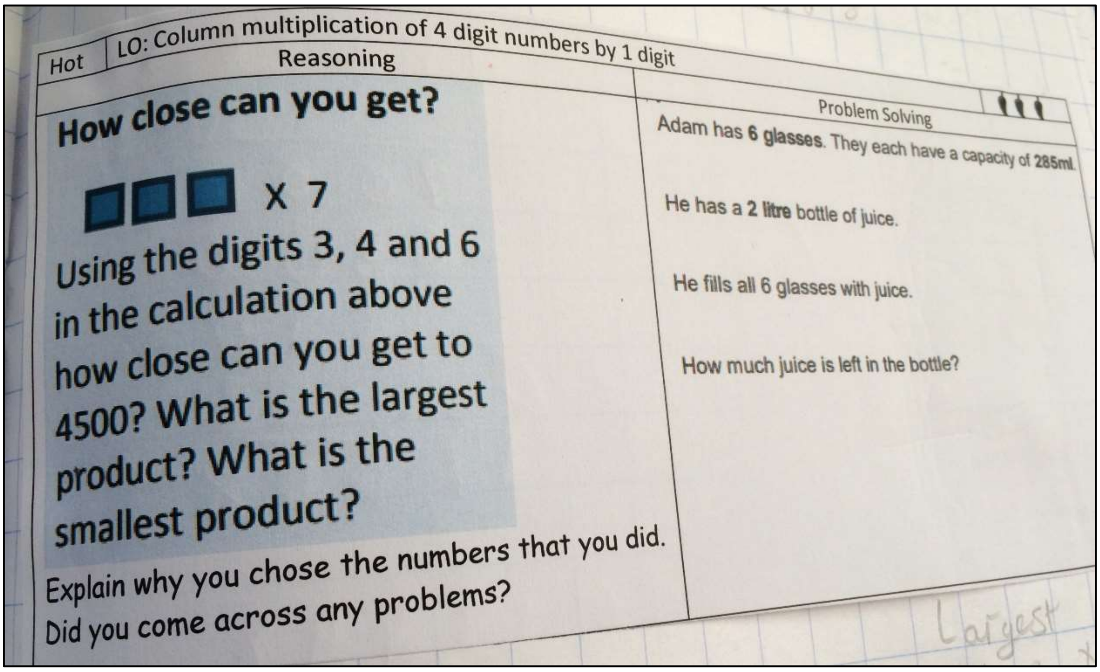


Figure 8-11 Example questions in the new lesson structure

Figure 8-11 gives an example. These questions were created with different levels of challenge indicated by the number of chillies in the top right hand corner. Children chose their level of challenge.

Whilst "*Making sure that reasoning and problem solving are really embedded in every lesson*" was a particular focus, additional short mathematics sessions, "*Maths Minutes",* were also introduced to "*boost fluency*" and continually revise "*basic skills*" (M4).

In addition to changes in routine teaching of mathematics, Orna and Liam decided to run a "*maths fayre*" where

> *Each class had their own zone […] and parents came in and did all the problems.* (M4)

Although Liam's idea, Orna took the lead in organisation. She "*selected the problems for each class*" and in a staff meeting

> *explained what they were doing and how it would work, gave out the problems and answered any questions they had.* (M4)

Each class then explored their problem and considered *"how do we want to get our parents doing this?".* Despite staff being *"a bit dubious"* when Orna first introduced the idea,

> *Afterwards they were all like "yes that was really good, I'm glad we did it"; so many parents came and the kids were really enthusiastic - it did go really well.* (M4)

Although Liam carried out most of the monitoring of learning in mathematics, Orna worked alongside him to carry out question level analysis on the SATs tests from the previous year to *"scale that down so that earlier in the school we are addressing weaknesses".* She particularly enjoyed the data analysis:

> *I like maths spreadsheets and stuff so Liam sends me all of those if there's anything like that to do.* (M4)

Orna's enthusiasm and expertise in mathematics were also utilised through coaching a Year 6 team to take part in a mathematics challenge competition. Whilst again it was Liam's idea, Orna *"shot-gunned to be able to take them"* (M4). Her reflection is further evidence of her noticing of the individual:

> *I got to coach them which was really fun and we got through to round 2 and then we didn't get through to the final – but they did really well and we've got one boy in Year 6 who's really good at maths and is used to getting 100% on everything and it was actually really fun to sort of see that he suddenly realised "I'm really bad at team work and I can't explain my thoughts to anyone" so yes, all four of them really benefitted from it actually.* (M4)

In Meeting 5 Orna described further changes resulting from the leadership course she and Liam were continuing to attend and their support from the local authority consultant who came to school to meet with them. They introduced "*Flashback Fridays*" for Years 1-6 to gain evidence of children's reasoning about mathematics "*separate from the point of teaching*":

> *The idea is you pick one objective that they've done relatively recently and two core skills and then we have two problems for each – so they start off by doing the left hand side which is like the general level and then we have a greater depth level on the right if they finish that.* (M5) (Figure 8-12)

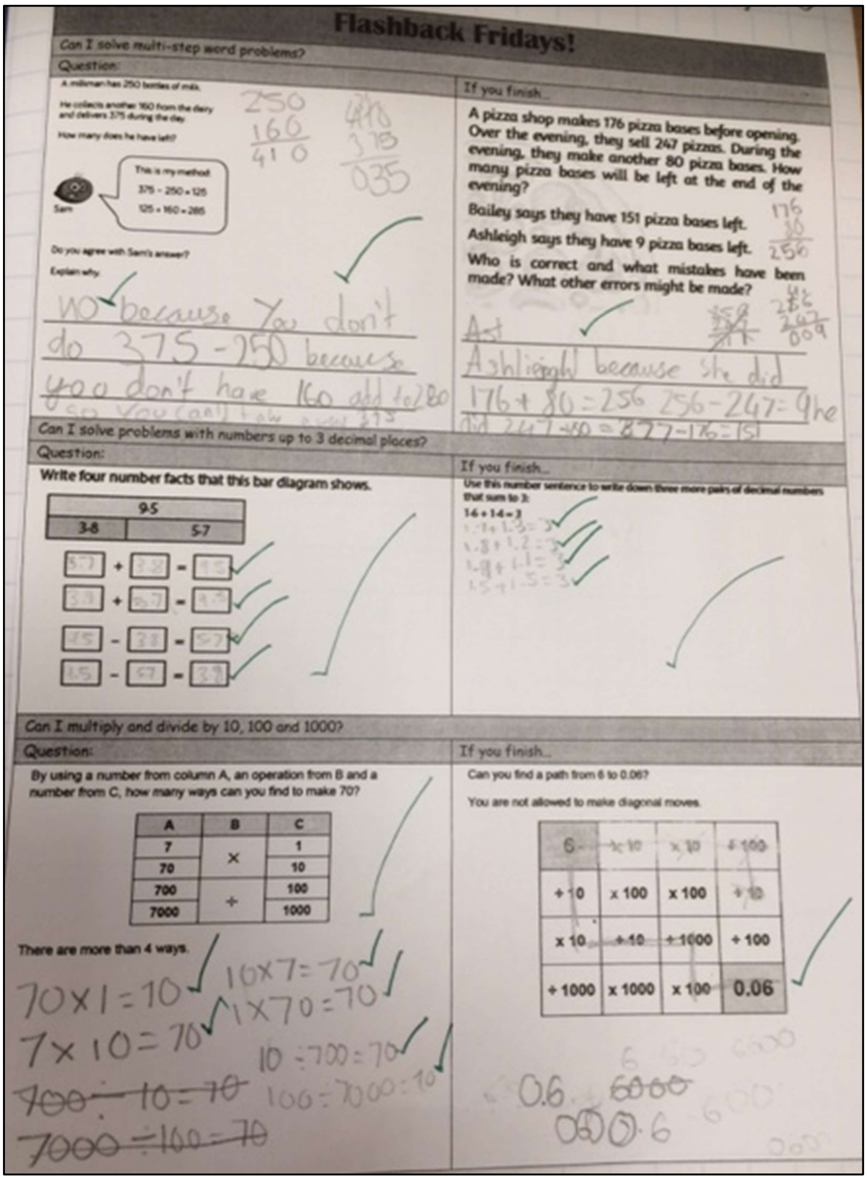


Figure 8-12 Example of a Flashback Friday worksheet

Children completed these "*in test conditions*" and then *"we go through it and teach on it".* Orna was fully involved in setting up this initiative. She led the staff meeting to introduce it, which was "*scary but fine*" and supplied questions to other teachers from a website she had come across through one of her other roles, that of Year 5 moderation leader for their triad of schools.

The moderation leader role was one that Orna was given by her headteacher and after attending training, she led meetings in mathematics and English moderation with other Year 5 teachers from the cluster of three schools. She found this a challenging role, particularly leading the mathematics meeting; she "*felt very young, very much a newby*" (M5). Although talking with a sense of humour, Orna revealed the difficulties she had found and her concern to convince others that what she had been told was good practice:

> *The maths one was horrible* (laughing) – *I told them what I'd been told* [at the leadership course, leading to her school's introduction of Flashback Fridays] *and they didn't like it and they got very angry at me and I was like "I'm just the messenger"* (laughing) *but I really tried to stick with what I'd been told while also saying that other people had decided this. And for me to then say that according to all the people at the training* [their] *evidence doesn't count, people got very negative and were like, "Well we don't have any problems which cross more than one area", and I'm like "That's nonsense, you must do – if you are doing any sort of reasoning problem it's going to cover more than one objective" – but it got a bit heated. But it was fine, by the end we had lots of biscuits, everyone left ok and I've got another one next week and I'm like "oh no, not again" but it's ok, it's writing again, so it should be ok.* (M5)

In this way, Orna began to influence the teaching of mathematics beyond her own school.

Whilst not taking the major responsibility for the developments in her own school, Orna valued having the opportunity to be well informed about changes. Her explanation here reveals her interest in the teaching of mathematics and her willingness to influence the practice of others:

> *It's been nice that I've got to see the picture a bit more because I got to be with Liam in his early meetings with Laura* [a local authority consultant] *and be on this course. I've been there when Maths Minutes was come up with and Flashback Friday, so it's nice to see things from their origin, and I think that's helped me to explain it to people a bit more and back it up when people have been moaning – I've been "no, there's a good reason behind this".* (M5)

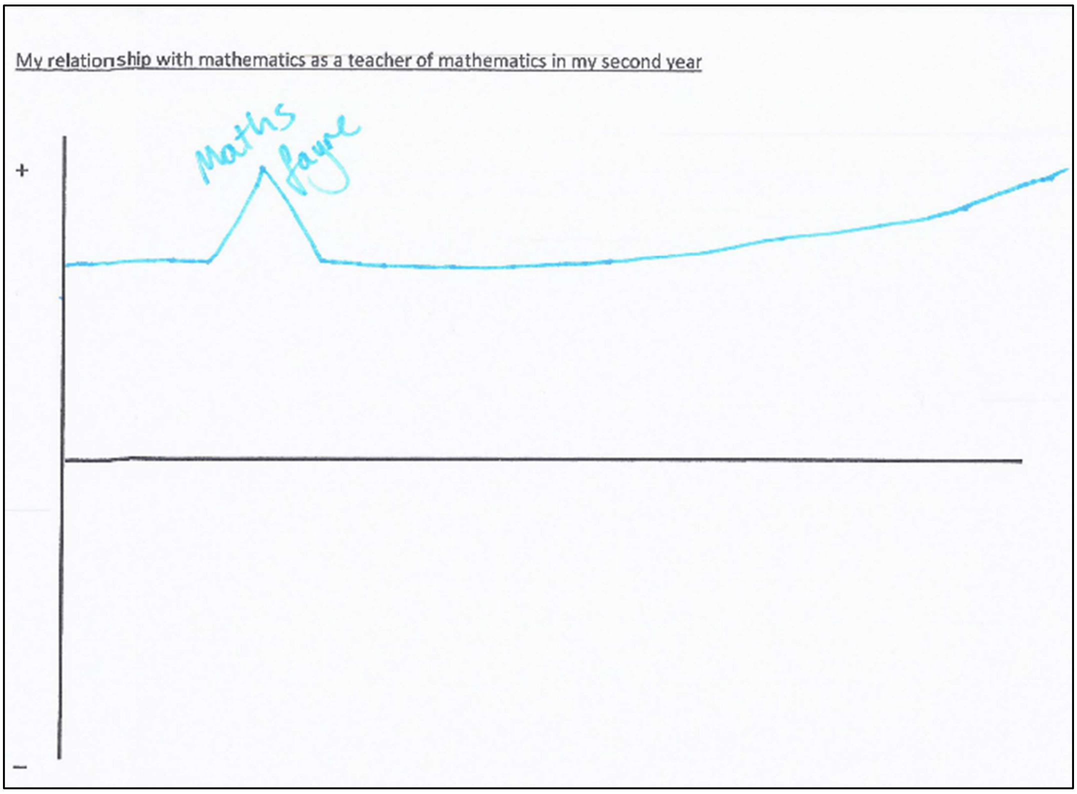


Figure 8-13 Orna's relationship with mathematics in her second year of teaching

Orna described her relationship with mathematics in her second year as "pretty steady" and the graph she drew in Meeting 5 (Figure 8-13) contrasts in its stability with her earlier graphs (Figure 4-4 and Figure 8-4). With a general "*slight incline*" she decided to draw a "*little peak for maths fayre; that was so much fun*" and summed up "*I do still really like maths*". (M5)

8.6.2 ***Rakesh's experience of leadership - Recognition of leadership qualities including proactivity and reflection***

Rakesh's influence map from Meeting 5 is shown in Figure 8-14. Although other participants also identified themselves as reflective and proactive, Rakesh, like Rahma, considered this the biggest influence on his practice. In contrast to Rahma he placed the influence of the school context in a largely overlapping position.

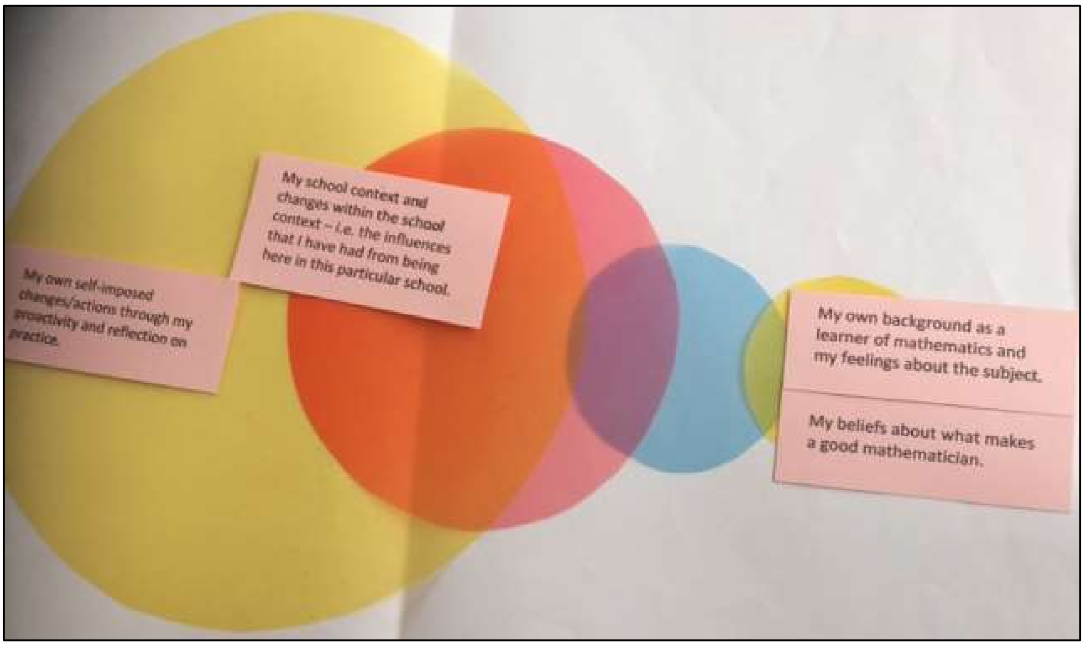


Figure 8-14 Rakesh's influence map Meeting 5

Rakesh's proactivity was apparent throughout the series of meetings, particularly as he sought to address barriers to children's learning in mathematics. Working within a school context where he felt by Meeting 5 that he had *"some influence, particularly within my own year group if I think we need to go in a particular direction",* he was the only participant who talked about researching in *"articles about education"* and *"trying to find solutions"* when he was *"experiencing difficulties"* in teaching mathematics (M5). One example he gave was how he had recently *"been thinking a lot about cognitive load"* and balancing the importance of *"making those connections in maths"* with *"not throwing too much information at the children"* (M5).

Rakesh considered proactivity to be one of the leadership qualities senior leaders recognised in him when, despite his inexperience and limited mathematical background, he was asked to take on the role of temporary mathematics subject leader at the end of the first term of his second year. Considering himself "*someone that tries my best to make sure that I'm clued in on developments in the subject",* he explained:

> *There are people in the school that are a lot more knowledgeable in maths in terms of subject knowledge. From what I understand the reason why they came to me […] was more the leadership side of things, thinking about next steps for the subject, thinking about when the school's inspected who would be able to talk about the data side of things, the progress side of things, and yes, the day to day organisation of the subject really, rather than someone who can talk about it from a subject knowledge point of view.* (M4)

At this early stage he found the prospect of leading mathematics *"exciting but also nerve wracking"* as he was very aware of his own inexperience and lack of expertise:

> *I still have to go to other colleagues for things that I am unsure of. I don't see myself as a maths specialist in terms of subject knowledge*. (M4)

Rather, he was *"trying to ensure the day to day organisation is managed well".*

During Meeting 5 Rakesh reflected that being asked to take on the role had *"raised my confidence as a maths teacher"* and was a *"really positive experience".* Rakesh's tasks as subject leader contrasted with those Orna's experienced. He expressed ideas that he was keen to implement in the future and he had been proactive in seeking opportunities for personal and whole-school development:

> *I applied to join a […]* [Maths Hubs] T*eaching for Mastery workgroup, so we'll be joining with other schools to help our school develop its mastery curriculum further.* (M5)

By Meeting 5, though, his role had been mostly organisational with the anticipated *"big next step"* from Meeting 4, carrying out a review *"to monitor and evaluate the subject",* being postponed. However, he had gained a *"wider view"* of mathematics in the school outside his own classroom and "*Thinking […] at that whole-school level of what other people's needs are"* led him to organise professional development opportunities for colleagues.

Showing again his reflective approach to his development as a teacher, Rakesh perceived that his subject leader role had made him a *"better teacher"* as he was able to learn from strategies other teachers used:

> *Having that awareness of how other people do things and different year groups approach different areas of maths has been really valuable.* (M5)

He also looked forward to reflecting on his experience with the subject leader when she returned to school *"and then work on it together maybe"*:

> *It's nice to have this time to do it by myself and then to reflect on it with someone who has been doing it for years and see what went well and what didn't.* (M4)

The subject leader responsibilities taken on by Orna and Rakesh led to contrasting experiences. Whilst Orna developed and actioned suggestions and opportunities delegated to her within the context of a whole-school focus on mathematics, Rakesh's experience was more limited in scope. Both, however, demonstrated proactivity and reflection, enabling them to develop their own practice whilst also influencing the practice of others.

8.7 Summary

When creating their influence maps at Meeting 5 the school context was chosen by most participants as the strongest influence on their developing practice. This chapter has highlighted some of the complexity of this influence, with various elements highlighted by different participants which in turn interrelated with other influences. The children's individual characteristics, their age and their backgrounds were all identified as significant influences on participants' development. Learning and development opportunities, both formal and informal, enabled participants to extend their subject knowledge, develop their beliefs about what makes a good mathematician and reflectively implement changes to their practice, including in some cases taking on responsibilities to influence the practice of their colleagues.

9 Discussion

9.1 Introduction

In this chapter I discuss the findings of my research in relation to the reviewed literature. I ascertain the extent to which my data aligns with the views expressed in existing literature and where my analysis extends the current understanding, leading to a new model of the interacting influences on early career primary teachers' teaching of mathematics.

The literature review identified that characteristics of a teacher themselves and their learning and development through reflection on practice and through the wider influence of the school context, combine to influence their evolving practice. In 3.3.6.6 I outlined how this understanding alongside insights from the ongoing data analysis led to my decision to ask participants to talk about four specific influences on them. This chapter is structured with a section relating to each of these four influences: 'The school context and changes within the school context', 'Background as a learner of mathematics and feelings about the subject', 'Beliefs about what makes a good mathematician' and 'Self-imposed changes through proactivity and reflection on practice'. The links between each influence and the other three are an integral part of these discussions.

The content of this chapter is developed from the findings set out in the previous chapters and so is based on the teachers' own perceptions of the influences on them as early career primary teachers of mathematics. A discussion comparing the evolving practice of mathematics specialist pre-service teachers with non-specialists is included in the section related to the background of the teacher.

Each section ends with a summary outlining key findings related to that influence and the contribution of this study to the existing literature. Alongside this a diagram is presented summarising both sub-categories of the influence and also the nature of the interconnections between that influence and the other three. Diagrams related to the individual influences are combined to form a full model of the interacting influences on early career primary teachers' teaching of mathematics which is presented with a summary of the discussion at the end of the chapter.

9.2 School context and changes within the school context

9.2.1 *Introduction*

This section explores the significance and implications of the findings about the school context, including changes within this context, in relation to relevant literature.

This influence is considered first both because of the perception of most of the participants that it was their largest influence on practice, but also because the data suggests that the influence of the school context affects the impact of the other three core influences. Evidence presented in earlier chapters highlights the complexity of this influence with a range of elements and interactions with other influences highlighted by different participants.

In this section I argue, in line with Llinares and Krainer (2006) that the social and organisational dimensions of teacher learning and development provide the backdrop to the influence of the school context; they are particularly influential and interlinked but also very specific to individual school contexts. Within these dimensions, three particular components of the school context are apparent from the data which combine to influence a teacher's practice: the influence of the school structures, procedures and policies; the influence of the children being taught; and the influence of opportunities for learning and development. The impact of change in the school context was highlighted by participants and is discussed as the final element of this section.

The three theoretical frameworks introduced in the literature review (2.3) for discussing teacher learning and development are used as the basis for the discussion in this section.

9.2.2 *School as a community with social and organisational dimensions*

The social and organisational dimensions of a teacher's school context were very apparent in the data, with emphasis placed by most of the participants on learning alongside others in their school context, working together to "develop, share and maintain" their knowledge about teaching mathematics (Wenger, McDermott and Snyder, 2002, p.27). This suggests that, alongside consideration of the influences identified in Millett and Bibby's (2004) model that impact on a teacher's zone of enactment (ZoE), the notion of legitimate peripheral participation (LPP) within communities of practice (CoPs) provides a helpful framework and vocabulary for understanding the school community as a driver of teacher learning and development (Lave and Wenger, 1991, Wenger, 1998).

With the exception of Penny, who had been working within her school context for several years, albeit not in a teacher role, the teachers in this study entered their first teaching jobs as complete 'newcomers' to their school. In practice for each this necessitated a shift from their identity as a pre-service teacher, learning from both "formal and apprenticeship contexts" at university and in school placements (Adler, 1998, p.11) to a context where they needed to immediately establish themselves as a 'legitimate' class teacher (Lave and Wenger, 1991), whilst also learning the routines, norms and attitudes of the professional practice of their individual school (Levine, 2010). The ease and extent to which they negotiated this change and made the transition through LPP towards becoming full participants within the CoPs of their schools varied. In part this was due to the teachers' practice, learning and development operating at a range of levels within the organisational framework of their schools.

Wenger's (1998) suggestion that an individual belongs to several CoPs on their own personal landscape seemed applicable to the teachers in this study. Working alongside other teachers teaching parallel classes in a year group, within a phase or key stage, or within the whole school, in effect meant that they belonged to at least two interconnected CoPs within the school context. In addition, collaboration and learning might happen within a cross-school community, such as Orna's moderation meetings, or completely outside the social and organisational context of the school, such as Penny's highly influential course. The learning from these occasional events, where external factors contributed to teacher learning (Millett and Bibby, 2004), was used by these participants predominantly for self-reflection, although with potential for shared learning with others from their in-school CoPs.

The evidence from my research emphasises the interrelated nature of the CoPs within the school context and for different participants the different significance of the various levels. Rahma, for example, identified her partnership with Nadia, her year group colleague, as the most important aspect for her of the influence of the school context (5.3.1). This two-person community seemed a key part of Rahma's ZoE. Within this she engaged in "rich deliberations" (Millett and Bibby, 2004, p.4) as she reflected on her experiences, shared ideas and influenced Nadia's teaching. In doing so she was taking some responsibility beyond her own classroom. In this situation, it could be argued that Rahma quickly reached 'full participation' despite her inexperience (Lave and Wenger, 1991). Nadia's support, feedback and acceptance of Rahma's ideas as a newcomer facilitated this process and seemed to provide further motivation for Rahma as she sought to develop her practice (Walshaw and Anthony, 2006). It is an interesting example of a newcomer quickly establishing their identity as a stakeholder in the development of the practice of the CoP (Lave and Wenger, 1991). Within this level, Rahma seemed to have gained the access needed to enable this through the willingness of Nadia to accommodate suggestions to changes in her practice. Rahma's self-efficacy as a teacher of mathematics (Bandura, 1997) and the perceived impact of her style of teaching may have been factors leading to this position.

Rahma was also part of the Key Stage 1 phase CoP where she shared ideas and learnt from others, confidently and proactively seeking out advice and support to develop her practice (Eraut, 2004); her learning trajectory here seemed to be rapidly leading towards full participation (5.3.5). Thirdly, although giving the context for her evolving practice in terms of the comparatively flexible procedures and policies within which she taught, the school level CoP for Rahma seems to have had a relatively small influence on her learning, possibly because of its seeming inactivity in relation to the development of mathematics teaching. A relatively limited whole-school focus on mathematics and limited opportunities for rapid growth of professional identity (5.5 and 5.3.5) left Rahma keen to take on greater responsibility at the whole-school level for the teaching of mathematics but not yet given access to this responsibility. A visual representation of the significance of her CoPs to her evolving practice is suggested in Figure 9-1.

In contrast, for Gina, the whole-school CoP was the level at which she learnt from others – this included senior leaders and external ‘visitors’ to the CoP. However, low self-efficacy as a teacher of mathematics, through awareness of her inexperience and seeming inability to please others, resulted in anxiety for Gina in her first year of teaching as she sought to be assured of her legitimacy in this CoP (6.3.2). She endeavoured to adapt her practice to satisfy those assessing and supporting her, motivated by both the internal factors of a strong desire to develop her subject knowledge for teaching to prove that she could teach effectively, and external pressure from accountability to senior leaders. (Bibby, 2002; Millet, Brown and Askew, 2004).

Gina’s self-efficacy as a teacher was notably stronger in her second year when learning alongside her more experienced colleagues in new whole-school initiatives (6.3.3). A sense of an ‘inbound trajectory’, developing a greater understanding of the evolving ‘shared repertoire’ of the whole school as they together negotiated the meaning of effective teaching for mastery, seemed to give Gina more self-efficacy in her legitimacy and competence as a teacher of mathematics (Wenger, 1998).

The year group CoP was much less significant for Gina and her learning here was nested within the overall school directives (6.3.2 and 6.3.3). She did not mention any learning at key stage level. A visual representation for the significance of Gina’s CoPs to her evolving practice is suggested alongside the representation for Rahma's CoPs in Figure 9-1.

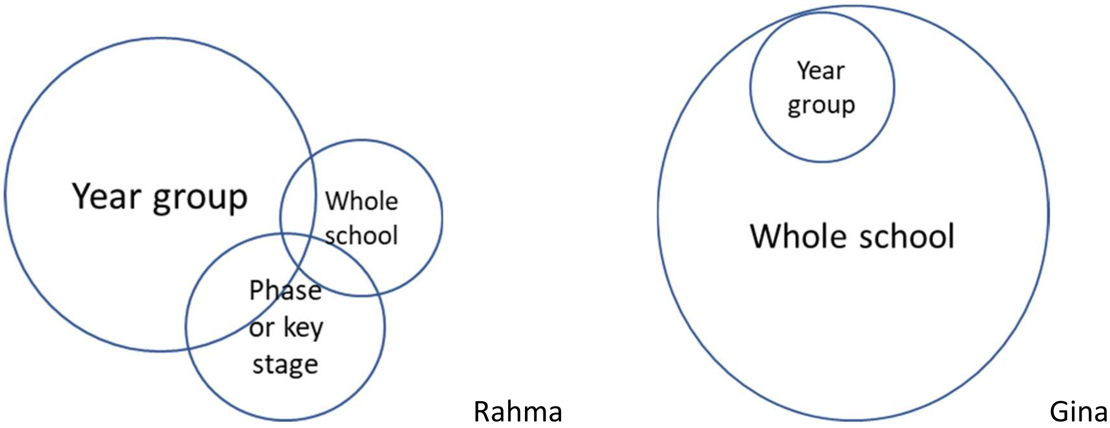


Figure 9-1 The significance of the influence of CoPs for Rahma (left) and Gina (right)

Within the social and organisation dimensions of the school context, the extent of a teachers' independence in planning and teaching was linked to the structures, procedures and policies of the school. In addition, their practice was influenced by the children who were seen as dynamics objects of practice and by various opportunities for learning and development. These three aspects of the school context are now discussed in turn.

9.2.3 *Independence resulting from the extent of the influence of structures, procedures and policies*

The evidence from this research suggests there are two specific influences on the extent of the independence an early career primary teacher has in their planning and teaching of mathematics i.e. the extent to which they are able to teach according to their beliefs rather than being limited by the social and organisational context within which they work (Ernest, 1989) and the extent to which they might rely on their own proactivity and reflection on practice to inform their evolving practice (Llinares and Krainer, 2006). Firstly, the organisational structure of the teaching in parallel or setted classes, and secondly, the resources available and permitted to the teachers to support their planning and teaching. Together these can be considered as the influence of the structures, procedures and policies of the school.

Although the teachers in this study all taught within an organisational structure where there were other teachers working with children of the same age, the formal 'team' (Krainer, 2003) within which they actually collaborated in day to day planning and teaching varied considerably. Those teaching their own mixed attainment classes planned and taught alongside one or two other teachers, with more potential for learning from colleagues and potentially less independence than those who taught setted groups. The dynamics of relationships within these year group level CoPs varied with the quality time to engage in rich discussions, thought to enhance teacher change and development (Millet, Brown and Askew, 2004), differing between participants. For example, Gina and her colleague Alan took it in turns to plan, giving their planning to each other to teach from (6.3.1); in contrast Rahma and Nina discussed a week's planning in depth before taking it in turns to put ideas on paper (5.3.1).

For those teaching sets, independence in planning and teaching varied from Penny (in both years) and Chloe (in her first year) planning very independently, with minimal influence from colleagues, to Evie (in both years) and Chloe (in her second year) planning alongside teachers working with parallel sets or adapting planning from other teachers. Meanwhile Emily, whilst planning independently, drew on support and guidance from others within her year group, notably including her learning support assistant in her second year (8.4.2).

It seems that the participants fitted pragmatically into organisational structures imposed on them by senior leaders over which they had no known control. Interestingly none expressed particularly strong opinions about the organisational structure and were generally positive about the extent of their independence, recognising the benefits of working alongside colleagues where they did so, welcoming the freedom to be more independent where this was permitted, but also seeking advice when they felt they needed it. The only participant who expressed concern about the structure imposed on her was Chloe, who worried about teaching children across two age groups with a consequently wide spread of attainment. Interestingly, she was the only participant whose collaborative situation changed, and she welcomed the opportunity to plan with a colleague in her second year because of the sense of shared responsibility it offered (8.4.1).

In all schools some direction for the practice of teaching mathematics was provided at whole-school CoP level. This was generally linked to current government policy as an external factor influencing teachers' development (Millett and Bibby, 2004), directed by a mathematics subject leader, and supported by a range of resources. Whilst all teachers had a range of artifacts and technologies available to them (Lave and Wenger, 1991) such as school planning frameworks and policies, published schemes, physical and technological resources, it was the extent of the prescribed use of these by senior leaders and changes with this that particularly influenced teachers' evolving practices. Interestingly, although all schools followed the National Curriculum for Mathematics (Department for Education, 2014), and all teachers believed they were teaching a mastery approach, in practice the school approaches and resources varied considerably. A range of initiatives was being implemented, but cross-school working on these seemed minimal.

In most schools a published scheme was available as a source of resources for planning and structuring lessons. While none of the schools in the study directed teachers to follow such a scheme with absolute precision, the flexibility in delivery that was perceived as permitted varied. Those schools who had a particular focus on mathematics during the period of the study also introduced a range of new initiatives such as Method Monday (time spent practising mathematical procedures) and Problem Solving Friday in Evie's school, Flashback Friday in Orna's school and the introduction of a published scheme in Gina's. Whilst Gina in her second year worked within the tightest structure using a published scheme, Emily at the other extreme had no scheme resources at all to draw on and worked within her school's long-term planning structure providing only an outline of topics to be taught. For Emily and Rakesh, the externally imposed SATs tests provided a significant influence on their planning and teaching approaches as their Year 6 classes moved towards taking their tests (8.4.3).

Interestingly, other than the anxiety expressed by those teaching Year 6 about these tests, participants seemed at least content with the level of independence afforded to them in terms of planning frameworks and resources. In general, it seemed those who worked more independently enjoyed taking ownership of their teaching whilst those who worked within more imposed systems expressed understanding of the reasons for the implementation of these.

9.2.4 *Children as dynamic objects of practice*

Goos (2013, p.523) suggests that a teacher's Zone of Free Movement (ZFM), which structures the environment within which they work, includes the teacher's perceptions of their students' "social background, motivation, beliefs and attitudes, mathematics achievement and behaviour", and Adler (1998) notes the significance of the relationship between teachers and those they teach. The evidence from this study strongly corroborates these points in suggesting that not only is the children's learning the prime focus of teacher learning and development in teaching mathematics, but that teachers perceive the children themselves to be an influence on their evolving practice.

Section 8.3 outlines a range of evidence of the perceived influence of the children, articulated most strongly by Orna. However, this influence is evident in the narratives of all the participants and the children themselves seem highly influential on a teacher's day to day practice. The object of a teacher's attentions and intentions is not the inanimate object of Wenger and Lave's (1991) initial conceptions of a CoP; rather the dynamic nature and characteristics of the children as individuals and as classes impact in varying ways on their teacher's practice.

Evidence from my study provides insights into each of Goos' points above; each can be illustrated with examples from my study. The evidence also, though, provides clues as to how these characteristics may be seen as challenges, opportunities to develop their practice or indeed both and affect a teacher's practice accordingly. Interestingly there is also evidence that these characteristics of the children taught might in turn be influenced by the teacher's practice.

9.2.4.1 ***Social background***

The influence of children's social background was particularly evident in the narratives of those who taught children from different social and cultural backgrounds, many of whom were learning English as an additional language. Whilst finding aspects of this challenging, these participants reacted positively to the challenge and sought to develop and adapt their teaching strategies to support such children's access to mathematics and overcome their barriers to learning (8.3.1 and 8.3.2).

9.2.4.2 ***Motivation, behaviour, beliefs and attitudes***

The influence of participants' perceptions of the motivation, behaviour for learning and beliefs and attitudes of the children they taught includes an additional layer of complexity. Whilst not often explicitly stating these perceptions, these seemed connected with the motivations, beliefs and attitudes of the participants themselves. Rahma's assertion, for example, that *"the children tell me "I want the challenge""* (5.4.3), Penny's comment about *"the determination in their little heads"* as they *"loved"* working out a challenging problem in groups (7.5) and Orna's claim that *"They persevere so much more than they did at the beginning of the year"* (8.3.3) were all stated within the context of the participant articulating their belief that resilience is a quality of a good mathematician and hence a quality that they promoted in their classrooms. These three participants all specifically aimed to promote resilience; Orna's anecdote in 8.3.3, for example, about the progress of the selective mute and the impact of telling the rest of the class about his progress is an interesting example of the encouragement she gave to her children to persist in problem solving.

In contrast, whilst there is no evidence that her teaching approach caused the issue, Chloe felt the behaviour of some of the children she taught impacted negatively on the quality of her teaching. Expressing frustration with the negative attitude and motivation of some of the children she taught, especially in her first year when teaching a Year 4 class without the highest attaining children (8.4.1), Chloe attributed the children's attitude to them not recognising the importance of mathematics. In seeking to address this Chloe felt limited in the scope she had to make learning mathematics fun because of the behaviour of her class.

9.2.4.3 ***Mathematics achievement***

Goos' (2013) 'perceived mathematics achievement' is a notion that could be considered from a range of perspectives, as no definition for achievement is given. On a broad scale, the influence of the age and experience of the children taught had an inevitable influence on practice, both in terms of the curriculum taught and age-related pedagogies, but the influence of perceived mathematics achievement went beyond this.

Certainly, Rakesh and Emily's perceptions as to how well their children would achieve in the forthcoming SATs tests dominated their teaching approaches whilst teaching Year 6 (8.4.3), but across the participants a range of approaches to teaching children with a perceived spread of achievement was evident. Analysis of these suggest that the influence of the school context in terms of school policies combines with the influence of the beliefs of the teachers themselves as to how this worked out in practice.

Chloe seemed particularly concerned as to how she could effectively challenge children with a wide range of attainment and addressed this issue by essentially aiming to teach as effectively as she could at a range of levels simultaneously, using the curriculum targets given for her to teach to (8.4.1). In contrast, for Penny, the influence of perceived mathematical achievement was more about giving children independence and opportunities for choices in the use of resources and level of 'starter' activities (7.4), providing activities where children could create their own questions and encouraging learning from others in group tasks, linked to her beliefs about what makes a good mathematician (7.5). Gina's use of a system where children chose their level of independent work followed school policy (6.3.3) and Rahma used mastery challenges provided by the school scheme, encouraging all her children to work on these challenges once they had completed the work she set for their perceived attainment (5.4.3).

Orna, with regard to the learning challenges of individuals, and Rakesh, with regard to wider learning challenges, seemed particularly proactive and reflective in aiming to develop their practice to address these. They seemed to view children's learning challenges as challenges for them to solve. Orna sought to address these by reflecting and adapting practice for individuals and her whole class in line with her beliefs about what makes a good mathematician, while Rakesh sought to research good practice and put this into practice in his classroom.

These examples suggest that the approaches used by the participants in response to the perceived mathematical achievement of those they taught were at least to some extent shaped by their beliefs but operated within the constraints of their school context. This theme is returned to in 9.4.

In summary, the evidence above suggests that the influence of the children was dynamic and varied, providing both challenges and opportunities to the participants and hence a significant element of the influence of the school context.

9.2.5 *Learning and development opportunities as 'promoted actions'*

The findings chapters (Chapters 4-8) include details of a range of specific learning and development opportunities received by the participants which impacted on their subject knowledge for teaching and beliefs about what makes a good mathematician. The notions of Lave and Wenger's (1991) CoPs and Millett and Bibby's (2004) model for discussing teacher change are useful to analyse the context within which these opportunities occurred, alongside Goos' (2013) notion of Zone of Promoted Action (ZPA). The ZPA consists of those particular "activities, objects or areas in the environment in respect of which the individual's actions are promoted" (Goos, 2013, p.523) by more senior colleagues and which might be within or beyond their current

Zone of Free Movement (ZFM), the environmental structure within which the teacher is working. Comparisons of Penny, Orna and Rahma, three participants with strong mathematical backgrounds, are illustrative of a range of promoted actions facilitated by their school leaders, with the evidence suggesting that Goos' model can usefully explain the impact of each.

Both Penny (7.6) and Orna (8.6.1, in her second year) had responsibilities beyond the year group within which they were working. Penny, unusually, started her teaching career with an already established identity in her whole-school CoP as an expert in both mathematics and school data and a developing identity as a teacher of mathematics. Continuing her responsibilities from previous years and building her identity as a valued teaching member of the community, willing to share her expertise, she relished opportunities for learning new skills and gaining new knowledge about teaching. Although she had some opportunities for learning within her whole-school CoP, Penny did not consider these significant, but rather emphasised the learning gained from outside which she then proactively sought to action (7.3). Her approach to implementing changes to her practice is perhaps indicative of her character as a conscientious professional with strong internal motivation (Millett, Bibby and Askew, 2004), but applying Goos' zone theory encourages further insights. The promoted action of the professional development opportunities she received seemed to fit with her ZPD; the new knowledge built on her previous subject knowledge, attitudes and self-efficacy to implement changes within her practice in a school context where her ZFM was comparatively open and broad. In comparison with Orna, Penny had a limited ZPA, but the new learning she received had impact on her practice; there was alignment between her ZPD and ZFM/ZPA complex (Goos, 2013).

Orna, of all the participants, seemed to have the most rapid incoming trajectory within her whole-school CoP. Recognising the importance of the school context on her evolving practice (8.2) she spoke of a range of school level developments that influenced her practice in her first year of teaching (8.5.2). These involved the benefit of time given for the implementation of new initiatives, alongside ready access to the expertise of the subject leader, Liam, who taught a parallel class (8.2) (Millett, Bibby and Askew, 2004). Orna talked positively about these developments and perceived that she was developing her subject knowledge for teaching whilst linking closely with her beliefs about learning and teaching mathematics (8.5.2). It seems likely that promoted actions in line with a ZPD based on these beliefs and strong mathematical subject knowledge, within a ZFM where all teachers were being encouraged to develop their practice, led to impact on her teaching practice.

At this early stage of her career, it seems that Orna's legitimacy within the CoP was high; despite feeling inexperienced, a feeling possibly heightened by comparing herself to the mathematics subject leader alongside whom she taught, she was respected by senior leaders and other teachers as a mathematician and a teacher of mathematics (8.6.1). It seems that Orna's perceptions were that senior leaders had slightly different perspectives on her trajectory within the school CoP than she did. Being put forward at the end of her first year to lead moderation meetings was a surprise to Orna but suggests that she was viewed as a potential leader with sufficient legitimacy to influence more experienced teachers in a cross-school CoP. The evidence in 8.6.1 suggests Orna felt her position as a relatively new teacher in this CoP did not give her the legitimacy to be fully respected by others, which led to tensions and a lowering of self-efficacy in this context.

The mathematics subject leadership responsibilities given to Orna in her second year of teaching steered her towards full participation within the school level CoP, with greater responsibility and impact on colleagues (8.6.1). Attending training from a consultant that seemed to impact on her understanding and beliefs about ways to both develop and evidence children's learning in mathematics, and working alongside Liam in the implementation of whole-school developments, her legitimacy within the school seems to have grown further, with colleagues taking instruction from her as the whole-school CoP renegotiated the meaning of effective teaching practices in mathematics. Although approaching leading whole-school staff meetings with understandable trepidation, Orna seemed to relish these responsibilities and talked pragmatically about her leadership role.

Orna's new experiences impacted on her learning and on her practice. They also went beyond this to impacting the practice of others. In Goos' terms, it seems that there was a strong alignment between Orna's ZPD and ZFM/ZPA complex. Again, conditions in the ZoE noted by Millett, Askew and Bibby (2004) for deep change in practice were evident: time to engage in professional development events, time to action changes, rich collaborative discussions, readily available expertise and motivation to further develop her practice.

For Rahma, formal professional development opportunities for gaining knowledge in the teaching of mathematics were limited (5.5). Her school context provided her with contexts within which she could informally share her practice and learn from others within the CoPs at year group, key stage and whole-school levels, and she attended a small number of staff meetings to support teacher access to resources. There were no individualised promoted actions for Rahma from senior leaders within her school context; rather, she relied on proactivity and reflection on practice within a broad and open ZFM to develop her teaching practice. Whilst she proactively put herself forward as a potential leader in mathematics, and she was recognised as an excellent teacher of the subject by senior leaders, these leaders had not yet permitted or promoted leadership opportunities. In Goos' terms, her ZPD in the sense of moving into leadership of mathematics was not yet aligned to her ZPA/ZFM complex.

These three situations in turn contrast with Gina's learning and development opportunities in her first year which were individually focused to address perceived weaknesses in her subject knowledge for teaching (6.3.2). Gina's rollercoaster experience through these suggest that the ZPA/ZFM complex was not always well aligned to her ZPD; tension here resulted in a crisis for her identity and self-efficacy as a teacher of mathematics. Although not entirely clear from Gina's narrative, it seems that although she had access to expertise from both within the school and an external professional (Millett and Bibby, 2004), she was perceiving mixed messages from the various interventions put in place to support her. Hence the intended outcome of developing her subject knowledge for teaching mathematics took several months to realise. At the time of the most intense interventions, Gina did not seem able to reconcile the promoted actions with the factors related to herself as an individual upon which her ZPD was based. In contrast, in her second year Gina was much more comfortable, although not totally confident, within her whole-school CoP as together they renegotiated the meaning of mastery under the guidance of a visitor to their CoP. Enjoying learning in a community alongside others (Barth, 1984), Gina felt a greater degree of legitimacy.

Together these examples illustrate that specific learning and development opportunities not only influence a teacher's practice and do so in a variety of ways connected to their subject knowledge for teaching and their beliefs related to this, but can also impact on others within their CoPs. It seems that rapid development towards full participation in CoPs for the teaching of mathematics is possible for early career teachers. However, this is dependent on the promoted actions offered to them, including the investment of time, expertise and rich collaborative discussions within their ZoE (Millett and Bibby, 2004), and the alignment of these with the school context and factors related to the teacher themselves. Hence Goos' zone theory seems a particularly helpful framework for discussing and comparing participants' experiences.

Penny's school was the only school represented in the study where some inquiry-based community activity was in place (Paine and Ma, 1993). Penny had experienced lesson study in teaching English in her school and was very keen to further develop her teaching of mathematics in this way in the future (7.3). However, although currently promoted to the schools on the Teaching for Mastery programme in England (Maths Hubs, 2018), it seems that inquiry was not part of the development cultures of the schools in the study.

9.2.6 *Impact of change within the school context*

Notable in the evidence from all participants was the notion of change imposed on them within the school context. It is clear that schools are dynamic environments; all participants talked at each of Meetings 2-5 about how changes had influenced their practice. Examples of these changes are evident in each of the findings chapters, and in the discussion above, such as the implementation of initiatives in schools where mathematics was a particular whole-school focus, changes affecting the organisational structure of the school and the nature of the children taught, and changes in responsibilities.

Notable throughout the narratives was the commitment of the participants to their schools and their generally positive and accepting attitude to change. This contrasted with the range of attitudes found by Gómez (2002) but was consistent with the responsiveness of newly qualified teachers found by Cuddapah and Clayton (2011) and suggests that within school-based CoPs early career teachers welcome opportunities to learn and develop their practice.

The schools represented in this study all introduced changes that influenced the participants' teaching of mathematics to some extent over the two years of the study. However, the intensity and nature of the changes varied with Orna and Gina particularly impacted by changes in their school policies and practices. Interestingly both of these participants when creating their influence maps at Meeting 5 placed 'the school context and changes within the school context' as their largest influence on practice, but commented that because of the extent of the changes they felt their own self-imposed changes through their own proactivity and reflection on practice was their smallest influence (6.2 and 8.2). In contrast, Rahma and Penny, teaching in schools with much less change in their school context mostly developed their practice with self-imposed changes through proactivity and reflection on practice alongside, in Penny's case, learning from courses attended. The more moderate changes experienced by Evie and Emily seemed to allow proactivity and reflection alongside this.

Thus, it seems that whilst the school context provides the context for self-imposed changes through proactivity and reflection, the extent to which learning and development comes from this or from directives from the school may depend on the rate and extent of imposed changes. The influence of reflection is discussed further in 9.5.

9.2.7 ***Summary – influence of the school context***

The social and organisational dimensions of the school context provide the landscape of CoPs within which a teacher develops their practice (Lave and Wenger, 1991).

In this study the interrelated nature of the various levels of the CoPs within the school context was particularly apparent in the data, with differing significance of the levels for different participants. Within these social and organisational dimensions, the structures, procedures and policies imposed on the early career primary teachers were seen to affect the independence of their planning and teaching of mathematics and hence access to rich collaborative discussions (Millett, Brown and Askew, 2004).

The children taught were recognised by participants to be a dynamic and varied influence, providing both challenges and opportunities to develop their practice. Participants sought to adapt their teaching strategies to respond to the challenges of teaching children with EAL and children with a range of attainment, motivation, learning behaviour, beliefs and attitudes. Whilst working within the constraints of their school context, the approaches they used in response to the perceived mathematical achievement of the children taught were at least in part shaped by the teachers' beliefs. It also seemed that the motivation, learning behaviour, beliefs and attitudes of the children taught might in turn be influenced by the teacher's practice.

With schools being dynamic environments, the participants were subjected to a range of changes within their school context. Whilst participants were generally positive about such changes, showed commitment to their schools and welcomed opportunities to learn and develop their practice, the extent to which they perceived their learning and development to come from school directives or from proactivity and reflection within the context of the school seemed to depend on the rate and extent of imposed changes on practice.

Specific learning and development opportunities were seen to extend teachers' knowledge and inform their beliefs, including beliefs about what makes a good mathematician. Analysis of the impact of such opportunities using Goos' zone theory (2013) illustrated that the influence of promoted actions on a teacher's practice is connected to the alignment of these with the school context and factors related to the teacher themselves.

Whilst the theoretical frameworks of Lave and Wenger (1991), Millett and Bibby (2004) and Goos (2013) were found to be particularly useful in analysing the various elements of the influence of the school context and changes within this, from this analysis insights have been gained that go beyond the existing literature.

In summary, firstly, the evidence in this study suggests that early career primary teachers perceive their school context to be a very important influence on their teaching of mathematics. Whilst this finding is in line with related literature, this study provides more evidence of the complexity and individualised nature of this influence on a teacher's evolving practice. Secondly, the evidence suggests that it is possible for early career teachers to make rapid progress towards full participation in CoPs for the teaching of mathematics, hence influencing the practice of others, if there is full alignment of their ZDP with their ZPA/ZFM complex.

Figure 9-2 summarises the influence of the school context, including how this influence impacts on each of the other three core influences; learning and development through the school community impacts on a teacher's background knowledge and feelings about the subject and on their beliefs, including beliefs about what makes a good mathematician, and hence also self-efficacy for teaching mathematics. The school also provides the context within which a teacher makes their own self-imposed changes through proactivity and reflection on practice.

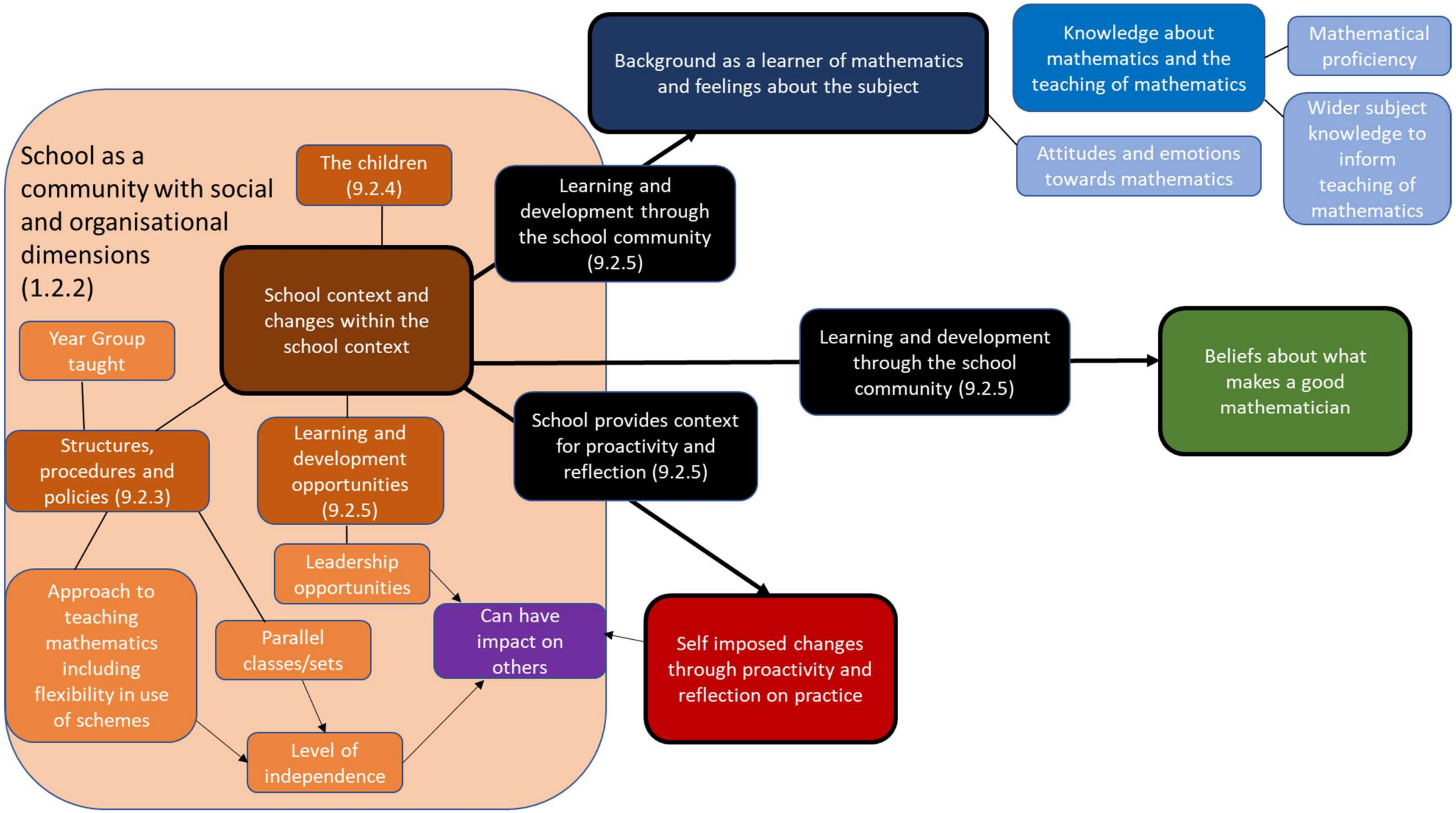


Figure 9-2 The influence of the school context and changes within this, with links to related influences.
Arrows indicate direction of influences. Lines connect sub-categories to main influences. Black boxes label the links between the main influences. Shades of brown represent the influence of the school context; shades of blue represent the influence of the background of the early career teacher as a learner of mathematics and their feelings about the subject; shades of green represent the influence of beliefs about the learning and teaching of mathematics and shades of red represent the influence of self-imposed changes through proactivity and reflection on practice.

9.3 Background as a learner of mathematics and feelings about the subject

9.3.1 *Introduction*

This section considers the influence of the background of the participants and seeks to answer the research sub-question 'How does the evolving practice of mathematics specialists compare with non-specialists?'

When creating their influence maps, most of the participants placed the background as a relatively small influence on their practice (Figure 8.1) and their discussions of this influence tended to be briefer and in less depth than their discussions of the other influences. However, as discussed when presenting the individual narratives, this influence is possibly more important than was perceived by most participants when creating their maps and seems particularly entwined with the influence of their beliefs about what makes a good mathematician.

In this section I argue that their mathematical background frames a teacher's beliefs about what makes a good mathematician and is itself an evolving influence. It provides the subject knowledge and self-efficacy for planning and teaching the subject and related reflection on practice, and these qualities are in turn enhanced by the knowledge gained from experience and reflection. Differences between the evolving practice of specialists and non-specialists are presented relating to their attitudes and emotions to mathematics influencing practice and their priorities in their learning and development as teachers of mathematics, suggesting that it is probably an advantage to have studied mathematics beyond the minimum required level.

The discussions below start with a summary of points made by participants about their background as they created their influence maps at Meeting 5 to clarify which aspects of their background they felt were influential. Wider evidence is also then considered.

9.3.2 *Perceptions of the influence of their background – non-specialists*

Gina, Rakesh and Emily, as the three participants who did not take the mathematics specialism of the PGCE course, taught mathematics as a subject which they had studied to the minimum required level for a teacher in England. As Williams (2008) contends, this provides a basic mathematics knowledge but not necessarily the mathematical proficiency advocated by Kilpatrick *et al.* (2001) in terms of depth of knowledge.

Gina, Rakesh and Emily all interpreted the 'Background' label for their influence map as their experience when they were learning mathematics at school. Interestingly, their verbal responses contrasted markedly. Whilst Gina stated that her background as a learner of mathematics was always on her mind and impacted her priorities when teaching (6.4), Emily said she had not considered that her *"quite good"* mathematical background had any influence on her teaching (8.4.2). Rakesh considered his background to be increasingly insignificant because he was plugging gaps in his mathematics knowledge as a teacher and enjoying teaching the subject more than he enjoyed learning it (8.4.2).

It is interesting to compare these comments to those stated in Meeting 1 as each participant drew a graph of their relationship with mathematics up to that date; Emily's graph was entirely in the positive section of the graph and rose during her PGCE year to a stable high (Figure 4.8), Rakesh's graph showed a stepped rising profile with a markedly steep rise during his PGCE year (Figure 4.7) and Gina's was a generally positive graph with a dip into a negative relationship after leaving school and before starting the process of joining the PGCE course (Figure 4.2). Thus all ended their graphs on a high - the overall impression is that although they had times as a learner at school when they found the subject difficult and felt less than fully competent, by the time they started their first teaching job, their relationship with mathematics was good, with a notable influence being the PGCE course. Despite this overall positivity, the influence of the limitations in their backgrounds suggested by Williams (2008) was recognised by each.

In line with Bibby's (2002) research of teachers' prior experiences of shame in mathematical contexts, Gina specifically articulated that much of her learning prior to the PGCE course was insufficient, being merely instrumental in nature (Skemp, 1976). Despite gaining a grade A at GCSE, she readily admitted to having weaknesses in her prior conceptual understanding and her understanding of *"why", r*ecognising the limitations of such knowledge, as noted by Di Martino and Zan (2010). She drew on this internal motivation (Millett, Brown and Askew, 2004), proactively seeking to teach in such a way as not only to ensure her children had a deep understanding of concepts, but also that they gained some recognition of the purpose and importance of mathematics. Thus, her priorities also touched on the knowledge needed for a productive disposition to the subject (Kilpatrick *et al.*, 2001) (6.4.1).

The subject knowledge challenges for Gina's teaching of Year 1 children were related to Ball, Thames and Phelps's (2008) specialised content knowledge (SCK), alongside knowledge of content and students/teachers (KCS, KCT), with the actual mathematics content knowledge taught being comfortable for her at this level. The input she received following her "disaster" lesson focused on these aspects of subject knowledge for teaching (6.3.2) and by Meeting 4 Gina perceived aspects of these to be strengths: using vocabulary effectively, breaking down the different parts of problems and using a pictorial approach (6.4.3). Gina's self-efficacy for teaching mathematics seemed to rest on her growing confidence in her subject knowledge and her ability to use this to reflect in action (Schön, 1983; Schön, 1995) (6.5).

Emily and Rakesh, when teaching Year 6 children in their second year, were faced with the challenge of understanding for themselves the mathematics they had to teach, Shulman's (1987) subject matter content knowledge, alongside the wider subject knowledge needed for teaching. With further external motivation relating to effectively preparing children ahead of their SATs tests (Bibby, 2002), both proactively sought to address the subject knowledge challenges they faced. Emily particularly drew on learning from her learning support assistant, including asking her to teach lessons where she did not feel "*confident*" with her subject knowledge (8.4.2). In contrast, Rakesh more independently practised the more difficult content, rehearsed his teaching strategies and actively researched to further develop his subject knowledge for teaching (8.4.2 and 8.6.2). Although both teachers experienced some anxiety about the pressures of teaching Year 6 children, these development strategies enabled them to gain the self-efficacy that they were capable of teaching at this level and both expressed that they had improved their teaching of mathematics over this year (8.4.3).

Whilst all showed positivity towards mathematics in their graphs at Meeting 1, and Rakesh expressed enjoyment in teaching the subject, none of these three participants talked explicitly about passing on an enjoyment of mathematics to the children they taught. Rakesh and Emily in their second year were particularly focused on the content of the curriculum for SATs (8.4.3) whilst Gina's focus was on teaching her children sound basic skills rather than attempting to go beyond this in terms of making mathematics interesting and fun (6.4.4).

In his second year, despite his inexperience and a background with greater strengths in other subjects, Rakesh found himself taking on responsibility for mathematics in his school, albeit in a temporary capacity (8.6.2). Although this suggests that senior leaders in his school considered his subject knowledge strong enough to advise and support others in their teaching of mathematics, Rakesh's perception was that it was on the basis of his potential leadership skills that he had been appointed. Whilst gaining in self-efficacy as a mathematics teacher as a result, he did not see himself as a mathematics specialist; rather he proactively used the opportunities presented to further extend his subject knowledge for teaching mathematics.

It seems that other than during the period following the *"disaster"* lesson for Gina, these three teachers seemed to perceive their background as a learner in mathematics was good enough for competent teaching (Newell, 2011). When recognising gaps in subject knowledge, proactivity and reflection combined with accessing support from others in their school context ensured their self-efficacy as teachers of mathematics was maintained. Evidence in this study does not therefore provide any further support to Schuck's (1999) and Brown's (2005) concerns related to potential negative attitudes of weaker teacher mathematicians.

9.3.3 *Perceptions of the influence of their background – mathematics specialists*

Five of the eight participants started their PGCE course with at least an A level in mathematics and took the mathematics specialism of the course/Primary with Mathematics PGCE. Of these Penny, Orna and Chloe had taken mathematics at degree level, with Penny having extensive experience as a mathematician in her previous career.

In contrast to the non-specialists, when talking about the influence of their background, all these five participants talked about their attitudes to, and emotions about, mathematics. With hints at self-efficacy as teachers relating to their subject knowledge, they used phrases such as *"I just love maths"* (Penny), *"I'm still very passionate about maths and I still really enjoy maths, and I think that does still have an impact"* (Orna), *"I've had a positive mind about it"* (Rahma), *"My background is really important because it influences my attitude towards the subject and my knowledge"* (Chloe) and *"I really like maths, I'm confident with maths, I'm confident teaching it, I think it's really important"* (Evie). Such an emphasis on emotion is consistent with Van der Beek *et a*l.'s (2017) research finding that those who perceive their mathematical competence to be high tend to link this to positive emotion.

Although my research provides no comparative evidence related to actual learning outcomes for the children taught by the participants, evidence from across the meetings of these five participants suggests three particular ways in which their strong mathematical background impacted positively on their practice: motivating them to try to pass on a love of mathematics to those they taught; giving self-efficacy in teaching the subject, leading to a desire to further increase their expertise and at times influencing the practice of others; and providing an informed network of beliefs about what makes a good mathematician. The link between background and beliefs about what makes a good mathematician is discussed below in relation to all the participants.

Firstly, reflecting Leavy and Hourigan's (2018) view of the importance of positive teacher attitudes to mathematics, these teachers were keen for their children to gain a love of the subject. Rahma specifically chose to do this through her enthusiasm and creative cross-curricular teaching (5.6.1) and her reassurance for her children that mathematics was not to be feared (5.6.2). Chloe wanted to teach mathematics in a way the children enjoyed (8.4.1) and Orna stressed the importance of her enthusiasm which she felt in turn enthused the children she taught (8.2). Evidence from Penny is more implicit in this regard; her emphasis on children becoming independent problem solvers (7.5) suggests she was equipping children for the mathematics she particularly enjoyed - problem solving.

It seems that these teachers all had a positive mathematical intimacy (DeBellis and Goldin, 2006) that they were keen to pass on to those they taught.

A second consequence of the participants' strong mathematical background was their self-efficacy in teaching the subject (Bandura, 1997). Whilst, for example, Evie explicitly expressed her self-efficacy as a mathematician and as a teacher of mathematics (8.5.1) and Rahma stated her *"love"* of teaching it and finding it easier than English to teach (5.6.1), implicit evidence goes beyond this. Morris, Usher and Chen's (2017) notion of self-efficacy being enhanced by self-recognition of strong subject knowledge for teaching mathematics can be seen, for example, in Rahma's working relationship with Nina (5.3.1), her confidence to take risks and contribute ideas (5.3.2) and her desire for more responsibility for the subject across the school (5.3.5); in Penny's independent development of teaching according to her beliefs about what makes a good mathematician (7.5) and her mentoring of a pre-service teacher (7.6); in Evie's discussions about the role of concrete and pictorial resources in children's learning

(8.5.1) and in Orna's enthusiasm and willingness to take on subject leader responsibilities (8.6.1).

Strong self-efficacy was particularly apparent in the way Penny discussed her roles in data analysis and mathematics support beyond her own classroom (7.6). Her self-efficacy in her data analysis role was likely based on her identity as a mathematician. It seems that her self-efficacy as a teacher of mathematics combined with her identity as a mathematician to give her the motivation and commitment to willingly support less confident colleagues, perceiving value in this additional work (Eraut, 2004).

Considering the evidence about attitudes and emotions towards mathematics alongside the evidence above, it seems likely that the self-efficacy these participants had as teachers of mathematics was particularly strong because it was based on what Bandura (1997, p.80) terms "enactive mastery experiences" of both learning mathematics and, possibly to a lesser extent given their inexperience, their teaching of the subject.

There was no evidence though that strong self-efficacy led to complacency or to a sense that these teachers knew all there was to know about teaching mathematics. Rather, evidence such as Penny and Rahma's proactivity and reflection as they sought to further support the learning of their children, Evie's desire to learn from her subject leader about the use of concrete and pictorial resources, Orna's learning about assessment and moderation in mathematics and consequent changes to her practice and discussions with colleagues, all suggest that these teachers used their background mathematical knowledge and skills to support their further development in teaching the subject. In essence, in line with Eraut's (2004) findings, they were self-motivated to draw on their self-efficacy as mathematicians and teachers of mathematics to address further perceived challenges within supportive school environments.

9.3.4 *Background as a framework informing beliefs about what makes a good mathematician*

Whilst creating influence maps at Meeting 5, links between background and beliefs about what makes a good mathematician were only explicitly stated by Evie and Gina. Evie emphasised that her beliefs in the value of mathematics and the importance of teaching children to be competent at reasoning, came from her mathematical background (8.5.1). Gina's background, where she experienced being held back by limitations in her understanding as a learner, informed her belief that what makes a good mathematician is having deep conceptual understanding (6.4.2). In both cases, there was impact on the participants' priorities in their teaching and the development of their practice.

It seems that although evidence from elsewhere in the series of meetings suggests a strong connection between these two influences, maybe seen most clearly with Penny who had the freedom within her school context to teach according to her beliefs (7.5), it was not necessarily recognised by the participants themselves.

Possibly a useful representation for the connection between the two influences was provided by Orna at Meeting 3 (8.2). In line with the findings of Simon, Millett and Askew (2004), her influence map at this stage placed the influences of background and beliefs as connected overarching influences on which the influences of her school context and proactivity and reflection operated on a day to day basis (Figure 8-3 and repeated below as Figure 9-3). Whilst the beliefs Orna referred to are specific to beliefs about what makes a good mathematician, this idea seems consistent with Rowland *et al.*'s (2008) notion of foundation knowledge. Orna was explicit that these beliefs came from her mathematical background, including her experience of learning mathematics at university.

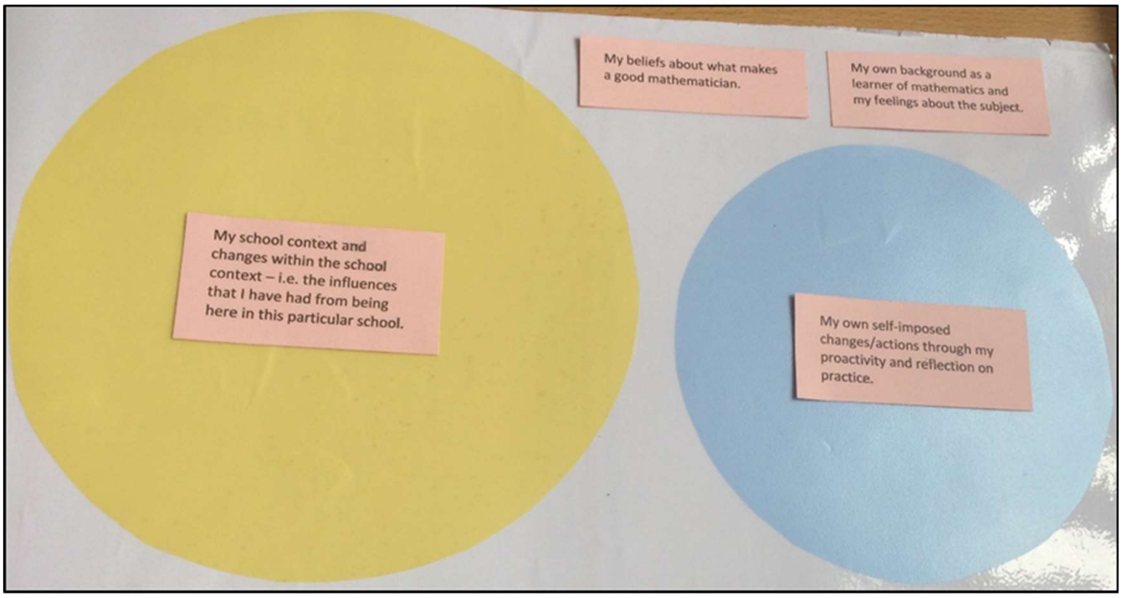


Figure 9-3 Orna's influence map Meeting 3

Orna's Meeting 3 model with the overarching influences seems to apply to other participants, if not actually articulated by them, to the extent that when constructing Gina and Penny's chapters, the influence of their beliefs about what makes a good mathematician and their backgrounds seemed so entwined that these influences were considered together. Penny gave very strong evidence that her teaching priorities and self-imposed changes to develop her practice were based on her beliefs about what makes a good mathematician and these were framed on characteristics of her own identity as a mathematician (7.5). Gina's core beliefs about what makes a good mathematician, linking to her ideas about the characteristics of effective teachers of mathematics and perceptions of her strengths related to these, were all based on her perceptions of her background (6.4).

Rahma's narrative also seems to fit the model. Her complex background, which saw her move from being an anxious mathematician afraid of making mistakes, to one who enjoyed the freedom of learning from mistakes and taking ownership of her learning (4.2 and 5.6) seems to have been a similarly strong overarching influence in her beliefs about what makes a good mathematician and her priorities when teaching the subject.

Orna's Meeting 3 model, therefore, backed up by other evidence from the study, links with Rowland *et al.*'s (2008) notion of foundation knowledge and evidence from Cai and Wang (2010) and Simon, Millett and Askew (2004) to suggest that a teacher's mathematical beliefs are not only deeply rooted but also framed by their background.

The influence of beliefs about what makes a good mathematician is considered further in 9.4.

9.3.5 ***Background providing resources for proactivity and reflection***

The background of a teacher not only provides a framework for beliefs, but also provides the resources needed for teaching and for reflection on practice, with the quality of this reflection dependent on the subject knowledge, competence and confidence, and hence the background, of the teacher (Calderhead, 1989; Rowland *et al*., 2008). The relevance of the wealth of literature relating to the importance of teacher subject knowledge on their practice is reinforced by the evidence from this study. Whilst the participants seemed to interpret the words 'Background as a learner of mathematics' to refer to their time before their ITE course, the evidence suggests that this prior learning, enhanced by wider subject knowledge for teaching mathematics gained from their ITE course and continuing opportunities for learning whilst in service, provided the resources of both knowledge and self-efficacy for their teaching of mathematics. Using these resources, they made decisions in planning and teaching mathematics and, through proactivity and reflection, made self-imposed changes to their practice.

There is a clear link in this argument with beliefs about what makes a good mathematician; as discussed above these also relate to a teachers' background. Hence strong evidence of the impact of Rahma's wider subject knowledge, for example, is seen in 5.4 where her beliefs are presented, as well as in 5.6.4, the section about subject knowledge. Teaching 5-6 year old children, Rahma needed to have a secure understanding of early number concepts and 5.4.1 provides evidence of Ball, Thames and Phelps's (2008) SCK and Askew *et al.*'s (1997) connectionist persuasion as she explains teaching strategies to ensure her children understand different facets of the number five. Rahma's perceptions of strengths in her subject knowledge (5.6.4) relate particularly to Ball, Thames and Phelps's KCS and KCT, and Rowland *et al.*'s (2008) transformation and contingency categories, suggesting self-efficacy in planning and teaching alongside the ability of reflection-in-action (Schön, 1995), evidence of which is seen in examples of her chosen best and most challenging lessons. Rahma's *"Double Trouble"* lesson (5.3.3) was not only creative and enjoyable for the children, but the examples used, the way these were presented and the anticipated next steps for the children led to her reflection that all were appropriately challenged.

There is a sense throughout Rahma's narrative that her subject knowledge for teaching was evolving. Both by proactively seeking advice (5.3.5) and reflecting on her practice, as is clear in her discussion of her subject knowledge strengths (5.6.4), Rahma was learning how to more effectively advance the learning of the children she taught.

Penny, also teaching Year 1 and with a particularly strong mathematical background, also gives much evidence that her subject knowledge for teaching young children had evolved such that she had gained the knowledge and self-efficacy to teach 5-6 year olds in accordance with her beliefs about what makes a good mathematician (7.5). With characteristics of Askew *et al.'s* (1997) connectionist teacher, Penny's focus for development related to her use of questioning, mathematical language and task design (7.4 and 7.5) in her specific context (Scheiner *et al*., 2019), and seemed to enable her to transform her mathematical knowledge to facilitate accessible learning for the children she taught (Rowland *et al*., 2008). Such transformation strategies evolved over time, particularly due deliberative learning through reflection on action (Eraut, 2004; Schön, 1983; Schön, 1995) and implementation of learning from courses (7.3).

The sense of an evolving background of subject knowledge for teaching is also evident in the narratives of other participants, with Evie and Orna, for example, building on their strong mathematics content knowledge to develop a greater depth of knowledge related in particular to Ball, Thames and Phelps's (2008) KCT (8.5.1, 8.5.2 and 8.6.1).

Thus, it seems that while a teacher's background provides the resources for proactivity in planning and teaching and related reflection on practice, the knowledge gained from experience and reflection on practice in turn enhances the depth of a teachers' subject knowledge for teaching. A teacher is continually learning more about their craft and hence their background is not a static influence. It seems that there is a two-way connection between the background and 'self-imposed changes though proactivity and reflection' influences. For those with weaker backgrounds this includes mathematics content knowledge, as outlined in 9.3.2 above, whereas for the strong mathematicians, the emphasis is towards enhancing understanding of other aspects of subject knowledge for teaching mathematics.

The background subject knowledge of a teacher is interlinked with their relationship with mathematics and feelings about the subject. When drawing their graphs of their 'relationship with mathematics', accompanying narratives suggested that this term was generally interpreted as encompassing subject knowledge alongside attitudes and emotions, and hence self-efficacy as mathematicians and as teachers of the subject. All the participants in this study started their teaching careers with positive relationships with the subject despite a range of prior feelings over the years as learners in school (see graphs in Chapter 4). Their relationships with mathematics also became more positive overall for each participant in each year, other than for Chloe in her second year (Figure 8.6). This reflects their perceptions that they had indeed developed their practice positively.

9.3.6 *How does the evolving practice of mathematics specialists compare with non-specialists?*

The relatively low importance assigned to background when making their influence maps at Meeting 5 seems to have been at least partly due to most participants' interpretation of the wording 'background as a learner of mathematics' as limited to their time studying mathematics at school/university before their ITE course, rather than considering their recent learning as pre-service teachers and ongoing learning as in-service teachers or from other areas of experience. Nevertheless, the five mathematics specialists all considered their background a positive influence on their practice as a teacher, and Gina's reflection on her background also led to a perceived positive influence on her beliefs about what makes a good mathematician and hence her practice.

Acknowledging that my sample did not include any teachers with a sustained dislike of mathematics or sustained difficulties teaching it, clues have emerged as to how the evolving practice of mathematics specialists might differ from that of non-specialists. Firstly, there are interesting contrasts in the points mentioned by participants about their background when creating their influence maps. These brought out the most obvious difference between the perceptions of the mathematics specialists and non-specialists; their attitudes and emotions towards mathematics. It seems that the evolving practice of mathematics specialist teachers might be based to a greater extent than the non-specialists on developing in children a positive mathematical intimacy (De Bellis and Goldin, 2006), with a love of mathematics and an interest in the subject. Indeed, in line with the productive disposition element of Kilpatrick *et al.*'s (2001) model of mathematical proficiency, these qualities seem to be part of their framework of beliefs related to the characteristics of good mathematicians.

Whilst all the teachers in the study sought to develop their practice through both development opportunities within their school content and their own self-imposed changes, a further contrast between the specialists and non-specialists suggests the focus of this development might differ. For the non-specialists, this seems to focus on maintaining and extending the self-efficacy that they are 'good enough' teachers of mathematics, addressing weaknesses in content knowledge as necessary. For the specialists with stronger self-efficacy as teachers of mathematics based on their wider and deeper experiences of learning mathematics, this focus seems to be on developing expertise in other aspects of subject knowledge for teaching mathematics. Thus a sense of seeking to develop further towards becoming a more accomplished teacher of mathematics was apparent, with increasing potential to not only teach effectively, but also influence the practice of others. These findings are in line Bjerke's (2017) assertion of the importance of a teacher's perceptions of, and reflections on, their mathematics subject knowledge on their self-efficacy and identity as a teacher of mathematics.

Askew *et al*.'s (1997) study suggests that it is not the qualifications or amount of mathematical knowledge that affects the effectiveness of a teacher, but the connectedness of their knowledge. The evidence from this study suggests that those with a strong mathematical proficiency themselves are more likely to have this connected knowledge and, in line with William's (2008) views, that all things being equal, it is of advantage in teaching primary mathematics to have studied the subject to greater depth than the minimum required level.

9.3.7 *Summary – influence of the background of the teacher and their feelings about the subject*

Although the full scope of their backgrounds as learners of mathematics was not explicitly discussed by the participants when creating their influence maps, wider evidence from the study suggests that a teacher's knowledge about mathematics and knowledge about the teaching of mathematics combine with their attitudes and emotions about the subject to influence their self-efficacy as teachers of mathematics and their evolving practice.

In addition, the influence of a teacher's background seems particularly connected with the influence of their beliefs about what makes a good mathematician and together these two influences could be considered overarching influences on which teachers' daily practice and changes to this take place. As such, the background provides a framework for the development of a teachers' beliefs about what makes a good mathematician.

Evidence from this study also suggests that a teacher's background provides the resources for proactivity in planning and teaching and related reflection on practice, with teachers using their background mathematical knowledge and skills to support their further development in teaching the subject. In turn, a teacher's background knowledge and feelings about the subject are also subject to change. Section 9.2.5 outlined the influence of the learning and development opportunities within the school context on a teachers' practice, at least in part because of the impact on their subject knowledge for teaching mathematics. Further strengthening of a teacher's background is through learning and development related to reflection on practice.

Whilst the evidence in this study aligns with the related literature in confirming the importance of an early career primary teacher's individual background as an influence on their evolving practice, insights have been gained from this study that go beyond the existing literature, particularly in exemplifying the nature of the links between this and other influences on a teacher's practice and suggesting some specific differences between the perceptions and priorities of specialist and non-specialist teachers of the subject.

Key elements of the influence of a teacher's background, including links with related influences, are summarised in Figure 9-4.

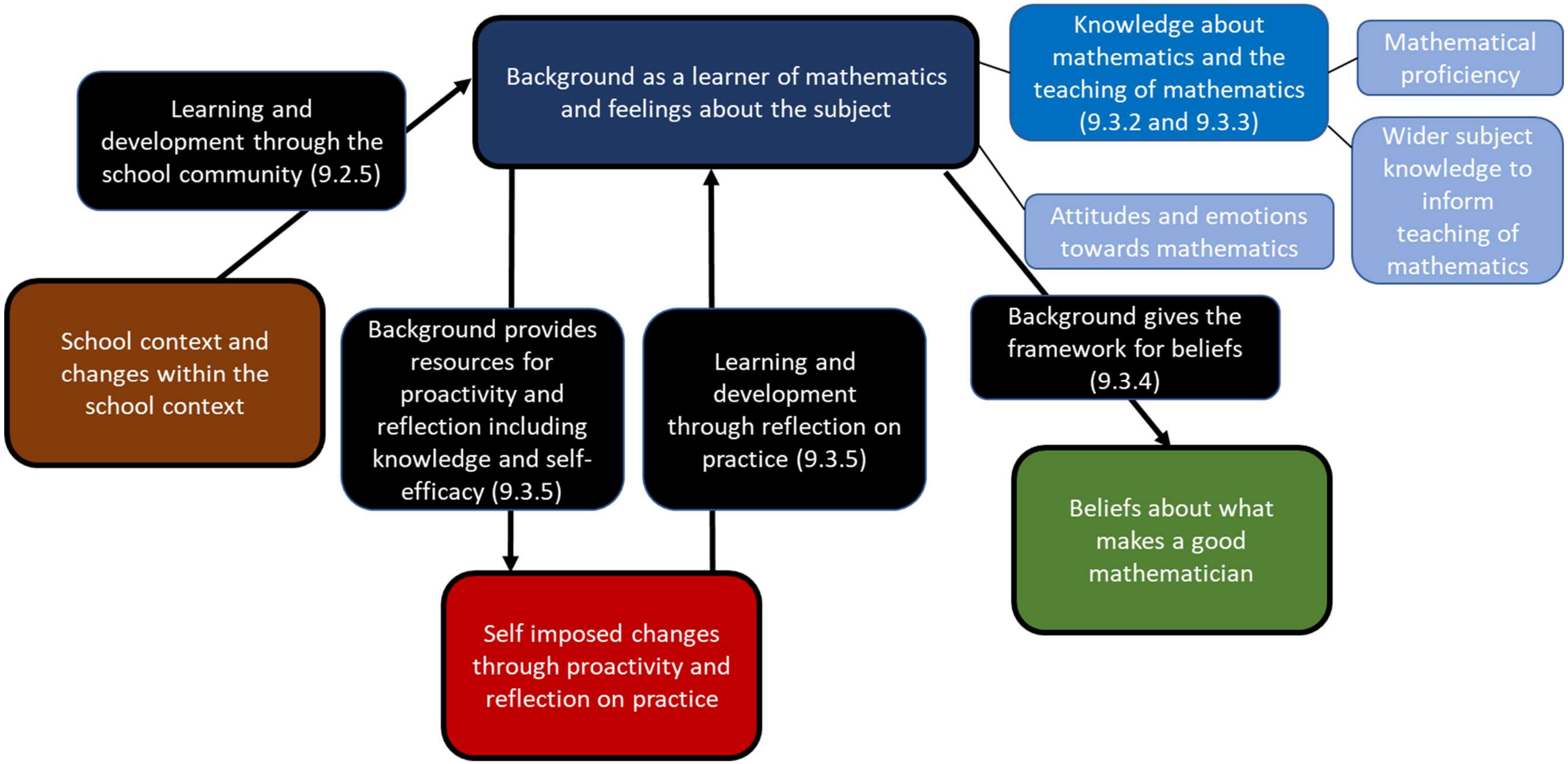


Figure 9-4 The influence of background and links to related influences.
Arrows indicate direction of influences. Lines connect sub-categories to main influences. Shades of brown represent the influence of the school context; shades of blue represent the influence of the background of the early career teacher as a learner of mathematics and their feelings about the subject; shades of green represent the influence of beliefs about the learning and teaching of mathematics and shades of red represent the influence of self-imposed changes through proactivity and reflection on practice.

9.4 Beliefs about what makes a good mathematician

9.4.1 *Introduction*

The literature concerning beliefs about learning and teaching mathematics focuses on the related aspects of beliefs about the nature of mathematics and beliefs about understanding in mathematics (2.4.4). These can be considered alongside literature relating to the nature of mathematical proficiency in analysing teachers' beliefs. As discussed in the methodology, when creating their influence maps, the participants were asked to reflect specifically on their 'beliefs about what makes a good mathematician' because this notion encompasses beliefs about the nature of mathematics and of understanding in the subject and hence the type of mathematical proficiency the teacher is aiming for in the children they teach. In turn this is likely to impact on their teaching approaches (Ernest, 1989).

When creating their influence maps, most of the participants placed beliefs about what makes a good mathematician as a relatively small influence on their practice (Figure 8.1). However, this influence is possibly more important than was perceived by most participants as they created their map, partly because of its connection with the influence of a participant's background (see 9.3.4 above). In this section, after discussing the evidence related to beliefs about what makes a good mathematician in relation to the relevant literature, I argue that these beliefs also have a direct impact on a teacher's practice, that they can evolve in response to learning and development through the school community and through reflection, and that they can influence a teacher's practice by providing the criteria against which they reflect.

9.4.2 *Impact of beliefs - variation between participants*

Much of the evidence presented in the narratives in Chapters 4-8 relating to beliefs comes from wider evidence than the participants' comments as they created their influence maps. Their beliefs were apparent as they discussed examples from their practice, talked about how they had developed their practice and responded to specific questions relating to their perceptions of effective or secure learning.

Alongside the literature that links beliefs to teachers' practices, Kilpatrick *et al.*'s (2001) model of mathematical proficiency provides a useful tool with which to analyse these beliefs (Figure 2-1 and repeated below as Figure 9-5). The comparison of four of the participants below demonstrates that although the beliefs of these early career teachers seemed to be in line with the five strands of the model, different strands were emphasised by the various participants, influencing their teaching approaches accordingly.

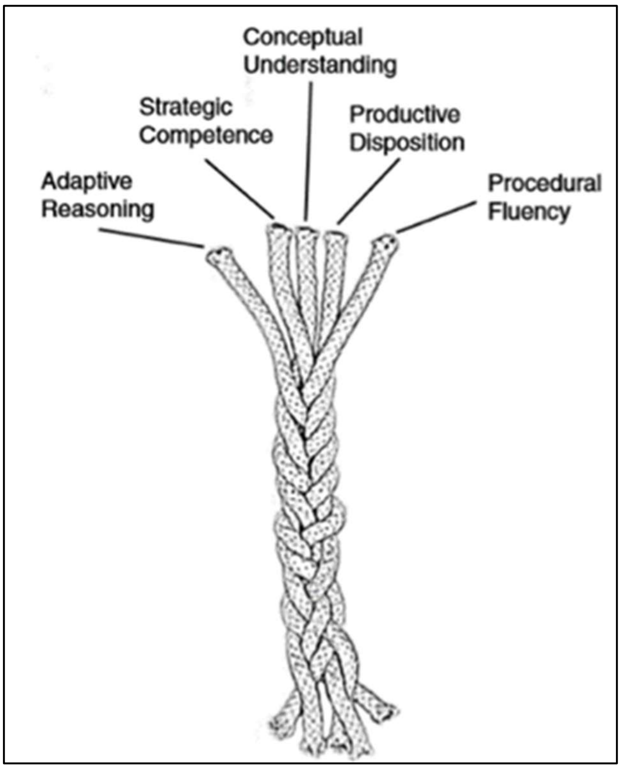


Figure 9-5 Model of mathematical proficiency (Kilpatrick, Swafford and Findell, 2001, p.117)

In line with Bryan *et al.*'s (2007) international findings, understanding as a goal of children's learning, and in particular, conceptual understanding, was a prominent aspect of all the participants' beliefs. There was a general sense that children need to understand not just a series of learnt procedures, but have the relational understanding that goes beyond this to provide the depth of connected understanding needed for problem solving (Skemp, 1976).

For Gina (6.4.1) knowing *"why"* was very significant because of her background as an instrumental learner (Skemp, 1976), and conceptual understanding was the major emphasis of her teaching. Of all the participants she seemed to fit most closely to Ernest's (1989) 'Explainer', to the extent that her other beliefs, particularly those related to the independence needed for strategic competence and their enjoyment of the subject, were side-lined (6.4.3). However, Gina did acknowledge the importance of problem solving skills; setting children non-routine problems (Pólya, 1957; Kilpatrick *et al.*, 2001) was part of her practice with regards to assessing the depth of children's learning and challenging their thinking (6.4.5.1). She also believed the children needed to be aware of the importance of mathematics, an element supporting their productive disposition (6.4.1). Gina's conception of a mathematician who had attained mastery, articulated at Meeting 5 having developed over the two years of the study, was that they would respond with adaptive reasoning skills to such problem solving challenges (6.4.5.2).

In comparison, Rahma's ideas about mathematical proficiency seem to link in a more balanced way to the model of Kilpatrick *et al.* (2001), possibly reflecting her stronger background as a mathematician. As presented in 5.4.1, Rahma related her ideas about characteristics of effective learning in mathematics to specific examples from her practice. Taking the general notion of conceptual understanding as read, with a comment suggesting instrumental understanding *"has no point",* Rahma's emphasis went beyond Gina's to the specific importance of a mathematician developing conceptual links, in line with Askew *et al.*'s (1997) connectionist teachers. It seems likely that Rahma would whole heartedly agree with Kilpatrick *et al.*'s definition of conceptual understanding as "an integrated and functional grasp of mathematical ideas" (p.118). Procedural fluency and strategic competence, in the form of coping with open ended questions and explaining thinking with adaptive reasoning, were also prioritised (5.4.2) along with the resilience and openness to challenge which might characterise a mathematician with a productive disposition (5.4.3). Rahma's question *"What can you tell me about the number sentence 3 + 4 = 7?"* (5.4.1) is maybe illustrative of a problem that, whilst aimed at assessing conceptual understanding, enabled children to demonstrate each of the strands of the model of mathematical proficiency. In addition, as highlighted in 5.3.3., Rahma was particularly keen for children to develop an enjoyment of mathematics; although not explicitly stating so, it seems likely she would include positivity towards mathematics as a characteristic of a good mathematician. Rahma's examples give evidence that not only did she have strong beliefs about what makes a good mathematician, but that she aimed to teach according to these, as noted by her when creating her influence map (5.2 and 5.3). Rahma's narrative also suggested that her teaching evolved in line with her beliefs, with increased emphasis in her second year on developing children's reasoning and problem solving skills alongside more specific emphasis on children's procedural fluency through a thorough knowledge of number bonds (5.4.2).

The focus of Penny's beliefs about what makes a good mathematician was again slightly different; although all aspects of Kilpatrick *et al*.'s (2001) model were apparent in her narrative, for her the emphasis was on the elements of the model related to the application of mathematical knowledge and skills; strategic competence, adaptive reasoning and a productive disposition (7.5). Penny's beliefs regarding the identity of a mathematician being a problem solver, linking to her definition of mathematics as *"a logical way of solving problems"* and her background as a professional mathematician, echo the beliefs of McClure (2103). Notable in Penny's narrative was how, over time, she developed her teaching strategies in order to teach according to her beliefs, informed by her own reflection on practice within the independence of her position in her school context. Penny's emphasis on developing children's mathematics language to facilitate their adaptive reasoning and developing their productive disposition as independent learners through giving them ownership of tasks, were also particular features of the impact of her beliefs on her practice. Penny's approach is thus very consistent with the US teachers in Cai and Wang's (2010) study who considered effective teaching encouraged children to "explore, generate and use knowledge by themselves" (p.284).

Orna, at Meeting 3, when creating her influence map with beliefs about what makes a good mathematician linking with her background as *"overarching influences",* stated that her belief in the importance of problem solving, reasoning and justification in mathematics stemmed from her learning of mathematics up to degree level (8.2). These traits, linking clearly to Kilpatrick *et al*.'s (2001) strategic competence and adaptive reasoning and Ernest's (1989) 'Facilitator' role, are very apparent as she discussed the influence of the children on her practice (8.3). Orna's beliefs did not sit comfortably with the over-emphasis, as she saw it, placed in school and picked up by the children, on the value of learning times tables (8.5.2). Whilst not quite suggesting Beswick's (2012) dichotomy because she had not changed her beliefs as such, she expressed concern that she was not fully able to convince the children she taught that a good mathematician was not necessarily one who knows all their times tables! Orna was not content for children with limited English language or other specific needs to have a diet of lower level mathematics based on procedural fluency, but sought to solve the issue of ensuring that they were reasoning and problem solving at a mathematically appropriate level. Like Penny and Rahma, Orna also seemed to promote resilience and positivity in the children she taught and thus encouraged a productive disposition towards mathematics.

Rakesh was the one participant who felt he could not teach according to his beliefs (8.4.3). His specific idea that a good mathematician is a *"problem seeker"* fits neatly with Kilpatrick *et al.*'s (2001) strategic competence, going beyond simple problem solving to being able to formulate a problem and think flexibly and resourcefully (Schoenfeld, 2007). However, he considered that preparing for national tests meant he had to teach within a national *"system"* that values getting set answers in mathematics quickly and efficiently rather than valuing children who *"question things".* Thus, Rakesh's experience resonated with Ernest's (1989) suggestion that the influence of context can lead teachers to teach in ways that are not in line with their beliefs.

However, whilst the teachers in this study all worked within the framework of the National Curriculum for Mathematics (2014) and within school directives, it seems that, with the exception of Rakesh, they were nevertheless able to promote the strands of mathematical proficiency that to them were most important and adapt their teaching approaches to reflect this. The evidence from this study, therefore, is in line with Rowland *et al*. (2008), Askew (1999) and Ernest (1989) in suggesting that a teacher's beliefs impact on their teaching practice. Also apparent in this study though, is the evolution of the practice of these early career teachers to be increasingly in line with their beliefs, which in turn are subject to change.

9.4.3 *Changes in beliefs about what makes a good mathematician*

As discussed in 9.3.4, the background of the teacher seems to provide a framework for their beliefs. The influence of the participants' background is evident in the summaries above of participants' network of beliefs about what makes a good mathematician, both in terms of the emphasis placed on the different strands of the model of mathematical proficiency and the emotional emphasis linked with this.

Whilst in essence these beliefs seemed deeply rooted, in line with Simon, Millett and Askew's (2004) findings, and radical shifts in belief systems were not apparent, evident for some participants in the study was a sense of the evolving of their belief systems through learning and development in the school community (also discussed in 9.2.5 above) and through reflection on practice. Gina's beliefs about the meaning of mastery in mathematics, for example, evolved with the ongoing collaborative discussions related to this within her school context (6.4.5.2); Chloe's beliefs in the importance of a positive and resilient attitude towards mathematics were reinforced by her reflection on teaching some children who did not seem to want to work in mathematics lessons (8.4.1); and Evie's beliefs, articulated as she created her influence map at Meeting 5, that a good mathematician can *"reason in different contexts, spot patterns, make links and show it in different ways"* seem to have been strengthened by the influence of her subject leader in school and her reflection on practice, with consequence changes to the emphasis in her teaching approaches (8.5.1). Rakesh uniquely also sought to research effective teaching approaches through reading and through this his beliefs evolved (8.6.2).

9.4.4 *Beliefs as criteria for reflection*

Askew (1999) suggests that teachers' pedagogical decisions are based on their beliefs about the relationship between teaching and learning. My study confirms this notion and but also provides evidence of an additional and related function of beliefs about what makes a good mathematician; their use as criteria for reflection. Whilst Korthagen (2010) considers that teachers use beliefs about what constitutes a good teacher as criteria for reflection, the participants in this study seemed to go beyond this to emphasise reflection based on the learning of the children.

Rahma recognised this connection in her overlapping of the influences of 'My own self-imposed changes through my proactivity and reflection on practice' and 'Beliefs about what makes a good mathematician' on her influence map, with *"Was it right for my children"* as her stated reflective measure (5.2). Similarly, Orna's Meeting 3 influence map suggests that her beliefs are an overarching influence against which reflection took place (8.2). Whilst implicit in the narratives, changes due to reflection against the criteria of beliefs seem particularly apparent in the narratives of Penny, Rahma and Orna. Section 7.5 outlines Penny's journey as she increasingly sought, through proactivity and reflection on practice, to teach according to her beliefs. Rahma, even during her ITE course, seems to have used her beliefs to support her reflection (5.3.2) and Orna's discussions of how she sought to develop her practice to address the needs of individuals show a determination to reflect on the needs of the children against her network of beliefs and adapt her practice accordingly (8.3.3).

9.4.5 *Summary – influence of beliefs about what makes a good mathematician*

Using the notion of 'beliefs about what makes a good mathematician' has provided insights into participants' beliefs related both to mathematics and to the learning of mathematics and thus the influence of these beliefs can be analysed in relation to the literature on these themes. Participants were able to discuss the influence in relation to their own practice when creating their influence maps and it was possible to gain further evidence from their wider discussions.

The early career teachers in this study, with one exception, seemed able to incorporate their beliefs relating to what makes a good mathematician into their teaching approaches. There were similarities in the nature of these beliefs across participants, but differences existed in the emphasis placed on different strands of mathematical proficiency in the practice of these teachers, influenced at least in part by their mathematical backgrounds. These beliefs were dynamic, being subject to change and development in response to learning and development from the school community and through an individual's own learning through reflection and research. They were also used as the criteria against which a teacher could reflect on their practice.

The evidence in this study reinforces the related literature in confirming the importance of a teacher's beliefs as an influence on their practice. In addition, Kilpatrick *et al.*'s (2001) five strands of mathematical proficiency was found to be a useful tool for the analysis of these beliefs and their impact on practice. My study extends the literature in exemplifying the links between the influence of beliefs and the other influences on a teacher's evolving practice, as summarised in Figure 9-6.

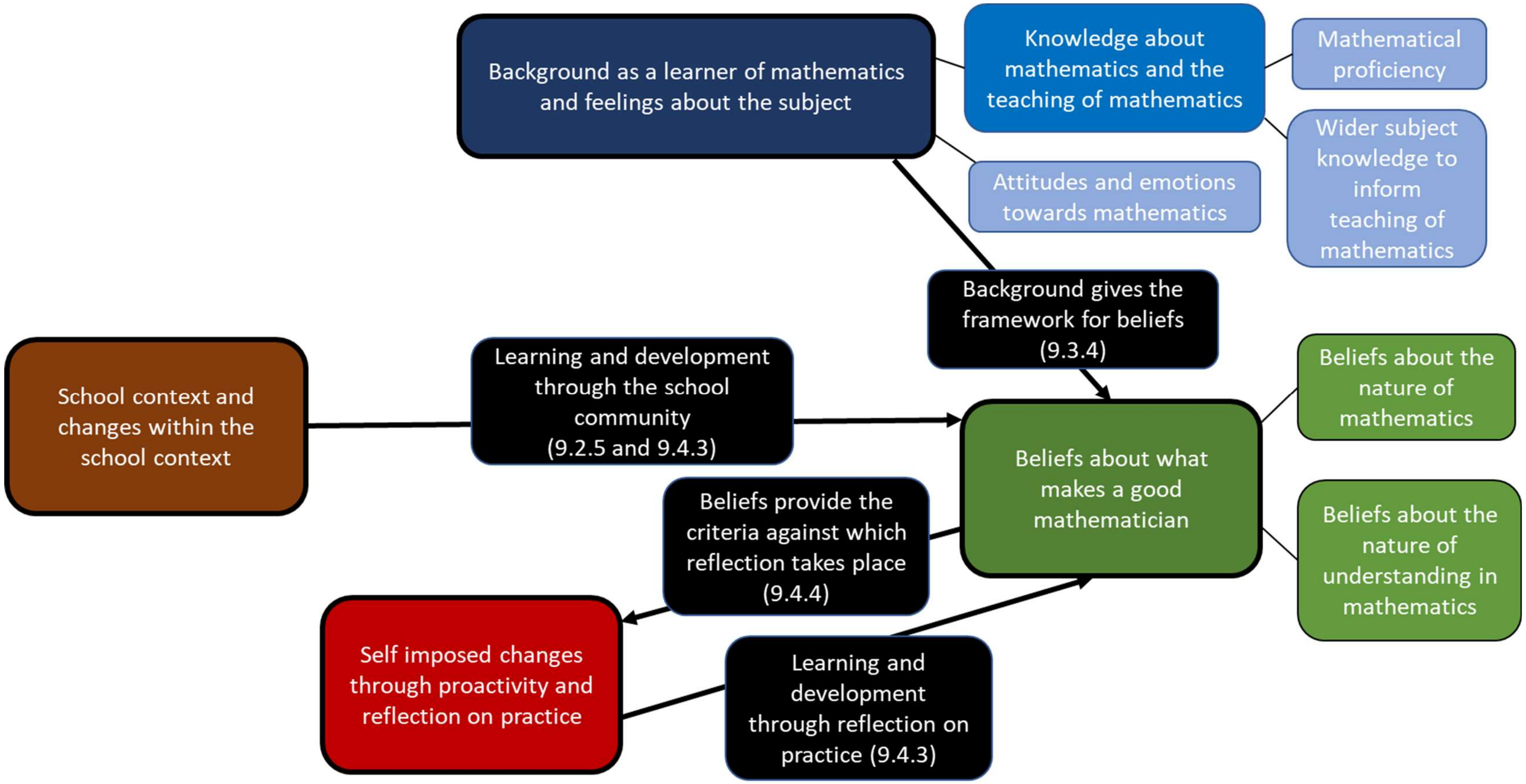


Figure 9-6 The influence of beliefs about what makes a good mathematician and links to related influences.
Arrows indicate direction of influences. Lines connect sub-categories to main influences. Shades of brown represent the influence of the school context; shades of blue represent the influence of the background of the early career teacher as a learner of mathematics and their feelings about the subject; shades of green represent the influence of beliefs about the learning and teaching of mathematics and shades of red represent the influence of self-imposed changes through proactivity and reflection on practice.

9.5 Self-imposed changes through proactivity and reflection on practice

9.5.1 *Introduction*

This section focuses on the influence of self-imposed changes through proactivity and reflection on practice which was considered to be the largest influence on their practice by Rahma and Rakesh, and the second largest influence for Penny, Evie and Emily. As outlined in the earlier sections in this chapter, the other three influences were found to impact on this influence, with the school context providing the context for proactivity and reflection, the background of the teacher providing resources for proactivity and reflection including knowledge and self-efficacy, and their beliefs about what makes a good mathematician providing criteria against which reflection can take place.

In this section I analyse the evidence connected to this influence in relation to relevant literature, arguing that early career teachers have an awareness of the value of reflection and the confidence and ability to use it to make proactive changes to their practice. The extent of the impact of this influence seems particularly related to the constraints and freedoms permitted within the school context.

9.5.2 *Reflection and proactivity*

> *I always like to reflect on my lessons and try to make it better.* (Rahma, M5)

> *What influences my teaching more than anything else now is just my own thinking about what I need to do next […] thinking about where I'm experiencing difficulties and trying to find solutions.* (Rakesh, M5)

The wording 'self-imposed changes through proactivity and reflection' suggests a two stage process towards adapting practice, in line with the "mediating processes" of Peter's (1995) model of professional growth (p.322). These stages are perhaps appropriately summed up by Rahma and Rakesh whose comments above also indicate the order of the cognitive processes. Firstly, reflection takes place against "valued outcomes" (Peter, 1995), which evidence from this study suggests might be beliefs about what makes a good mathematician (9.4.4), either in isolation or alongside colleagues (Krainer, 2003). Carrying out this reflection carries the implication that it is considered valuable to do so (Lerman, 2010). The second stage, Peter's 'enaction', or as named in this study, 'self-imposed changes through proactivity', requires the teacher to decide what changes in practice might be appropriate to develop their practice in response to their reflection, and action these.

9.5.3 *Perceptions of reflection as a mechanism of change*

The literature about teachers' reflection on practice focuses on this as a key mechanism of change because of its use in constructing new knowledge and developing beliefs (Llinares and Krainer, 2006) and specifically its developmental potential in relation to extending pupil learning (Gore and Zeichner, 1991). The participants in this study similarly perceived reflection to be a driver of change with a focus on pupil progress. Whilst Rahma and Rakesh in particular clearly valued reflection and used this as a learning and development tool to shape their practice (5.3 and 8.6.2), it seemed that all the participants recognised reflection as having potential to positively change their teaching approaches, even if, in Gina's case, only to acknowledge that she felt she should be doing it (6.5). For some, reflection was seen as an individual activity to develop their specific practice, whereas for others opportunities for collaborative reflection were taken.

Rahma (5.3) and Rakesh (8.6.2) recognised reflection as a trait of their character; they identified as "reflective individuals", seemingly internally orientated (Turner, 2008, p.113; Korthagen, 2010). For both the process of reflection seemed intensely personal and they seemed to take pride in how their reflective approaches could increase the quality of their teaching. Rahma explained how she *"used her own thoughts"* to reflect, with the aim that her children had a *"deeper knowledge of maths"* and Rakesh talked about researching *"to find solutions"* and seeking to be innovative in actioning new approaches, an attitude considered by Newell (2011) to be particularly effective. Rahma talked about *"taking risks"* (5.3.2) and Rakesh stressed his practice evolved when teaching his Year 6 class as he tried to *"identify the right point"* of lessons to proactively *"add that extra element"* (8.4.3).

Both also recognised value in reflecting alongside colleagues (Levine, 2010; Johnson, Hodgen and Adhami, 2004) and, despite their inexperience, felt confident to influence the practice of others. Rakesh, for example, had the confidence to share his ideas about approaches to SATs preparation with his Year 6 colleagues and thus perceived that he had some influence over the practice of the whole team (8.6.2). He was also looking forward to reflecting on his time as a temporary subject leader for mathematics with the permanent leader (8.6.2). Whilst particularly influencing the practice of Nina (5.3.1), Rahma's perceptions of her reflective discussions with other teachers within her key stage and whole-school CoPs, were that they supported her evolving practice through a sharing of experiences and consideration of alternative views and new ideas (5.3.5) (Johnson, Hodgen and Adhami, 2004).

For Penny and Orna, reflection was highly valued as a regular part of the teaching process, informing their teaching of subsequent lessons. Penny reflected individually *"after every lesson"* in preparation for her next lesson (7.4), seemingly internally motivated to do so (Millett, Brown and Askew, 2004), and Orna's close working relationship with her colleague Liam in her first year enabled her to engage in *"reflective discussion"* within their year group CoP (Wenger, 1998) (8.2). In discussing *"What did they get? What did they not get? What can we change?"*, Orna and Liam set aside time to use reflection for deliberative learning (Eraut, 2004).

Emily's comments as she created her influence map at Meeting 5 suggest an added layer of complexity and purpose for reflection (8.4.2), indicative of Lerman's (2001) view that reflective practice increases participation within CoPs and Hodgen and Johnson's (2004) suggestion that reflection focused on significant change is about the reconstruction of experience and knowledge. Emily's comments showed that, for her, reflection not only took place within the constraints of what was permitted (Goos, 2014), and indeed expected, within her school context, it also enabled her to meet these expectations: *"I will always try to fit in with what they're expecting by reflecting on my own way of practice"* (8.4.2). *"Mimicking"* the good practice of others was a particular strategy she used to develop her subject knowledge for teaching to enable her to do this and to become more closely aligned to her recognised image of a good teacher (Calderhead, 1989; Korthagen, 2010).

It seemed that for all these participants reflection in some way was an essential component of their ZoE (Millett and Bibby, 2004).

At their final meeting I asked participants whether taking part in my research had any influence on their practice. All responded positively about the opportunities my visits gave for their reflection, giving further insights on their perceptions of this process as a learning and development tool. Some, notably Penny as discussed in 7.4, but also Rahma, Emily and Evie talked about how reflecting in advance of our meetings impacted on their ongoing practice:

> *It's made me think which ones* [lessons] *went well and which ones I know I would maybe change for next year.* (Rahma)
>
> *Knowing in the back of my mind that I have these sessions with you makes me think about what I'm doing and why I'm doing it.* (Emily)
>
> *Particularly when I know you are coming in, I'm always thinking what went well, what hasn't gone well, why hasn't that gone quite as well.* (Evie)

Participants also emphasised that the process of talking within the meeting gave them the "*opportunity to actually sit back and reflect"* (Emily), adding an additional element to Lerman's (2001) argument about the value of reflecting alongside others. Whilst I merely listened and did not engage in reflective discussion, as Clara stated, "*It makes me voice my opinions and reflect on what has helped me".* Orna elaborated further, articulating that the development of children as mathematicians was the purpose and goal of her reflection:

> *It helps me to remember things that have gone well and repeat them or use them more […] It helps me to see how we're approaching different elements of the children becoming well rounded mathematicians and highlights in that way any gaps.* (Orna)

Again, this seemed to impact practice, as Gina and Orna explained:

> *At least for the following unit I'm thinking more about things I'm not so good at and trying to put them in place.* (Gina)

> *It's useful in terms of thinking "right, so how am I going to do that better?"* (Orna)

It seems then that the participants viewed reflection as a driver of change, an essential tool for their learning and development (Llinares and Krainer, 2006) as they focused on teaching to secure the most effective learning for those they taught. As discussed also in 9.3.5 and 9.4.4, it seems that the participants were continually adding to the depth of their subject knowledge for teaching and further developing their beliefs about what makes a good mathematician whilst carrying out the reflective process, although this is more implicit than explicit in their specific articulations about reflection.

The quotes above also suggest that the reflective process was one where the participants could take ownership of their development; reflection was a driver for change over which they had some control and, for some, could also be used to influence the practice of others.

9.5.4 *Types of reflective practice*

When discussing the notion of reflection, the participants all interpreted this word as reflection on their classroom practice after the event; reflection based on how they might adapt and develop this practice to enhance children's learning. All the examples of reflective thinking above thus specifically relate to Eraut's (2004) deliberative learning, achieved through specifically setting aside time to analyse their practice, essentially Schön's (1983; 1995) reflection on action. This possibly mirrors the emphasis placed on this type of reflection on their ITE course (see 10.5.4) when, as student teachers, participants were expected to add weekly to a reflective journal.

Whilst it could be argued that generally their reflection was at a relatively low level of Körkkö, Kyrö-Ämmälä and Turunen's (2016) hierarchy, as might be expected with early career teachers, the articulation of some of the participants, notably Rakesh, Rahma and Orna above, suggests a higher level of self-questioning of their beliefs and assumptions, and the evolving of these qualities. As discussed in 9.4.3, there is evidence that participants' beliefs about what makes a good mathematician evolved through their deliberative learning from individual or collaborative reflection on their practice.

It is possible that the participants' self-awareness of their reflection on action was stronger than their awareness of reactive learning through near-spontaneous reflection (Eraut, 2004); the reflection-in-action (Schön, 1995) that takes place as the contingency element of subject knowledge is put into practice (Rowland *et al.,* 2008). However, although not specifically articulating those 'in action' changes to be part of their reflective practice as such, wider evidence from the study suggests that some participants did perceive their competence with this to be a significant aspect of the development of the effectiveness of their teaching. Indeed, at Meeting 5 Gina stated that deviating from her plans whilst teaching was a major development in her practice since Meeting 4. This contrasts with her opinion that the influence of self-imposed changes through proactivity and reflection was limited because of the extent of changes imposed on her (6.5).

Conscious, reactive decision making through reflection-in-action was particularly evident in participants' descriptions of their best or their most challenging lessons, such as Rahma's lesson about halving odd numbers (5.6.4) Penny's about odd and even numbers (7.5) and Gina's lesson about adding using partitioning (6.5). When sorting subject knowledge cards according to their strengths at Meeting 4, Rahma and Gina included 'Responding appropriately (mathematically) to unplanned, unexpected questions and ideas from pupils' as particular strengths (see Figure 5.6 for Rahma's arrangement); Penny too stated *"I'm quite good at adapting […] I'll try any other method going".* It seems that such 'in the moment' reflection was recognised as a characteristic of their teaching, but not linked to reflection as an influence on practice.

9.5.5 ***Reflection and self-imposed changes influenced by the school context***

Both the nature and extent of the deliberative learning gained from reflection on action and the impact of this in terms of self-imposed changes seemed to some extent to be dependent on the school context.

As discussed in 9.2, the participants in the study varied in the opportunities they had to reflect collaboratively with colleagues in their CoP and hence benefit from the sharing of points of view and the expertise of more experienced teachers (Johnson, Hodgen and Adhami, 2004; Eraut, 2004). They also seemed to vary, as Korthagen (2010) suggests, in the extent to which they were internally or externally orientated with regards to their reflective practice, with Gina possibly showing the strongest need for guidance and feedback (6.3.2).

Although reflection is generally considered to have purpose and direction in terms of influencing future practice (Llinares and Krainer, 2006), the extent to which reflection leads to self-imposed changes cannot be assumed. Goos and Geiger (2010) suggest that the school context is a significant aspect of the Zone of Free Movement (ZFM) of a teacher, to the extent that "The teachers' perceptions of what is permitted by their professional contexts can promote or limit opportunities for teachers to change themselves" (p.503).

The evidence from this study suggests that the greatest perceived constraints to reflective practice were the impact of changes imposed within their school context. As discussed in 9.2.6, the extent to which a teacher's learning and development comes from self-imposed changes through proactivity and reflection or from directives from the school is possibly dependent on the rate and extent of imposed changes. Orna and Gina talked about changes due to proactivity and reflection being limited when significant changes were imposed on them within the school context (6.2 and 8.2). Rahma and Rakesh, in contrast, taught within school contexts where relatively little whole-school change was taking place.

A further consideration, as discussed in 9.2.3, was the independence and freedom given to these early career teachers in their planning and teaching of mathematics. The narratives of Penny (7.5) and Rahma (5.3), for example, illustrate how these teachers, within a context of relative freedom to adapt their classroom practice, were particularly able to action self-imposed changes; Evie, too, proactively developed her practice in using resources to support the children's learning. However, even in settings that were perceived to be more restrictive, there was some scope for self-imposed changes. Orna and others who taught a high proportion of children with EAL, for example, discussed how they implemented a range of self-imposed actions to develop their teaching to better support these children (8.3.1 and 8.3.2), and some of the changes Rakesh and Emily made to their practice as they taught children preparing for SATs tests were through self-imposed actions.

As mentioned in 9.2.3 the participants were generally pragmatic about the context within which they were teaching. Whilst Goos' discussions (2013, 2014) of significant changes made by teachers related to their ZFM/ZPA complex are particularly in relation learning from promoted actions that caused significant tensions, the examples of learning resulting from the reflective practice of the participants in this study could be argued to be relatively minor changes at classroom level which did not cause particular tension or bring them into conflict with others in their CoPs (Lave and Wenger, 1998). It seems likely that they did not seek to make major self-imposed changes to their practice that might have a profound impact on the nature of their ZFM (Goos, 2013).

Goos and Geiger (2010) suggest that early career teachers might find it more difficult than more experienced teachers to proactively change their practice because of perceived constraints on them, and other research suggests that the depth and extent of reflection for early career teachers is limited due to inexperience (Calderhead, 1989; Körkkö, Kyrö-Ämmälä and Turunen, 2016; Korthagen, 2010). However, the evidence in this study is more in line with Turner (2008), in suggesting that early career teachers in England do have the reflective ability and confidence to make proactive changes, albeit at a relatively low level of change.

9.5.6 *Summary – influence of self-imposed changes through proactivity and reflection*

In line with the related literature, the teachers in this study viewed self-imposed changes through proactivity and reflection as an important influence on their practice, with deliberative learning through reflection on action (Eraut, 2004; Schön, 1983; Schön, 1995) seen as an essential tool and a key driver of change within their ZoE (Millett and Bibby, 2004). Both individual and collective reflective practice were seen as valuable; even the process of verbally articulating their reflective thoughts, as they did when meeting with me, was considered beneficial. Although not specifically linked by participants to discussions on proactivity and reflection, Schön's (1983;1995) reflection-in-action was recognised as a characteristic of effective practice. Despite their inexperience and despite making fairly minor changes within the social and organisational dimensions of their school context, participants had the confidence and ability to make changes and through doing so took some control over their evolving practice. Reflection also impacted on their evolving beliefs about what makes a good mathematician.

The nature and extent of reflective practice and the resultant self-imposed changes were influenced by the reflective orientation of the individual (Korthagen, 2010) and the social and organisational aspects of the school context within which they worked. Whilst the greatest perceived constraints to reflective practice were the impact of changes imposed within their school context, it seems the independence and freedom given to these early career teachers in their planning and teaching of mathematics was also a significant factor related to reflection within the school context. For some, their reflective practice also influenced the practice of others.

The evidence presented aligns with related literature and extends this by providing further evidence of early career teachers' perceptions of the value of reflection, the nature of the changes made by the participants from the reflective process and their confidence to make such changes. This study also goes beyond existing literature in exemplifying the nature of the links between this and other influences on an early career teacher's evolving practice in the teaching of mathematics.

Figure 9-7 summarises these links.

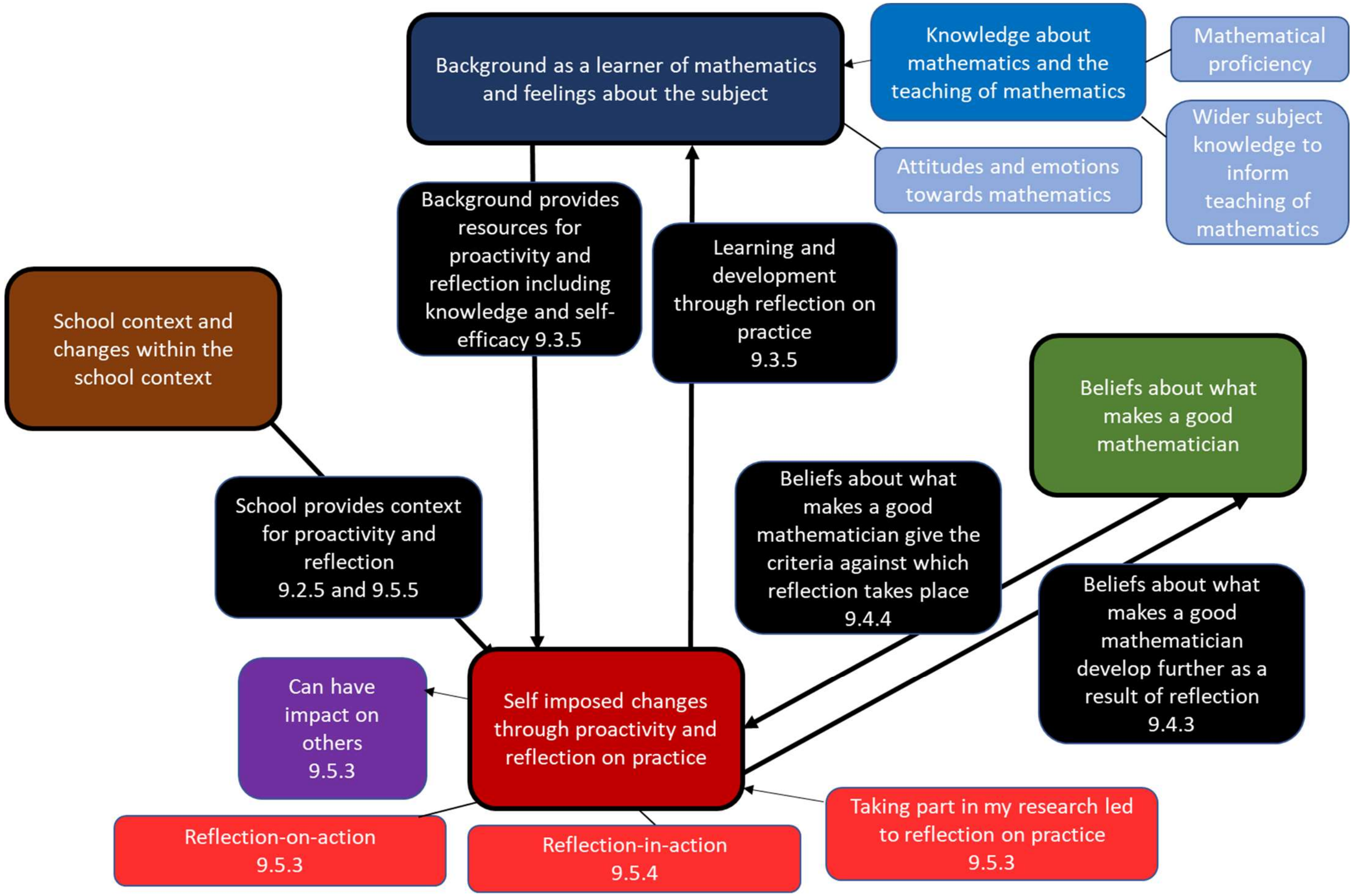


Figure 9-7 The influence of self-imposed changes through proactivity and reflection on practice and links to related influences.
Arrows indicate direction of influences. Lines connect sub-categories to main influences. Shades of blue represent the influence of the background of the early career teacher as a learner of mathematics and their feelings about the subject; shades of green represent the influence of beliefs about the learning and teaching of mathematics and shades of red represent the influence of self-imposed changes through proactivity and reflection on practice.

9.6 A theoretical model of the interacting influences on early career primary teachers' teaching of mathematics

9.6.1 *Introduction*

This chapter has brought together evidence from all the participants with discussion of the relevant literature to explore the different influences on the evolving practice of teachers of mathematics and the connections between these influences. A particularly important finding is that the influences are highly interconnected, as recognised by the participants when creating their influence maps (Figure 8-1).

In this section I summarise how my findings support and extend the related literature and present my own theoretical model of the interrelated influences on the evolving practice of early career teachers of mathematics.

9.6.2 *Fit with the theoretical framework*

The model constructed from the literature reviewed, which was presented at the end of Chapter 2 and is repeated in **Error! Reference source not found.** for ease of reference, provided a useful theoretical framework and structure for discussing the findings of this study.

The theoretical frameworks of Millett and Bibby (2004), Lave and Wenger (1991) and Goos (2013) were found to be particularly useful in analysing the various elements of the influence of the school context and changes within this, and have supported analysis of the links between influences. The body of literature relating to the characteristics of the teacher in terms of their subject knowledge, beliefs, attitudes and emotions, confidence and self-efficacy, and motivation, along with the evidence from my interviews, has supported the analysis of factors relating to the individual. Literature exploring reflection as a mechanism of change supported consideration of the nature of these teachers' reflection on their practice. Literature from across these elements was useful in analysing the nature and extent of the resultant self-imposed changes teachers might make to enhance the quality of their teaching and in turn, the children’s learning.

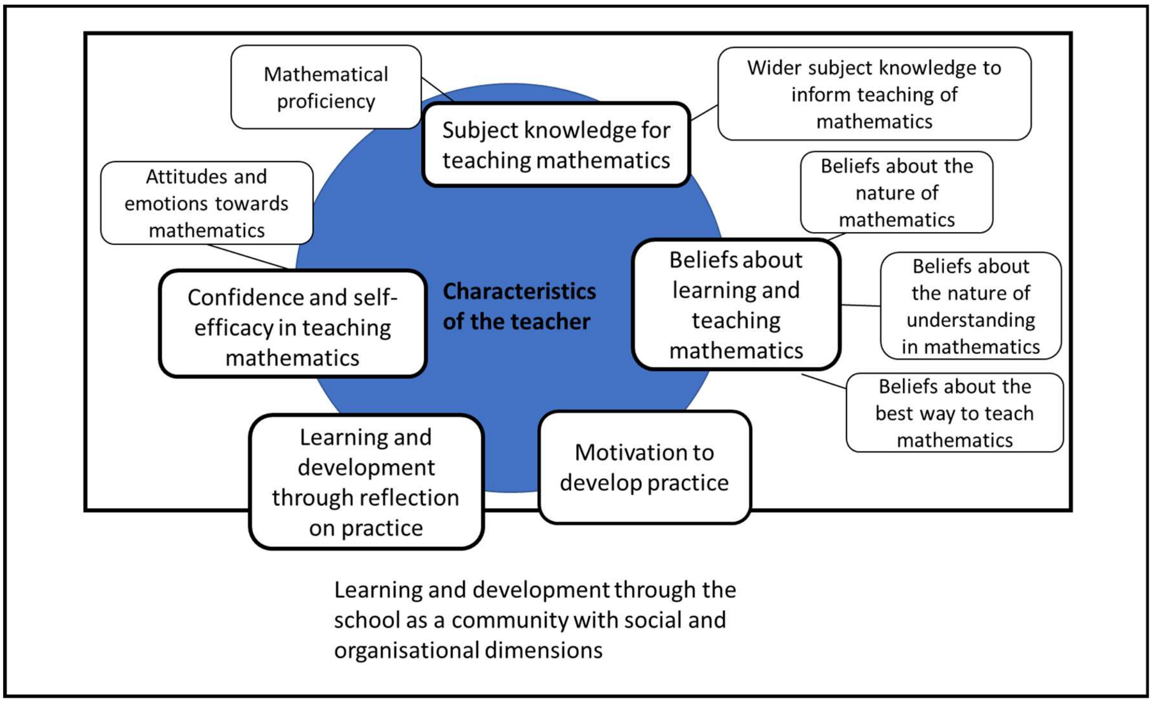


Figure 9-8 Theoretical framework: a model of the interacting influences on early career primary teachers’ teaching of mathematics.

9.6.3 *Extending the literature*

The understanding gained from this research into the factors influencing early career teachers’ teaching of mathematics builds on and extends the existing literature by considering the perspectives of the teacher themselves and also by seeking to provide a richer model of the interacting influences.

More specifically, the study provides detailed evidence from the perspective of early career primary teachers of the importance, complexity and individualised nature of the influence of the school context on their practice as teachers of mathematics. The study also provides evidence of early career teachers’ recognition of the importance of reflection on their practice as an essential driver of their learning and development and the confidence they have to make self-imposed changes, albeit changes within the social and organisational framework of their school community. Additionally, new evidence has been presented of the impact of the background of early career teachers as learners of mathematics, their feelings about the subject and their self-efficacy as a teacher of mathematics alongside their beliefs about what makes a good mathematician, with some specific differences noted between the perceptions and priorities of specialist and non-specialist teachers of the subject. The evidence highlights that each of these influences is very individualised and they combine to create a unique impact on the evolving practice of any one teacher.

While Goos' (2013, 2014) zone theory in particular goes some way towards explaining how aspects of these influences interact to effect change, perhaps the most important contribution of this research to the literature is in specifically identifying and evidencing the nature of the interactions between each of these influences within the context of the practice of early career teachers. Thus, whilst the influences on these early career teachers align closely with those in the reform context of Millett and Bibby's (2004) model, this study provides further research towards more fully understanding how the "interface" between teachers and their schools impacts on the way they develop their practice (p.3).

Although generally perceived as the most significant influence on practice, the school context, as Goos (2013) suggests, is far from simply being the "backdrop for practice" (p.531). Its varied and changing elements provide communities of practice for teachers' learning and development, influencing both their evolving subject knowledge for teaching mathematics and their beliefs about what makes a good mathematician. Teachers also learn and develop proactively through reflecting against criteria based on these beliefs and drawing on resources of subject knowledge and self-efficacy in teaching the subject, as products of their evolving mathematical background. The school provides a dynamic context for such self-imposed changes. The notion of change is very apparent in the practice of early career primary teacher's teaching of mathematics because of the changing nature of the influences on them.

Bringing together the diagrams of each of the individual influences on early career teachers of mathematics, a full theoretical model of how these influences interact is presented in Figure 9-8. The model extends that formed from the literature review and summarises how factors related to the teacher themselves and factors related to the school context combine to influence the evolving practice of early career primary teachers' teaching of mathematics.

The model does not attempt to represent the relative size of each influence. In this study, the influence of the school context was perceived by most participants as the greatest influence on their practice, but this was not universal and the influence maps and other evidence from the eight participants showed striking contrasts in their individuality. Whilst some teachers found themselves in a school context where mathematics was a particular focus and many opportunities for learning and development in teaching the subject were presented, for others, reflection on practice was a key mechanism of change, and the influences of the teachers' own background and beliefs about what makes a good mathematician were more proactively applied.

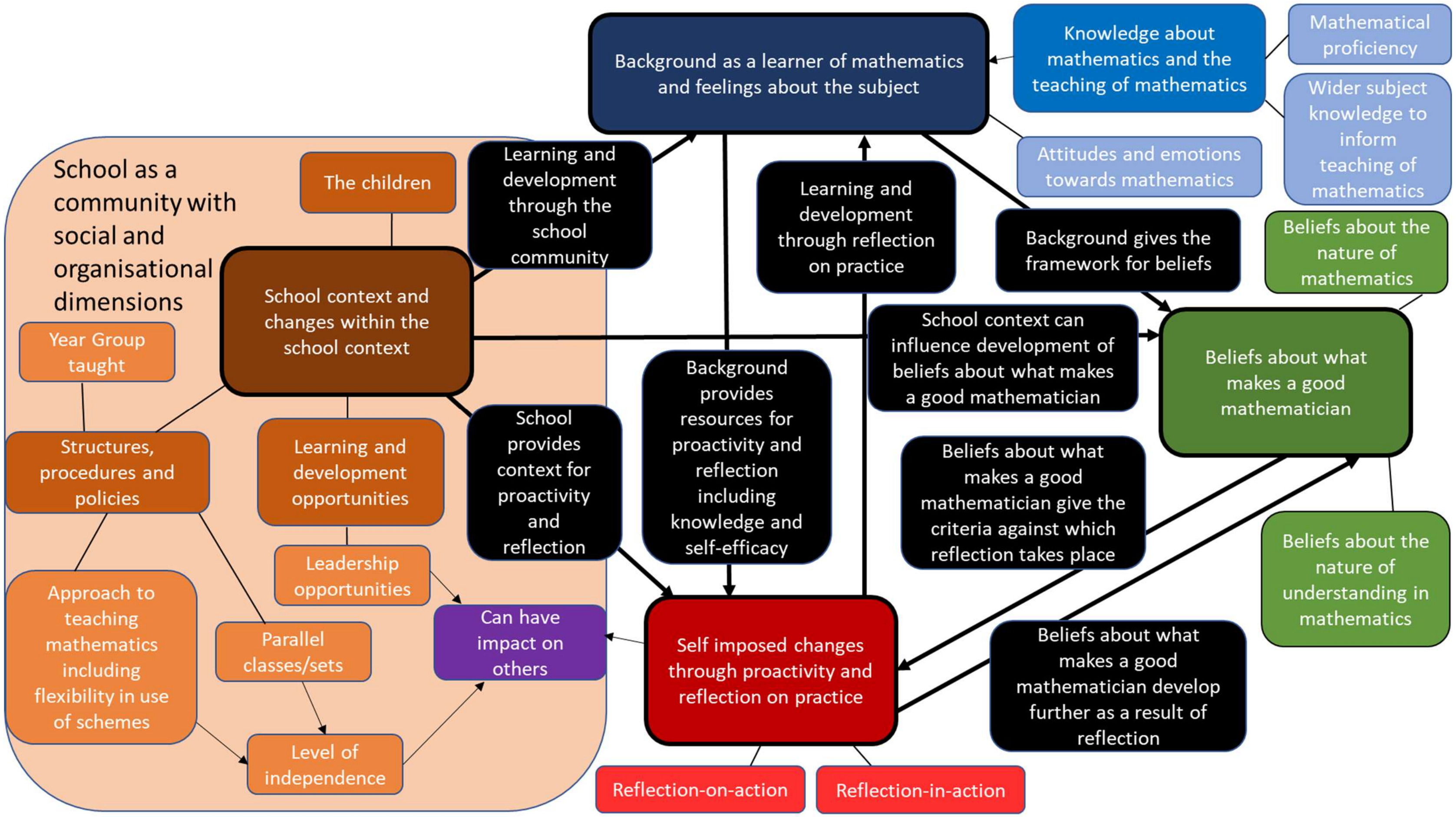


Figure 9-8 A theoretical model of the interacting influences on early career primary teachers' teaching of mathematics.
Arrows indicate direction of influences. Lines connect sub-categories to main influences. Black boxes label the links between the main influences. Shades of brown represent the influence of the school context; shades of blue represent the influence of the background of the early career teacher as a learner of mathematics and their feelings about the subject; shades of green represent the influence of beliefs about the learning and teaching of mathematics and shades of red represent the influence of self-imposed changes through proactivity and reflection on practice.

10 Conclusion

10.1 Introduction

In this final chapter I summarise how the research questions have been addressed and how the study provides contributions to knowledge, not only in the field of mathematics teacher education but also methodologically. I then present a range of implications arising from the study for ITE providers, policy makers and the research community. Finally, I consider the limitations of the study and highlight potential related areas of future research before reflecting on my journey as a researcher.

10.2 Addressing the research questions

The main research question *How do factors related to the teacher themselves and factors related to the school context combine to influence the evolving practice of early career primary teachers' teaching of mathematics?* has been addressed through the perspectives of the teachers themselves, both through directly asking teachers about influences on their practice across a two year period and through analysis of their wider narratives. In Chapter 9 evidence of the individualised and interacting nature of these influences is discussed, leading to the presentation of an extended theoretical model.

Answering the sub-question *How do early career primary teachers perceive the influences on them as teachers of mathematics?* has been an integral part of the study throughout. The methodology adopted focused on drawing out these perceptions and the analysis of the data collected focused on documenting and discussing these perceptions.

The sub-question *How does the evolving practice of mathematics specialists compare with non-specialists?* was addressed through comparison between the five participants who had mathematics qualifications beyond the minimum required for primary school teachers in England, and had taken the mathematics specialism of the PGCE course/Primary with Mathematics PGCE, and the three who only met the minimum requirements. Some differences were apparent in both their priorities when teaching mathematics and their priorities for their own further learning and development as teachers of the subject. Specific discussion of this research question was presented in 9.3.

The questions *Does my data align with the views expressed in existing literature? Where does my analysis extend understanding and have any contradictions emerged?* were an integral aspect of the discussion chapter. My data generally aligns well with the existing literature – there were no surprises or contradictions in the findings. However, my analysis has enabled me to make tentative additions to the understanding gained from the literature review, as summarised in 9.6.3. In addition, methodological contributions to literature are summarised in 10.3.2 below.

My final research question *What implications do the findings of my research have for ITE providers, policy makers and advisory bodies, and the research community?* is addressed in 10.4 below.

10.3 Contributions to knowledge

10.3.1 ***An extended theoretical model***

The new extended theoretical model derived from this research has been introduced and set out in detail in 9.6 above. Whilst complementing the theoretical framework developed from the existing literature in Figure 2-3 (repeated as 9-8) and benefitting from analysis relating to the three theoretical frameworks for discussing teacher learning and development introduced in 2.3, this framework goes beyond these in four main ways.

Firstly, this model has a particular focus which adds to the existing literature. Based on the rich individual narratives of the evolving practice of eight early career primary teachers of mathematics, this framework is specifically tailored to the perspectives of such teachers in the first two years of their career. Thus, whilst aspects of the model might be expected to apply to more experienced teachers of mathematics and possibly to teachers of other subjects, the model retains a very specific focus.

Secondly, the design of the study meant that the participants used both verbal and visual means to describe their perspectives on their evolving practice, the range of influences on them and how these influences interacted in greater depth than is apparent in related literature. Thus, the data very comprehensively documents participants' perspectives across the full scope of the study.

Thirdly, whilst other studies have described a range of influences on teacher learning and development, this study goes further in focusing on and exemplifying the nature of the links between the different influences.

Finally, with the interviews providing in depth narratives from individual teachers with varied mathematical backgrounds and the comparisons undertaken between these narratives, it has been possible to go further than previous research by describing the importance of the mathematical background of early career teachers. The key findings (developed in 9.3) are that those with strong mathematical backgrounds tend to have a network of informed beliefs about what makes a good mathematician, which includes placing considerable emphasis on developing a positive mathematical intimacy in the children they teach; they also have greater self-efficacy as teachers of mathematics and proactively seek to become more accomplished and expert teachers of mathematics.

In summary, this study has explored the rich narratives of the evolving practice of early career primary teachers' teaching of mathematics as told by the teachers themselves. The thesis provides both in depth narratives from individual teachers with varied mathematical backgrounds and provides comparisons between these. It has brought together these narratives and comparisons with relevant literature to reveal the complexity of the influences on these teachers. Insights gained from the study particularly relate to how the influences combine and interrelate and this has enabled an extended model to be presented which goes beyond the theoretical model established from the literature.

10.3.2 ***Enhanced visual techniques for data collection and analysis***

Two specific techniques were created for this study which go beyond the existing methodology literature:

- A participant generated visual data collection technique enabling participants to show their perceptions of not only the relative size but also the extent of the interaction of a number of factors, through the use of overlapping translucent circles. This technique can facilitate a greater depth of qualitative data than arrangements such as diamond ranking (Wall *et al*., 2013) and Q-sorting (Demir, 2016) which enable the ranking of factors but do not have the facility for participants to visually demonstrate the overlapping and interconnected nature of these factors.
- A technique for narrative data analysis which combines and adapts features of concept and mind mapping to summarise and communicate three elements on one map: factual information, participant perspectives and researcher interpretations of participant perspectives. The inclusion of these three elements on each analysis map allows links to be shown between them and goes beyond the scope of the mapping reviewed in the related literature (3.4.6). The data analysis mapping in this study represents a more sophisticated technique that provides extended benefits to the qualitative researcher and thus contributes to the call of Wall et al. (2013) for a broadening of the field of visual techniques in all parts of the research process.

I will now discuss the innovations in visual data collection and analysis techniques more fully.

10.3.2.1 ***Innovation in data collection through the use of visual techniques***

The collection of data over a series of meetings provides both challenges and opportunities for the researcher. Challenges include maintaining a positive and constructive relationship with the participants and keeping the meetings fresh and interesting, whilst also collecting data that is as useful and relevant as possible. Opportunities arise from the possibility of adapting data collection techniques over the course of the study in response to ongoing analysis.

As discussed in the methodology chapter, in addition to making subtle changes to verbal questioning, I have sought to be creative in the use of participant generated visual data and concept cartoons.

The influence map which I designed for this study was a particularly useful visual tool in relation to the main research question, as it enabled the participants to visually and verbally articulate their perceptions of the influences on them as teachers of mathematics, including the relative importance of these influences and how they overlapped. The graphs of participants' relationship with mathematics and the concentric circles used for card sorts also created useful visual images and, along with the concept cartoons, facilitated verbal discussion which contributed to better data collection.

Analysis of the use of these tools suggests that they facilitated depth and breadth of discussion without participants drifting off topic, thus stimulating verbal data and creating useful visual data that enabled the perspectives of participants to be articulated, compared and contrasted. In the case of the influence maps, the flexibility of the tool allowed participants to adapt the suggested use of the materials to best fit how they saw the influences on them and the facility to overlap circles allowed them to consider the relationship between these influences in a way that more rigid structures would not have done. There were also benefits linked to relational ethical considerations within the interview process (Stutchbury and Fox, 2009): positive and engaged participation resulted from empowering participants to take some control of the meetings and stimulating their interest and motivation.

Although the influence maps are not statistically or formally comparable because the participants interpreted the labels slightly differently, with the term 'background' in hindsight seeming particularly open to interpretation, nevertheless in this small scale study, useful and interesting comparisons could be made by using verbal data alongside the visual. Wall et al. (2013) suggest that the intent of the researcher is fundamental to the nature of the visual tools used; my research presents an example of how a researcher intent on exploring perspectives of their participants can facilitate a greater complexity in response through engaging participants in a comparative exercise allowing overlapping of ideas. The simplicity of the idea and resources used to create the tool would allow adaptation into a range of research contexts to provide an alternative to the more structured diamond ranking approach for the qualitative researcher working with relatively small numbers of participants.

Designing, creating and using visual tools is both challenging and rewarding for a researcher. The challenge lies predominantly in thinking through how best to obtain the data required and designing questions and activities to facilitate this, whilst acknowledging the inevitable limitations of the techniques. Whilst the choices I made both opened up opportunities for widening and extending the data, at times my choices also limited its comparative value. For example, although the notion of 'relationship with mathematics' as a variable for the graphs enabled the participants to discuss factors that to them were particularly relevant, they interpreted this in different ways and varied in the extent to which they considered and combined emotional and subject knowledge based aspects of this relationship. In addition, with no scales used on the axes of the graphs, any comparison of the shape of graphs must be treated with caution. Overall, though, this study has shown that such tools can be very rewarding in terms of the positive response from participants and the quality of the data collected.

A poster presentation summarising the purpose, creation, use and evaluation of the influence maps is included in Appendix 10 and was presented at the 42nd Annual Conference of the International Group for the Psychology of Mathematics Education (PME42) in 2018.

10.3.2.2 ***Innovation in data analysis through mind mapping***

A visual approach was also a key feature of the data analysis in this study. Data analysis in a qualitative longitudinal study raises challenges related to the quantity of data collected and the ongoing process of data collection and analysis running in parallel. Having rejected the complexities of attempting to code the data in a traditional way, I found mind mapping to be a suitably concise way of reducing and analysing the data whilst retaining its cohesiveness.

Building on the literature relating to concept and mind mapping, my own style of mapping combined elements of both to create a form of map that summarised the data from a single meeting on one A3 sheet of paper. The structure used also allowed analysis by making connections and linking ideas whilst considering the structure and function of narratives. Colour coding enabled a comprehensive visual presentation of three related elements: factual information, the interpretations of the participant and my interpretations. Further analysis resulted from the combining and comparison of maps.

This study provides evidence that mapping can be a useful tool for qualitative data analysis and contributes to the limited but growing number of examples of such tools in the methodological literature.

10.4 Implications

10.4.1 ***Initial Teacher Education providers, school leaders and teachers***

The model of the interconnecting influences on early career primary teachers of mathematics could benefit ITE providers as they consider how to effectively prepare pre-service teachers for their role as teachers of mathematics and give pre-service teachers themselves insights into the likely future influences on their practice. Beyond this, the model could also usefully inform school leaders and others working with early career teachers in the development of their classroom practice as teachers of mathematics and help these early career teachers themselves understand the influences on them.

A greater awareness for pre-service teachers of the range of factors related to the school context that might impact on their evolving practice in mathematics might support the process of seeking a suitable teaching post where there is a good fit between their development needs and the school context. Although it may not be possible to find out about future school priorities, even factors like the scheme/resource provision, the year group they would teach and the extent of independence in planning and teaching expected, would be useful information for pre-service teachers seeking employment in a school, so that they can consider a potential match with their perceived strengths and areas for development.

The findings of this study also suggest that it is important for pre-service teachers to be aware of the value of reflection as a mechanism of learning and development. ITE providers should support the development of pre-service teachers as reflective practitioners, equipping them to develop their own practice as early career teachers. Pre-service teachers should also understand that the quality of reflection depends on sound criteria and hence the importance of their beliefs about what makes a good mathematician. Whilst ITE programmes seek to support and extend pre-service teachers' subject knowledge for teaching mathematics, the evidence from this study suggests programmes should also raise awareness of teacher beliefs about the learning and teaching of mathematics and the links between these and the teacher's background as a learner of the subject. They should also seek to clarify for pre-service teachers what research suggests are the essential elements of mathematical proficiency and address any negative attitudes to the subject.

This study provides example narratives from recent early career teachers at a range of timeframes from individual lessons to summaries of teacher development over a two-year period. These examples, which illustrate that all teachers are unique in the precise nature of the factors influencing their practice, might usefully inform pre-service and early career teachers about potential situations they might face and help them to reflect on their practice. Inviting early career teachers to talk to pre-service teachers about their development as teachers of mathematics might similarly be useful. Two vignettes from this study have already been shared in a book for pre-service teachers (Cremin and Burnett, 2018, p.539).

The narratives from this study might also support the reflection of school leaders, mentors and ITE tutors as they consider the potential next steps for development for each of the teachers they work with, and the nature of support they require. The evidence linked to Goos' (2013) zone theory of the effect of promoted actions on the practice of teachers, suggests the need for understanding of the background and beliefs of the teacher they are supporting as well as the environment within which they are working in order to promote actions that are likely to be successfully implemented by the teacher. Additionally, suggestions for potential modifications to the teaching environment or enhanced subject knowledge, with consequent impact on self-efficacy for teaching mathematics and/or beliefs about what makes a good mathematician, might be needed for successful implementation of feedback requiring a change in approach. Helping early career teachers make sense of the influences on their practice could provide clarity for these teachers as they seek to proactively develop their practice.

10.4.2 *Policy makers*

The findings of this study have implications for national policy makers within the Department for Education, and advisory bodies such as the Advisory Committee on Mathematics Education and Ofsted as they consider future policy related to the learning and development of teachers of primary mathematics.

The model of the interconnecting influences on early career primary teachers of mathematics suggests that to be effective, investment in teacher development needs to recognise the interrelated influences on teachers' practice and go beyond only seeking to extend teachers' mathematical and pedagogical knowledge, important though that is.

Policy makers, through organisations such as the National Centre for Excellence in the Teaching of Mathematics, could therefore use this model to inform guidance given to schools and professional development providers of the value of an individualised approach to teacher learning and development. This should address not only teachers' knowledge but also their beliefs about the learning and teaching of mathematics and their attitudes and emotions towards the subject, building on a deep understanding of the value of reflective practice.

In addition, my study could provide examples to contribute to a national evaluation of the current drive to increase the expertise of all teachers of primary mathematics and the initiative to recruit a greater number of teachers with a specialism in the subject.

10.4.3 ***Research community***

Implications for the research community from this study link to the contributions to knowledge outlined in 10.3. The outcomes of the study will be of interest to other researchers working in the field of mathematics teacher education and potentially those working more widely in teacher education as they consider the application of the extended model to other subject areas. The methodological approach will be of interest to researchers carrying out qualitative longitudinal studies as the techniques I have used could be adapted to other research contexts.

Initial findings and innovative methodological aspects of the study have already been reported and discussed widely in the mathematics education research community. These include presentations at PME40 (Godfrey, 2016), PME42 (Godfrey, 2018), CERME10 (Godfrey, 2017) and CERME11 (Godfrey, 2019) as well as at day conferences of the British Society for Research in Learning Mathematics in 2016 and 2018 and at my own institution. Interest and feedback have been positive and I plan to continue to publish, highlighting various outcomes and approaches used within the study.

10.5 Limitations and future research

Whilst important conclusions have been drawn from this study, the research is not without limitations. This leads on to several areas of possible future research which might provide more detailed answers to the research questions.

10.5.1 *Limitations and future research related to the longitudinal nature of the study*

It was necessary, as in any longitudinal study, to decide on an appropriate frequency and number of data collection points. With the narratives of the participants ongoing over the course of the study but the data collection periodic, there will have been some impact on the nature and potential quality of the data in relation to the research questions, with the most recent experiences of the participants being uppermost in their minds. Many participants, for example, chose to discuss lessons they had very recently taught as their best or most challenging lessons since the previous meeting because they were most easily remembered. It is also possible that inaccuracies were related due to reliance on memory and significant information may not have been shared, with more distance events and opportunities for development having been forgotten; this might, for example, have impacted on the quality of data related to the construction of the influence maps.

When I introduced the influence maps, I asked the participants to consider influences on them over the whole time span of the research. However, in reality, these were a representation of the perspective of the participant from a particular point of time. Therefore, although the influence maps were very useful in their direct relation to the main research question, they were used as a starting point for the analysis with evidence from across the range of interviews used to provide a more complete picture of the evolving practice of each participant and the influences on them.

Similarly, as the narrative of change from meeting to meeting was being discussed, it is possible that participants may have lost track of when changes to practice were made and what influenced this. To minimise this limitation, I revisited data from previous meetings before my visits, so that I could summarise aspects of previous practice and help participants pick up the story of their evolving practice.

In relation to the panel conditioning effect (Bryman, 2012), where participation in longitudinal studies can affect the ongoing behaviour of participants, my visits inevitably both prompted and necessitated reflection on practice. As discussed in 9.5.3, all the participants acknowledged that this was a positive impact on their practice and is therefore a contributary factor to the influence of proactivity and reflection on practice in the model developed.

Finally, the time span of the data collection was limited to two years. A longer study would have given further insights as to how these early career teachers continued to develop as teachers of mathematics and the nature of the influences on them as they gained further experience and potentially more responsibility. None of the teachers in this study moved school during the research and the impact of such a move would also be interesting to explore. Longer studies of early career teachers would therefore be a useful focus of future research and, indeed, I hope to revisit these participants in the future to follow up this study.

10.5.2 *Limitations and future research related to the interpretations made by the participants*

This study focused on the perspectives of the participants with their views generally accessed through questioning and related participatory activities. My questions and the design of activities were informed by my reading and carefully considered in advance of meetings. A semi-structured interview approach also gave me the flexibility to respond to points made. However, it is not possible to make absolute comparisons between participants because they interpreted questions and activities in slightly different ways. For example, as mentioned in 10.3.2.1, the participants interpreted the labels of the influence maps slightly differently and the notion of ‘relationship with mathematics’ as a variable for the graphs was subjective and open to interpretation.

Most considered this in terms of their self-efficacy as a mathematician in their first graph as they reflected on their past relationship with mathematics, and then their self-efficacy as a teacher of mathematics in the graphs drawn at the end of their first and second years as teachers, but the scope of points made about this relationship varied.

I have therefore been tentative in any comparisons made and where visual representations have been used in the presentation of data in this thesis, I have aimed to clarify interpretations using the verbal descriptions of participants alongside the visual data.

In future research, further exploration of techniques to gain a range of insights into participant perspectives would enhance the quality of data collection.

10.5.3 *Limitations and future research related to the sampling of participants*

This was a small-scale study with a limited number of participants, all from the same teacher education institution in England, all teaching in relatively large primary schools, and all generally confident and positive teachers of mathematics who successfully completed their first two years of teaching. Hence the model developed from this research is tentatively presented as it may not be representative of the influences for many or even most new teachers. Future research could usefully involve a greater number of participants with a wider range of characteristics. It would be interesting to include early career teachers who have a specific weakness, or greater difficulty or anxiety, in teaching mathematics than the teachers in this study and useful to explore the influence of the school context both for teachers working within other types of primary schools in England and for those within the educational systems of other countries. Including teachers from across a number of initial teacher education routes and providers would also facilitate study of the influence of the initial teacher education programme itself on the ongoing practice of the teachers.

10.5.4 *The influence of the Initial Teacher Education course – an area for further research*

The main focus of the study has been participants' perspectives on the influences on their evolving practice as teachers of mathematics during their first two years as qualified teachers. However, although not identified as a separate influence in the extended theoretical model presented in 9.6.3, the participants did indicate that the University of Leicester PGCE course teaching and content had some impact and this is now briefly discussed.

At the time these participants were taking the University of Leicester PGCE course, reflection was highly promoted as potentially making a very significant contribution to the development of a pre-service teacher. During the first week of the course, the participants were introduced to literature highlighting the value of reflective thinking and they discussed examples of reflective writing in teaching contexts. During their entire PGCE year, they wrote a weekly entry to a reflective log, receiving feedback from tutors to support the development of their reflective writing and to respond to issues raised in the content of the reflection. The participants also evaluated each lesson they taught and reflected on the development of their subject knowledge for teaching in specific subject areas.

Points raised by participants included the importance of the course for the development of conceptual understanding of mathematics (4.3) and that they had learnt of the importance of reflection through its emphasis on the course (6.5). The graphs of the participants' relationship with mathematics (Figures 4-1 to 4-8) show that the course was generally seen to be a positive influence.

Thus, whilst it was not considered appropriate to include the influence of the ITE course on teachers' ongoing practice as a separate element of the extended theoretical model, there is evidence to suggest that further, more specific and detailed research in this area would be beneficial.

10.5.5 ***The limitation of the researcher effect***

As a tutor on their course, I worked with the participants over their year as pre-service teachers before recruiting them as participants to this study at the end of the course. In my professional role I taught all the participants sessions about the teaching of primary mathematics and supported some of the participants more individually, for example with their reflective writing and their school placements. A consideration throughout the study was therefore my relationship with the participants.

Having known them previously as a tutor on their teaching course, I was aware that the participants might view me as more than just a researcher. Although this might mean they would want to make a good impression on me, it was not easy to determine the likely implications as pre-service teachers are used to openly discussing issues and challenges as well as positive developments in their practice with tutors. In making the transition to a researcher/participant relationship, I sought to build on the positive rapport already established with each participant, while setting renewed expectations for our relationship in the context of the research. This seemed to be successfully achieved and the eight participants all continued willingly through the two years of data collection with no benefit to themselves other than having a person external to their school context asking them questions that enabled them to reflect on their practice. In terms of ethical considerations, whilst there may therefore have been an impact on these teachers' practice as a result of taking part in the research, this was perceived positively and all considered that their participation was worthwhile.

10.6 Reflection on being a researcher

This thesis is the most extensive piece of research I have undertaken. I chose a focus that interested me as a tutor in initial teacher education and designed a study to explore the ongoing journey of my pre-service teachers into their early career as teachers of mathematics. Throughout the study, I have found the research interesting and thoroughly enjoyable as well as fascinating in terms of having access to the ongoing personal narratives of a varied group of eight teachers I previously knew. I have grown in knowledge of the field through my reading, my data collection and analysis and particularly through synthesising the literature with my data. My understanding of research methodology has developed through reading and experience. I have become both a more skilled interviewer, able to adapt my questioning in response to participant responses, and a more effective researcher through creatively exploring ways of enhancing the data and the participant experience.

My learning journey has also exposed me to the highs and lows of the researcher. The major challenge in this research was in finding appropriate data analysis methods. It was frustrating to have invested considerable time in coding to then realise that this was not a useful approach in my study, but this did lead to creative thinking, building on my instinctive visual approaches to organising and summarising data. Highs of the process not only included creating, implementing and reflecting on my innovative data collection techniques but also collecting genuinely interesting information from all eight participants, each of whom was a pleasure to work with. Although it was not possible to include detailed narratives of all eight in this thesis, I have a wealth of data that can be used in future papers and presentations and shared with future pre-service teachers.

10.7 Final thoughts

This thesis presents my journey through this longitudinal study. Along the way I have made methodological innovations to help me present evidence that all teachers of mathematics are on their own unique path in terms of their evolving practice. From a detailed analysis of the perspectives of eight early career teachers over a two-year period, I have been able to provide insight into the complexity and interaction of the factors related to their school context and factors related to the teachers themselves which influence this evolving practice. I have produced a new, more detailed, theoretical model to help understand the complexity and interactions.

I will now do what I can to ensure that my findings have a positive impact on the teaching, teacher education, mathematics education research and qualitative research communities.

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Appendices

Appendix 1 - National Curriculum in England Mathematics Programmes of Study: Key Stages 1 and 2 (2014)

Purpose of study

Mathematics is a creative and highly inter-connected discipline that has been developed over centuries, providing the solution to some of history's most intriguing problems. It is essential to everyday life, critical to science, technology and engineering, and necessary for financial literacy and most forms of employment. A high-quality mathematics education therefore provides a foundation for understanding the world, the ability to reason mathematically, an appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject.

Aims

The National Curriculum for mathematics aims to ensure that all pupils:

- become fluent in the fundamentals of mathematics, including through varied and frequent practice with increasingly complex problems over time, so that pupils develop conceptual understanding and the ability to recall and apply knowledge rapidly and accurately.

- reason mathematically by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language

- can solve problems by applying their mathematics to a variety of routine and nonroutine problems with increasing sophistication, including breaking down problems into a series of simpler steps and persevering in seeking solutions.

Appendix 2 - Meeting schedules

The meeting schedules for Cohort 1 are included below followed by a summary of adaptations for the schedules for Cohort 2.

***Meeting 1* Final week of the ITE course (June)**

Participants asked in advance to:

- bring the lesson plan and any other useful documentation about what they consider to have been their best maths lesson on their final teaching experience (TE3).
- bring a copy of any formal observations of their maths teaching on their final placement.

Participants informed in advanced that the interview discussion will focus on:

- Their mathematical background and how their relationship with mathematics has evolved.
- Their 'best' maths lesson – including why they chose this lesson, how it was planned, what were the essential and difficult points to teach in this topic.

Actual interview – approximately 1 hour

Preliminaries

- Are you happy that I record this interview?
- Huge thank you for participating.
- I asked you because you have done very well on the primary course and you have a job locally. I have asked two students with mathematical qualifications beyond GCSE and who did the mathematics specialism and two whose highest qualification is GCSE and who did not do the mathematics specialism.

Information: I am looking at how early career teachers develop as teachers of mathematics. This is my preliminary study and I will be analysing my methods and data from this year with a view to doing a larger scale study starting this time next year.

In this study I am very keen to have your particular views and find out about your experience. Please think of me now as a researcher, not as your tutor. My role is to explore ideas with you and certainly not to judge or assess you!

Ethics – I will store the data securely, ensure your confidentiality and you have the right to withdraw at any time. I will be writing to your headteachers next term to let them know about my project and asking for their permission to visit the school.

Reason for this interview

This is an initial interview so that I gain an understanding of your views about maths and the teaching of maths as you leave the PGCE course.

Question	**Resources, prompts**	**Time (max)**	**Links with reading**
Please talk me through what happened when and key moments in the history of your relationship with maths. Please have a go a mapping out your relationship with mathematics on this chart.	Graph of relationship with mathematics example and blank	15 mins	Di Martino and Zan (2010) Lewis (2013)
In your view what is mathematics?	• Some people believe that a lot of things in mathematics must be accepted as true and remembered and there really are no explanations for them. What do you think? • Some people think mathematics is abstract and therefore we need to help children to think abstractly. What do you think?	5 mins	Questions are from Cai (2007, p.268)

In your view what characteristics does an effective teacher of mathematics teacher have?		5 mins	
Tell me about your best maths lesson from TE3.	• Why did you choose this particular lesson? • How did you plan and prepare for this lesson? • What did you consider to be the essential concepts and knowledge in this topic? • What did you consider to be the most difficult concepts to children to learn in this topic?	15 mins	Questions informed by Makar (2014) and Cai and Wang (2009 p.278)
What are the most important ways you think you have developed as a teacher of mathematics during the PGCE course? What factors have influenced your development?	Ask for copies of their formal observation forms for teaching mathematics	5 mins	
What do you think are your next steps as a teachers of mathematics? How do you hope to achieve these?		5 mins	
<u>Discuss next steps</u> 1. Check school and year group and whether they will be teaching class/set and how many classes in the year group. 2. I will contact your headteachers near the start of next term to ask their permission to visit you in school and for you to share your professional development records and examples of children's work with me. I will be in contact with you near the end of the Autumn term to set a date for meeting with you in January. 3. Give next steps sheet (below) so that participants know what I would like them to consider before the next meeting.			

Maths research project – next stage (document given to participants at the end of Meeting 1)

1. Please keep a record of your professional development as a teacher of mathematics including, for example:

- Courses and staff meetings
- Your independent research about teaching mathematics e.g. subject knowledge preparation
- Observations and feedback on your teaching of mathematics
- Critical incidents and reflections on these – i.e. informal learning experiences for you about the teaching of mathematics

Please include information on date, content (e.g. of staff meeting), a summary of what you gained from it and impact e.g.

Date	**Professional Development**	**Summary**	**Impact on my teaching/children's learning**

You will be keeping this kind of record as an NQT anyway. There is no need for you to duplicate information, so it is fine if it is in a different format.

2. If you are involved in supporting anyone else with teaching maths, or have a role within school regarding mathematics, please note key aspects of this too.

3. I will contact your headteachers near the start of next term to ask their permission to visit you in school and for you to share your professional development records and examples of children's work with me. I will be in contact with you near the end of the Autumn term to set a date for meeting with you in January.

4. I will be asking about your best maths lesson to date with your NQT class, so please bear this in mind if you have a particularly good lesson. If you make a few notes about the lesson to help you recall it when you talk with me, and keep any resources, some examples of children's work etc that would be very helpful.

***Meeting 2* Approximately halfway through the first year as a qualified teacher (January or February)**

An email sent a couple of weeks in advance gave this information:

Please could you have with you:

- The lesson plan (and/or weekly plan) and any other useful documentation about what you consider to have been your best maths lesson so far as an NQT and similarly, your most challenging lesson/sequence of lessons. (e.g. examples of children's work, print out of a ppt used)
- Your record of your maths professional development.
- A copy of any formal observation feedback of your maths teaching so far as an NQT.
- Examples of children's work and assessments made to discuss the progress of your pupils.

The interview discussion will focus on:

- Your 'best' and most challenging maths lessons.
- Your beliefs about mathematics and what makes effective learning and teaching of the subject.
- How you feel you have developed as a teacher of mathematics since the start of your NQT year and what has influenced this.
- Your professional development opportunities in maths so far (This might include, for example, staff meetings, courses, your observations of others teaching maths, observations of you teaching maths, your subject knowledge preparation for teaching it, reflections etc.).
- Details of any role within the school regarding mathematics.
- What you feel are your next steps as teachers of mathematics.

Actual interview – approximately 1 hour

Preliminaries and Information As Meeting 1

Reason for this interview - The main purpose of this interview is to discuss your experience as a teacher of mathematics so far in your NQT year. Some of the questions are repeats of what I asked you in June.

Question	**Resources, prompts, follow up questions**	**Time (max)**	**Links with reading**
Establish year group taught, class/set for maths lessons			
Next 4 questions to be shown on cards for participant to choose order			
Tell me about your best maths lesson so far as an NQT.	• Why did you choose this particular lesson? • How did you plan and prepare for this lesson? • What did you consider to be the essential concepts and knowledge in this topic? • What did you consider to be the most difficult concepts to children to learn in this topic?	10 mins	Questions informed by Makar (2014) and Cai and Wang (2009, p.278)
How do you think your teaching of mathematics has evolved since the start of your NQT year?	What has influenced your development? Do you have any evidence of your development? (e.g. lesson observation feedback) What impact do you think your development as a teacher of mathematics has had on the children you teach?	5 mins	
Please talk me through your record of professional development in mathematics. (Courses, staff meetings, independent research, collaborative research, observations of other teachers, observations of your teaching, critical incidents)	What has been the impact on your teaching? Can you see evidence of impact on the children's learning? Which of these experiences would you particularly recommend to an NQT friend in another school? Why? What support have you had? Any collaborative practice?	10 mins	

	Have there been any barriers to your professional development in mathematics? Have you had any choices within this programme of CPD?		
Tell me about your most challenging maths lesson or sequence of lessons so far as an NQT.	• Why did you choose this particular lesson? • Why do you think you found it particularly challenging? • How did you plan and prepare for this lesson? • What did you consider to be the essential concepts and knowledge in this topic? • What did you consider to be the most difficult concepts to children to learn in this topic?	10 mins	Questions informed by Makar (2014) and Cai and Wang (2009, p.278)
The following questions to be asked in order:			
How would you define effective learning of mathematics?	How do you measure, assess or evaluate this for your children? (children's books, system of assessment etc)	5 mins	
In your view now what characteristics does an effective teacher of mathematics teacher have?	How has your thinking about this evolved since the start of your NQT year? What has influenced your thinking?	5 mins	
In your view what is mathematics?	Having taught many maths lesson now, has your thinking about what mathematics is changed at all?	5 mins	
Have you supported any other teacher with mathematics or shared your ideas and understanding of maths teaching with others?	What impact do you feel you have had on other teachers' teaching of mathematics?	5 mins	

Do you have any role within the school regarding mathematics?			
Here is your 'Me and mathematics' chart which you created in June. How has your relationship with mathematics continued since then?	• Graph of time against feelings from June • Can you explain why the trajectory has continued in this way?		Di Martino and Zan (2010) Lewis (2013)
What do you think are your next steps as a teacher of mathematics? How do you hope to achieve these?		5 mins	
Is there anything else that that you think would be useful for me to know about your development as a teacher of maths as an NQT that has not come out through my other questions?			

<u>Meeting 3</u> Near the end of the first year as a qualified teacher (June or July)

An email sent a couple of weeks in advance gave prior information, as previously. Preliminaries, information and reason for interview shared as previously. Questions with * below were asked in previous meetings and I have omitted their details in this chart.

Question	**Resources, prompts, follow up questions**	**Time (max)**	**Links with reading**
Have there been any changes to how you plan maths or how maths lessons are organised since I last saw you	**Know how maths was organised and planned previously**		
Next 5 questions shown on cards for participant to choose order			
Can you sketch me a graph of your year as a teacher of mathematics?	Graph blank.	5 mins	Di Martino and Zan (2010) Lewis (2013)
Tell me about your best maths lesson since we last met.*		10 mins	
What are the most important ways that you have developed as a teachers of mathematics in your NQT year?*	**May need to say what they mentioned last time**	5 mins	
Please talk me through your record of professional development in mathematics since we last met.*	**Take the documentation they gave me last time.**	10 mins	
Tell me about your most challenging maths lesson or sequence of lessons since we last met.*		10 mins	
The following questions to be asked in order:			

How would you order these in terms of how they best describe secure learning in mathematics? (Concept cartoon)	How do you measure, assess or evaluate learning for your children? (children's books, system of assessment etc)	5 mins	Question informed by literature around this
This time last year, you said effective teachers of mathematics …………Has your practice this year changed your beliefs about the characteristics of effective maths teachers?	**Be ready with what they said previously** What has influenced your thinking?	5 mins	
This is what you said about what mathematics is previously – can you add to this? Has your view change in any way?	**Be ready with what they said previously.** Having taught many maths lesson now, has your thinking about what mathematics is changed at all?	5 mins	
Have you supported any other teacher with mathematics or shared your ideas and understanding of maths teaching with others? Do you have any role within the school regarding mathematics?	What impact do you feel you have had on other teachers' teaching of mathematics?	5 mins	
What do you think are your next steps as a teacher of mathematics? How do you hope to achieve these?	What year group will you be teaching next year? Any other known changes as to how you will be planning or teaching maths?	5 mins	
Is there anything else that that you think would be useful for me to know about your development as a teacher of maths as an NQT that has not come out through my other questions?			

Meeting 4 *Approximately halfway through the second year as a qualified teacher (January or February)*

An email sent a couple of weeks in advance gave prior information, as previously. Preliminaries, information and reason for interview shared as previously. Questions with * below were asked in previous meetings and I have omitted their details in this chart.

Question	Resources, prompts, follow up questions	Time (max)	Links with reading
Last year *you were e.g. teaching your own class for maths alongside your Year 1 colleague and using the …. scheme as a basis for planning.* How are you planning and organising maths lessons this year? Have there been any changes?	**Know how maths was organised and planned previously**	5 mins	
Next 4 questions to be shown on cards for participant to choose order			
Tell me about your best maths lesson since we last met.*		5-10 mins	
What are the most important ways that you have developed as a teacher of mathematics in your second year of teaching?*	**May need to say what they mentioned last time. Take blank graphs in case these feel useful to include**	5-10 mins	
Please talk me through your record of professional development in mathematics/professional development opportunities since we last met. *	**Take the documentation they gave me last time.** Reflecting back on your teaching career so far, which professional development opportunities have you found have had the most impact on your teaching and the children's learning?	5-10 mins	
Tell me about your most challenging maths lesson or sequence of lessons since we last met.*		5-10 mins	

The following questions to be asked in order:			
On each of our previous interviews I have asked you about what you feel are the **characteristics of effective teachers of mathematics**. I have summarised your ideas on these cards. I'd like you to organise these for me on the chart, with those you now feel to be most important at the centre and those less important towards the edge. I have spare pieces of card if you would like to add any further points. I'd like you now to organise them according to what you feel are your strengths as a teacher of mathematics, with those characteristics you feel are your strongest at the centre.	**Need cards for each participant and a template for them to be sorted onto. Take photographs.** What are the most significant factors that have influenced your thinking? What are the most significant factors that have influenced your practice?	5 mins	
What do you understand by the term mastery in mathematics?	• How is mastery perceived in your school? • What has influenced your view? • How do you promote mastery in your classroom? • How do you measure, assess or evaluate mastery learning for your children? (children's books, system of assessment etc.)	5 mins	
I have cards with different ideas from researchers as to what aspects of **subject knowledge** a teacher may have for teaching mathematics. On the target board please could you put the three or four that you feel are your greatest strengths in subject knowledge in the	**Cards with types of maths subject knowledge on these. Take photographs** • Are there any of these that you think are particularly important for a teacher of primary maths?	5 mins	Shulman, (1987); Ball, Thames and Phelps,

centre, the three or four that you feel are next in strength for you in the yellow band and those that you feel you are least strong with in the blue section.	• Looking back to when you first started teaching, which of these do you feel you have made most progress with and why?		(2008) and Rowland *et al.*, 2008)
Have you supported any other teacher with mathematics or shared your ideas and understanding of maths teaching with others? Do you have any role within the school regarding mathematics?	What impact do you feel you have had on other teachers' teaching of mathematics?	5 mins	
What do you think are your next steps as a teacher of mathematics? How do you hope to achieve these?		5 mins	
Is there anything else that that you think would be useful for me to know about your development as a teacher of maths that has not come out through my other questions?			

Meeting 5 ***Near the end of the second year as a qualified teacher (June or July)***

An email sent a couple of weeks in advance gave prior information, as previously. Preliminaries, information and reason for interview shared as previously. Questions with * below were asked in previous meetings and I have omitted their details in this chart.

Question	Resources, prompts, follow up questions	Time (max)	Links with reading
When I came in January *you were e.g. teaching your own class for maths alongside your Year 1 colleague and using the …. scheme as a basis for planning.* Have there been any changes since January?	**Know how maths was organised and planned previously** E – ask particularly about the influence of SATs G – ask particularly about the impact of the scheme implementation	5 mins	
Next 5 questions to be shown on cards for participant to choose order			
Here are your two previous graphs about your relationship with mathematics. Today I'd like you to sketch me a graph of your relationship with mathematics as a teacher of mathematics through your second year.	**Graph blanks.** **Take their previous two graphs.**	5 mins	Di Martino and Zan (2010) Lewis (2013)
Please tell me about your best maths lesson since we last met.*		5 mins	
What are the most important ways that you have developed as a teacher of mathematics since we last met?*	**May need to say what they mentioned last time.**	5 mins	

Please talk me through your record of professional development in mathematics/professional development opportunities since we last met.*	**Take any documentation they gave me last time.** Reflecting back on your teaching career so far, which PD opportunities have you found have had the most impact on your teaching and the children's learning?	5 mins	
Please tell me about your most challenging maths lesson or sequence of lessons since we last met.*		5 mins	
The following questions to be asked in order:			
As it's my last visit, I would like to discuss your thoughts on the various influences there have been on you as a teacher of mathematics more widely than just the last 6 months. I've written some influences that are likely to be important for most teachers on these cards. I also have some circles of different sizes. I'd like you to think about which of these aspects are more significant for you than others and stick them on circles accordingly. Please summarise for me about how you think each of these influences has impacted on your progress as a teacher of mathematics to date. I've made the circles transparent so you can overlap	**Cards with labels and blank transparent circles of various sizes that they can put these on to show importance and how they overlap.** **Supplementary questions to try and include:** • How do you think having a strong maths background and taking maths as a specialism on the PGCE course has impacted on your teaching of the subject? • Has your attitude to maths itself changed at all over the last couple of years? • Do you enjoy teaching maths? Has your attitude to teaching it changed? • What are your beliefs about what makes a good mathematician? • Have you felt well supported by your school in these first 2 years of teaching? • How do you feel about changes imposed by your school? • What motivates you to develop your own practice?	10 mins	Question informed by my interpretation of a wide range of literature

them if you wish and tell me about links between them.			
On each of our previous interviews I have asked you about what you feel are the **characteristics of effective teachers of mathematics** and last time you arranged these on a target board for me (show this), with those you felt to be most important at the centre and those less important towards the edge. Looking at this again now, is there anything you would change or add to this? Last time you also arranged these by your current strengths. Is there anything you would change or add to this now?	**Take photographs from last time.** What are the most significant factors that have influenced your thinking? What are the most significant factors that have influenced your practice?	5 mins	
Last time you reflected on your next steps as a teacher of maths. What progress do you think you have made with these? What aspects of your teaching of maths would you like to develop further? How do you hope to achieve these?	**Have their next steps written out ready** What has impacted on your progress?	3 mins	
Have you supported any other teacher with mathematics or shared your ideas and understanding of maths teaching with others?	What impact do you feel you have had on other teachers' teaching of mathematics?	3 mins	

Do you have any role within the school regarding mathematics? Would you like to in the future?			
Do you think taking part in my research influenced your practice at all?	If so how?	3 mins	Consideration of panel conditioning effect (Bryman, 2012, p.65)
How well do you think the PGCE course prepared you for teaching mathematics?	Are there any changes that you would suggest to the course? Is there anything that would have supported your maths teaching further?	2 mins	
Is there anything else that that you think would be useful for me to know about your development as a teacher of maths?			

Cohort 2

The adaptations from the Cohort 1 meeting schedules are set out in the table below. No changes were made to Meeting 5.

Meeting 1	• Concept cartoon used to support discussion of views about the nature of mathematics and learning in mathematics. • Participants asked to prepare and talk about their most challenging mathematics lesson from their final placement as a student teacher.
Meeting 2	• "How would you describe effective learning of mathematics" changed to "How would you describe secure learning of a mathematical concept" to ensure participants talked about learning rather than teaching strategies. • Subject knowledge card sort activity included from Cohort 1 Meeting 4. • For those who had taken the Primary with Mathematics PGCE route: "How has the Primary with Maths route equipped you so far? Can you identify any specific impact so far of having been on this PGCE route"
Meeting 3	• Question asking how well supported they felt during their first year of teaching. • Concept cartoon question wording changed from 'secure learning' to 'successful learning' as some schools were using the word 'secure' for formal assessment. • Influence map activity included from Cohort 1 Meeting 5. Removed question about view of mathematics to allow time. • For those who had taken the Primary with Mathematics PGCE route: "I asked you last time about the impact the Primary with Maths course has had on you. You said….. Has there been any further impact on your development this year? If so, in what way?"
Meeting 4	• Reflection on subject knowledge card sort from Meeting 2 – showed participants a photo and asked whether they would change or add anything to this. • Asked mathematics specialists whether they consider themselves to be a specialist and why/why not.

Appendix 3 - Subject knowledge cards

These were used with participants at Meeting 4 (Cohort 1) and Meetings 2 and 4 (Cohort 2)

Aspect of subject knowledge	Description	Cards used with participants
Aspects of subject matter content knowledge (Shulman, 1987)	Knowledge of mathematical concepts and links between different mathematical concepts	Having a deep understanding yourself of mathematical concepts and structures, and also links between aspects of mathematics. Understanding goes beyond knowing what to do, but includes knowing why.
Common content knowledge (Ball, Thames and Phelps, 2008)	Mathematical knowledge to correctly solve the mathematics problems they need to teach.	Correctly being able to solve the mathematics problems you need to teach.
Specialised content knowledge (Ball, Thames and Phelps, 2008)	Mathematical knowledge that is specific to the teaching context e.g. • Working out where a pupil has gone wrong in a mathematical problem • Explaining procedures in such a way that children can understand why they work. • Being able to modify tasks to make them harder or easier.	Having the knowledge to work out where a pupil has gone wrong in a mathematical problem. Explaining mathematical procedures in such a way that children can understand why they work. Being able to adapt tasks to make them harder or easier.

	• Selecting mathematical representations for particular purposes. • Finding an example to make a mathematical point. • Considering what examples are appropriate for context.	Selecting appropriate mathematical representations/models/images/equipment for particular purposes.
Knowledge of content and students (Ball, Thames and Phelps, 2008)	Knowledge that combines knowing about pupils and knowing about mathematics e.g. anticipating what students are likely to think, what they will find easy, what they will find confusing, and which errors they are most likely to make.	Anticipating what pupils are likely to think, e.g. what they will find easy, what they will find confusing, and which errors they are most likely to make.
Knowledge of content and teaching (Ball, Thames and Phelps, 2008)	Knowledge that combines knowing about teaching and knowing about mathematics e.g. creating teaching/learning sequences, choosing progressive sequences of examples, and choosing representations, methods and procedures to teach mathematical concepts.	Creating progressive teaching/learning sequences. Choosing examples for teacher and pupil use.
Curricular content Knowledge (Shulman, 1987)	Knowledge of the maths curriculum e.g. programmes of study for their year, what is taught in previous or later years and what they are currently studying within other subjects.	Knowing the maths curriculum e.g. programmes of study for your year group.
Contingency (Rowland *et al.,* 2008)	Knowledge that enables the teacher to respond to unplanned, unexpected classroom events - responding to pupils' ideas and questions, and deviating from lesson plans in response to pupil's learning.	Responding appropriately (mathematically) to unplanned, unexpected questions and ideas from pupils.

Appendix 4 - Transcription extract from Gina’s Meeting 1

During this section, Gina is sketching a graph of her relationship with mathematics.

Interview	Comments
G: I think the earliest I can remember I was probably in the middle here when I was probably Year 6. Then I went into Year 9 and I was probably up here – that was the best I was at maths and I had a different teacher and I think being put in a top set meant that I had to perform at the same as everyone else and I was a bit of a smarty pants as well so everyone expected me to be good so I felt like I had to be.	Effect of setting and expectations
A: Right, yes	
G: Whereas when I was in Year 6 it was mixed ability and it didn’t really matter. Once you are in that, like I said there were 5 sets and I was in the top out of 5, so I really felt I needed to be … pushing, constantly. Then when I got to… I would say probably stayed quite high actually for GCSE over here but I had the, I could do the methods, but I didn’t understand them. So I could do maths and I got an A grade in Year 10 and it was all fine, it’s just, I didn’t have the understanding behind it because it was just rote. Then I just didn’t do any maths for about 9 years (laughing). No maths [written on the graph]. And then when I came back on the course I had to do the subject knowledge with you.	Expectations had an effect on her effort She emphasised these words (underlined) Recognises rote learning not conceptual understanding G did a pre-course tutorial with me as a condition of offer
A: Yes. That’s right, yes.	
G: And from that point I actually went and looked at maths and was like “actually I can do this” (laughing), I just haven’t done it for a long time. So I was probably back up here….. and now after teaching it I’d say I’m probably back to here again – quite high in terms of what I know about - well simple maths - but I understand maths again and that’s something now I’d say.	Regained confidence

A: Thank you, that's really interesting. At this point down here when you didn't do any maths, if anyone had asked you about your feelings towards maths, would they still have been positive feelings even though you hadn't actually done any for a while?	I'm referring to the graph. Useful follow up question!
G: Yes, because I think at the time people would have said to me that I have got younger siblings and they were doing GCSEs and things - "Oh Ginny, you're always good at maths" and I was like "Yeah, yeah I can do maths" but I hadn't done it, I hadn't tried it (laughing) so in my head I still could do it because I could do it five years ago but I hadn't used it so I think I probably thought I was quite good until I then looked back and was like no I wasn't cos all I was doing was tills, retail work, so that was the only experience of maths I had at the time.	Expectations of others affected her attitude to maths
A: That's really interesting, thank you very much for that, that's great….. This is a slightly different question: **In your view, what is mathematics?**	
G: Um, numbers and systems? Methods, …. I don't really know. I always think of maths as numbers. I always forget about the shape and corners, I always just think it's numbers, it's calculations, and that's the part I enjoy, so maybe that's why I think of it that way. But I don't ever look past it to… as soon as it got to sort of computing, I lost complete interest. No interest whatsoever with it anymore. So I guess I think of it as numbers, numbers, numbers.	No hesitation in starting her answer here. Limited view of what maths is – she does not seem to have thought of this question before, but reflective answer

Appendix 5 - Ethical approval and informed consent documents

Appendix 5a Ethical approval documents

University of Leicester

University Ethics Sub-Committee for Sociology; Politics and IR; Lifelong Learning; Criminology; Economics and the School of Education

05/06/2015

Ethics Reference: 1119-ag384-education

TO:

Name of Researcher Applicant: Alison Godfrey

Department: Education

Research Project Title: How do early career teachers develop as effective teachers of mathematics?

Dear Alison Godfrey,

RE: Ethics review of Research Study application

The University Ethics Sub-Committee for Sociology; Politics and IR; Lifelong Learning; Criminology; Economics and the School of Education has reviewed and discussed the above application.

1. Ethical opinion

The Sub-Committee grants ethical approval to the above research project on the basis described in the application form and supporting documentation, subject to the conditions specified below.

2. Summary of ethics review discussion

The Committee noted the following issues:

Thank your for your application and supply of requested amendments.

3. General conditions of the ethical approval

The ethics approval is subject to the following general conditions being met prior to the start of the project:

As the Principal Investigator, you are expected to deliver the research project in accordance with the University's policies and procedures, which includes the University's Research Code of Conduct and the University's Research Ethics Policy.

If relevant, management permission or approval (gate keeper role) must be obtained from host organisation prior to the start of the study at the site concerned.

4. Reporting requirements after ethical approval

You are expected to notify the Sub-Committee about:

- Significant amendments to the project
- Serious breaches of the protocol
- Annual progress reports
- Notifying the end of the study

5. Use of application information

Details from your ethics application will be stored on the University Ethics Online System. With your permission, the Sub-Committee may wish to use parts of the application in an anonymised format for training or sharing best practice. Please let me know if you do not want the application details to be used in this manner.

Best wishes for the success of this research project.

Yours sincerely,

Dr. Hillary Jones

Chair

University Ethics Sub-Committee for Sociology; Politics and IR; Lifelong Learning; Criminology; Economics and the School of Education

30/09/2015

Ethics Reference: 3056-ag384-education

TO:

Name of Researcher Applicant: Alison Godfrey

Department: Education

Research Project Title: How do early career teachers develop as effective teachers of mathematics? (second pilot stage)

Dear Alison Godfrey,

RE: Ethics review of Research Study application

The University Ethics Sub-Committee for Sociology; Politics and IR; Lifelong Learning; Criminology; Economics and the School of Education has reviewed and discussed the above application.

1. Ethical opinion

The Sub-Committee grants ethical approval to the above research project on the basis described in the application form and supporting documentation, subject to the conditions specified below.

2. Summary of ethics review discussion

The Committee noted the following issues:

This study is well thought out and full information provided in this application. We are therefore happy to approve it as described.

3. General conditions of the ethical approval

The ethics approval is subject to the following general conditions being met prior to the start of the project:

As the Principal Investigator, you are expected to deliver the research project in accordance with the University's policies and procedures, which includes the University's Research Code of Conduct and the University's Research Ethics Policy.

If relevant, management permission or approval (gate keeper role) must be obtained from host organisation prior to the start of the study at the site concerned.

4. Reporting requirements after ethical approval

You are expected to notify the Sub-Committee about:

- Significant amendments to the project
- Serious breaches of the protocol
- Annual progress reports
- Notifying the end of the study

5. Use of application information

Details from your ethics application will be stored on the University Ethics Online System. With your permission, the Sub-Committee may wish to use parts of the application in an anonymised format for training or sharing best practice. Please let me know if you do not want the application details to be used in this manner.

Best wishes for the success of this research project.

Yours sincerely,

Dr. Hillary Jones

Chair

University Ethics Sub-Committee for Sociology; Politics and IR; Lifelong Learning; Criminology; Economics and the School of Education

13/06/2016

Ethics Reference: 7452-ag384-education

TO:

Name of Researcher Applicant: Alison Godfrey

Department: Education

Research Project Title: How do early career teachers develop as effective teachers of mathematics?

Dear Alison Godfrey,

RE: Ethics review of Research Study application

The University Ethics Sub-Committee for Sociology; Politics and IR; Lifelong Learning; Criminology; Economics and the School of Education has reviewed and discussed the above application.

1. Ethical opinion

The Sub-Committee grants ethical approval to the above research project on the basis described in the application form and supporting documentation, subject to the conditions specified below.

2. Summary of ethics review discussion

The Committee noted the following issues:

Thank you for your application which is on order.

3. General conditions of the ethical approval

The ethics approval is subject to the following general conditions being met prior to the start of the project:

As the Principal Investigator, you are expected to deliver the research project in accordance with the University's policies and procedures, which includes the University's Research Code of Conduct and the University's Research Ethics Policy.

If relevant, management permission or approval (gate keeper role) must be obtained from host organisation prior to the start of the study at the site concerned.

4. Reporting requirements after ethical approval

You are expected to notify the Sub-Committee about:

- Significant amendments to the project
- Serious breaches of the protocol
- Annual progress reports
- Notifying the end of the study

5. Use of application information

Details from your ethics application will be stored on the University Ethics Online System. With your permission, the Sub-Committee may wish to use parts of the application in an anonymised format for training or sharing best practice. Please let me know if you do not want the application details to be used in this manner.

Best wishes for the success of this research project.

Yours sincerely,

Dr. Laura Brace

Chair

Appendix 5b Email script send to participants for Cohort 2 to invite them to take part in the study

Dear

I hope all is well with you and that you are enjoying the final weeks of TE3!

I am writing to ask whether you would be willing to take part in some research I am doing.

For my doctorate I am using a case study approach to explore how early career teachers develop as teachers of mathematics. The findings of my research will be helpful for future development of the Primary PGCE course at Leicester and, I hope, will inform other providers of initial teacher education, policy makers and the wider research community. This time last year I started a pilot study and I am now ready to commence my main study. I would like to follow some of the current PGCE students into the start of their teaching careers, with a focus on the teaching of primary mathematics.

I am therefore looking for some current PGCE students who have jobs locally to be part of the study and I would very much like you to be one of these.

If you are happy to take part, I would like to interview you at the end of this term and I will visit you in school to interview you again twice in your NQT year – likely in January and June - and twice in your second year of teaching. My data collection will come through interview discussion including discussion of some documentation e.g. planning for maths lessons and children's work. Each interview will be about an hour in length and there will be a small amount of preparation involved before we meet each time. I would be keen that you share with me a record of your on-going professional development for mathematics and ideally any observation feedback of your teaching of mathematics. You will be keeping records as an NQT anyway so I am not anticipating that this study will be onerous in any way for you. I will contact your headteacher having gained your official permission to let them know about the project and ask for their permission to visit you in school and for you to share your documentation with me.

I would like to assure you of the following:

- My work with you will be in my role as a researcher only. The research will not in any way affect your assessment for the PGCE course or the NQT assessment by your school.
- All data will be confidential and will be scored on a protected system.
- I will fully protect your anonymity within my writing and any presentations I give about my research. I will use pseudonyms in all my notes.

- You can decide not to give any specific data that I request and you have the right to withdraw from the project at any time without giving a reason.

I would be very grateful if you were willing to be part of my study. If you have any further questions or would like to discuss this by phone or in person, please let me know – I would be very happy to elaborate further.

If you are happy to take part, please respond to this email, completing the sentence below and I will be in touch again next week to arrange the interview.

Many thanks and best wishes

Alison

I, ………………………………………………….. (name), am willing participate in the research project outlined above.

I understand that I can withdraw from the project at any time by contacting Alison Godfrey.

Appendix 5c Letter to headteachers

UNIVERSITY OF LEICESTER

School of Education

To
Headteacher name
School address

1st October 2016

Dear

I am one of the PGCE tutors who worked last year with xxxx and I am writing to ask your permission to continue some research with xxxx as part of my PhD.

For my PhD I am using a case study approach to explore how early career teachers develop as teachers of mathematics. The findings of my research will be helpful for future development of the Primary PGCE course at Leicester and, I will I hope inform other providers of initial teacher education, policy makers and the wider research community.

Following a successful pilot study, I approached six of last year's PGCE cohort, including xxxx, to take part in the study. After explaining the study to them and gaining their permission, I interviewed them individually at the end of their PGCE year and I would like to visit each one twice during their NQT year and twice the following year – most likely in January and June. I am enclosing the email thread I have had with xxxx where she gives her consent to this.

For each visit I would like to interview xxxx and discuss some of her documentation e.g. planning for maths lessons and children's work. I would be keen for her to share with me a record of her on-going professional development for mathematics and ideally any observation feedback of her teaching of mathematics. I would like to take copies of the documents. Each interview will be about 45mins – 1 hour in length.

I have assured the participants of the following:

- My work with them will be in my role as a researcher only. The research will not in any way affect their assessment for the PGCE course or the NQT assessment by their school.
- All data will be confidential and will be scored on a protected system.

- I will fully protect their anonymity within my writing and any presentations I give about my research. I will use pseudonyms in all my notes.
- They can decide not to give any specific data that I request and they have the right to withdraw from the project at any time without giving a reason.

To ensure that I comply with the first two statements above my visit will be strictly as a researcher. I will therefore not be able to discuss the meetings I have with xxxx, or the documentation she provides, with yourself or with anyone else at the school.

I would be very grateful if you are able to agree to xxxx being part of my study. If so, please sign a copy of this letter (I have enclosed two copies so that you can keep one and return one) and return in the enclosed envelope, completing the sentence below, or email me to confirm.

If you have any questions or would like to discuss this further by phone or in person, please let me know.

Many thanks and best wishes

Alison Godfrey
Lecturer in Primary Mathematics

School of Education,
University of Leicester, University Road, Leicester, LE1 7RH.

I, ………………………………………………….. (headteacher) am willing to give Alison Godfrey access to my school and agree that the documentation outlined above can be shared with her to inform the research project outlined above.

Appendix 6 - A structural analysis of the impact of Gina's "disaster" lesson following Labov (1972) and Riessman (2008)

Abstract – A story of Gina's turbulent relationship with the teaching of mathematics during her NQT year.

Orientation – Gina needed prompting to be clear about the timescale and people involved in her narrative, but established approximate dates in the Spring and Summer terms, with the 'disaster' lesson happening in March. She had a series of mentors who observed mathematics lessons and gave formal feedback. She took opportunities to observe other teachers.

Complicating action – A "disaster" lesson observed by the mathematics subject leader, leading to a diagnosis of difficulties, loss of confidence and receiving of support.

Evaluation – Many negative emotional statements, for example:

> *Then disaster [….] I was really not very confident with it at all and it seemed that no matter what I was doing to change this I was still getting negative feedback and it was, really what's the word, disheartening. Really didn't enjoy that time, I was just thinking I can't do anything right, no matter what, I'm doing the things you asked me to do and I can't do any right here.*

> *There was a big period of time when I literally dreaded every single lesson, because you just think "What could happen? I don't know what I'm doing" and now it's just, it's your daily life, so it's strange, very strange.*

> *It's not too bad now – I feel better about maths now that we've done some data and assessments and they have learnt something, it's ok!*

This quote sums up her mixed emotions:

> *I didn't like it because I haven't really done badly […] throughout training […..] and I really hate to disappoint anyone but having a focus is always a good thing.*

<u>Resolution</u> – With support, Gina addressed the issues raised and regained confidence. With hindsight she began to see the intervention of others in her professional development as a positive experience.

<u>Coda</u> – There was a not one particular coda moment in the narrative, as Gina returned to the story more than once. She finished the final part of the narrative with:

> *So now it's just the final couple of weeks, last bit of time and that will be it, the summer, the summer.*

Appendix 7 - A functional analysis of the impact of Gina’s “disaster” lesson following Coffey and Atkinson (1996)

Colour coding:
Relationship with mathematics
Self-efficacy as a teacher of mathematics
Lack of control
Acceptance of support and the value seen in this
Feeling inexperienced and knowing she has more to learn
Impersonal way of talking about senior staff
Blaming her performance in one poor lesson as a major turning

Intended – Gina is answering my question about how she has developed as a teacher of mathematics during her NQT year and is open about the difficulties she has been through and the support she has been given.

Unintended – The story dominates the interview and she keeps returning to it, with rather repetitive reinforcement of points.

Implicit – Gina’s self-identity as a teacher of mathematics comes through.

(The phrases below are indicative of the phrases Gina used when telling her narrative and are matched to the transcript in Appendix 8)

Relationship with mathematics: *“I was getting more and more, I suppose, hating maths, hating teaching it”*

Self-efficacy as a teacher of mathematics: *“I wanted a little bit of an in between to say “but you’re good at that””*

Lack of control: *“I was just thinking I can’t do anything right, no matter what, I’m doing the things you asked me to do and I can’t do any right here”*.

Acceptance of support and the value seen in this: *"We sort of plateaued while we were having the feedback then I saw the benefit of it"*.

Willingness to change and wanting to do the right thing: *"I haven't really done badly sort of throughout training and things like that and I really hate to disappoint anyone"* [from elsewhere in the interview]

Feeling inexperienced and knowing she has more to learn: *"I'm just still very aware of the things I'm not so good at and yes starting the year again I feel like almost this year's been a trial run".*

Impersonal way of talking about senior staff: *"Your focus area is what they want to keep seeing how things are going".* It is also interesting to note that she does not mention the headteacher at all in her interview.

Blaming her performance in one poor lesson as a major turning point: *"It* [graph of her relationship with mathematics] *sort of came back up slightly, then and that was in the Spring. Then disaster"*

<u>Explicit</u> – Some specific points about what went wrong, but some lack of clarity. Philosophical about changes made, points of view of others and implications going forward.

Appendix 8 – Section of Gina's transcript from Meeting 2 linked to Coffey and Atkinson's (1996) functional analysis

Gina referred to the *"disaster"* lesson in several places within Meeting 2. This is the most concentrated part of this narrative, spoken while she was drawing her graph of her relationship with mathematics during her first year of teaching.

Colour coding:
Relationship with mathematics
Confidence as a teacher of mathematics
Lack of control
Acceptance of support and the value seen in this
Feeling inexperienced and knowing she has more to learn
Impersonal way of talking about senior staff
Blaming her performance in one poor lesson as a major turning

G: I feel like this was the start of the year. I'd say here was maybe Autumn 1 and towards Christmas I think, I don't know if everyone has this panic, but we were having "they're never going to get there" panic at this point. So that was sort of the end of Autumn 2. We changed some of the way that we were planning after that and it sort of came back up slightly, then and that was in the Spring. Then disaster, down here, I was really not very confident with it at all and it seemed that no matter what I was doing to change this I was still getting negative feedback and it was really, what's the word, disheartening. Really didn't enjoy that time, I was just thinking I can't do anything right, no matter what, I'm doing the things you asked me to do and I can't do any right here.

A: How often were you being observed?

G: Once every half term but like I said I had one extra in between, just because of the disaster observation and it was more I had no sense of how well it had gone and I didn't like that feeling. I was like I'd followed the plan and done what I was meant to have done but it just wasn't what anyone wanted. So here, that's Spring 1 and 2 border and it was just

A: Those observations were all maths were they?

G: Yes I think that was the thing I was getting more and more I suppose hating maths, hating teaching it, because at the start of the year I quite enjoyed teaching maths because it was much easier as a whole class in terms of their attainment and I was preferring it to the English and I'm levelling back out now but there was a point where I only wanted to teach English, I just thought I want to avoid that maths as much as I possibly can, it was awful.

A: Were you being observed teach other subjects as well or was it..

G: No, I think that was the thing. At the start of the year I had a maths observation and that was fine, then I had phonics and that was fine. Then I had maths that was fine, then I had an English, that was fine, and then I had solid maths for 3, 4 in a row and I was just thinking, it was almost like, every single time I felt like I was going to get negativity, so I was dreading observations. It just wasn't nice and I don't think it was anything that anyone was doing, it was just, I wanted a little bit of an in between to say "but you're good at that" almost, but obviously your focus area is what they want to keep seeing how things are going, and now I feel much better because I've had a positive one and I think someone else coming in, just a different view point was nice because I had a different mentor, she was observing me and pulling out different focus rather than looking for the things that were terrible the previous time I suppose. And having another English observation bolstered my confidence because I was like, "That went really well", so that was fine. So that was when it was the low point. To be honest it was probably lower than that actually, down here somewhere (laughs). And then my second observation was a lot better and I'd responded to the particular focuses I'd been given so that was a positive and since I've been having this feedback, as much as at the time I was thinking "ah, this is just more work", so we sort of plateaued while we were having the feedback, then I saw the benefit of it and it became less of an extensive thing, more of a, because it was ok, it was good, it was a "Yes, I agree with that, maybe just change that one lesson" rather than it being everything. And I would say I'm probably back to where I was at the beginning if anything (laughing) but I feel more like I know the curriculum and I can plan it much more quickly, much more efficiently, I'm just still very aware of the things I'm not so good at and yes starting the year again I feel like almost this year's been a trial run…

Appendix 9 – Penny's preparation notes from Meeting 5

Penny used the outline I gave participants by email (see Appendix 2) to structure her preparation notes.

Math's research: Thursday 4th July

Please could you have with you:

• The lesson plan (and/or weekly plan) and any other useful documentation about what you consider to have been your best maths lesson so far this academic year and similarly, your most challenging lesson/sequence of lessons. (E.g. examples of children's work, print out of a ppt used)

- Money
- Weight
- Chips and beans

• Your record of your maths professional development (if you are using one) or just be able to tell me about any professional development opportunities you have had in maths since I last saw you at the end of June and your thoughts on their impact.

- Printed off copy, please note from SLT the focus has been on English lesson study, questioning observation in English or topic, growth mind-set and reading.

• A copy of any formal observation feedback of your maths teaching since I last saw you.

- Only observation this summer term has been an English observation which was on Tuesday! Focus was reading.

• Examples of children's work and assessments made to discuss the progress of your pupils.

- Assessment for maths using twinkl number and place value for Term 4 and Term 6
- Use of TT statements for Spring and summer 1, 2 for progress and highlighting gaps
- Continued to update documents outlining expected outcome as at the end of KS1 and year 1, based on steps in Target tracker.
- Discussion with SLT to provide data about pupil progress and attainment from a course they had gone on, to highlight pupils for intervention.
- Updated folder for discussion about pupil progress for KS1 as at May 2017, using EYFS outcome against current attainment, to highlight intervention.
- Pupil progress meeting as at May for Year 2 and Year 2, to highlight intervention.
- Book: Top, middle and bottom and test paper
- Mastery check point from abacus in books.

The interview discussion, as previously, will focus on:

• Your 'best' and most challenging maths lessons

• Your evolving views about what makes effective learning and teaching of the subject, including the subject knowledge required by teachers.

- Understanding where they have come from and where they need to be ready for year 2 started using chips and beans for addition etc., rather than using cubes etc.

- *Absorbing the children in the key vocabulary and the process in different ways VAK for the children to find which works for them.*
- *Talking them through what you are doing, why, what should I do and why? How do I write that?*
- *Giving children different opportunities to explain their answers*

• *How you feel you have developed as a teacher of mathematics so far in your second year of teaching and what has influenced this.*

- *Growth mind set , school approach*
- *Asking a range of questions, agree and disagree, this is the answer what is the question, which is the odd one out etc.*
- *Giving children the opportunity to choose their work rather than give a set of questions to answer , I wanted a clearer understanding of what they think they understand and what they do understand. Introduced mild and spicy questions.*
  Opportunity to apply what they have learnt with a question to their partner.

• *Your professional development opportunities in maths since I last saw you (This might include, for example, staff meetings, courses, your observations of others teaching maths, observations of you teaching maths, your subject knowledge preparation for teaching it, reflections etc.)*

- *Reflecting on the children's answer from the staff meeting.*
- *looking at SEN and interventions.*

• *Details of any role within the school regarding mathematic*

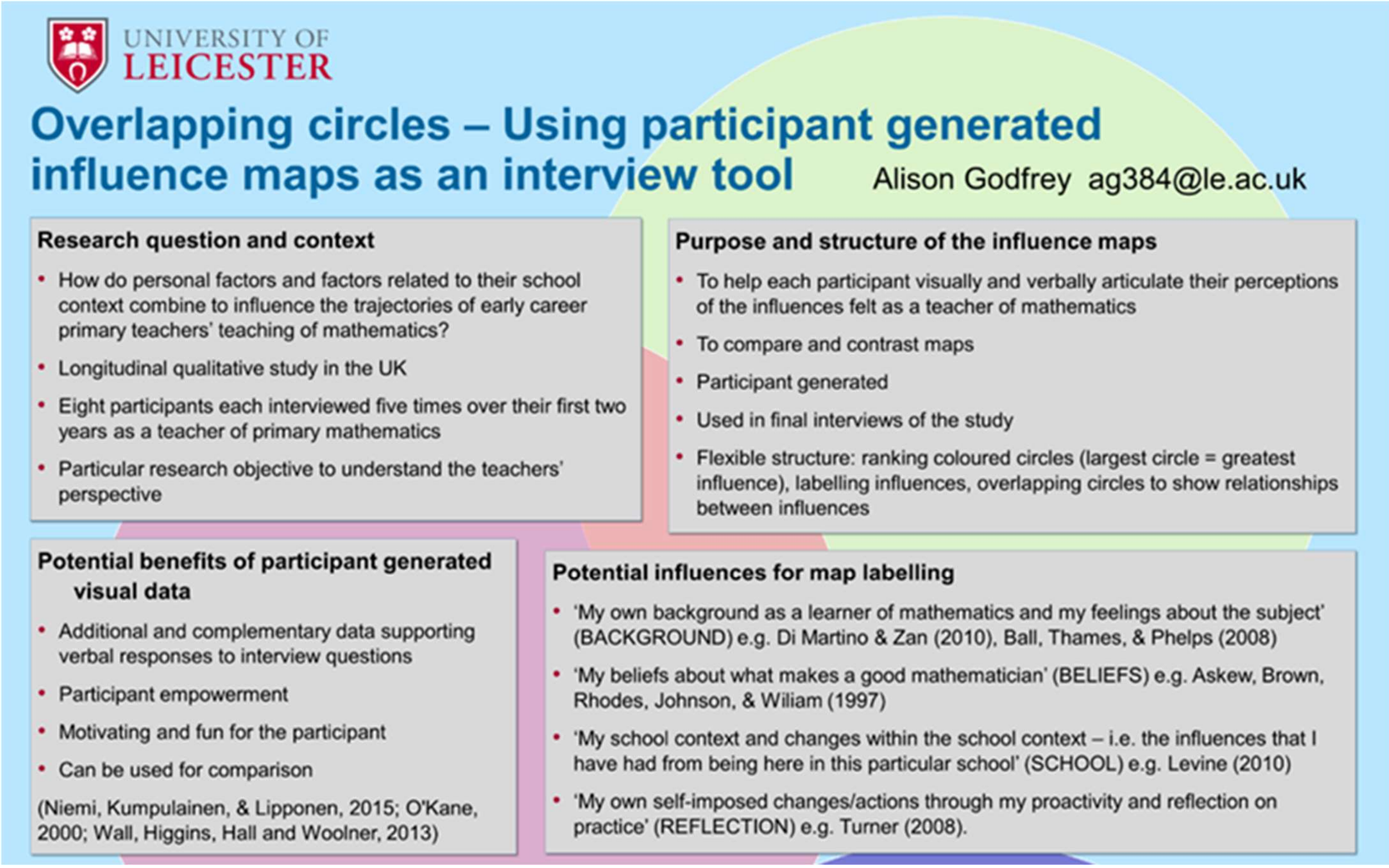
- *KS1 data on Target tracker including input of statements and steps and check.*
- *Continued discussions with SLT about KS1 data*
  - *About progress of children and highlighting children requiring intervention.*
  - *SLT had a meeting about raise on-line, I provided the data to take to the meeting and then following the meeting discussed the findings and applied to the school data. This highlighted the pupil progress based on EYFS attainment and end of KS1 attainment.*
- *Continued intervention groups with year 2 concentrating on place value and giving strategies for addition and subtraction.*
- *Delivery of KS1 Maths test and marking*
- *Outlining intervention for September for whole school for maths.*

• *What you feel are your next steps as a teacher of mathematics*

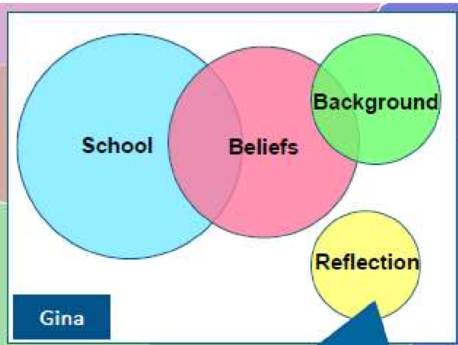
- *List of success criteria in the book (currently on the board)*
- *Deliver year 2 maths for the whole year group…SATS*
- *More outdoor learning for maths*
- *Continue to develop the format of the maths lessons team teaching.*
- *Monitoring of intervention groups*
- *Support teachers with Year 1 maths.*

Appendix 10 – Poster (Godfrey, 2018)

Presented at the 42nd Annual Conference of the International Group for the Psychology of Mathematics Education (PME42)

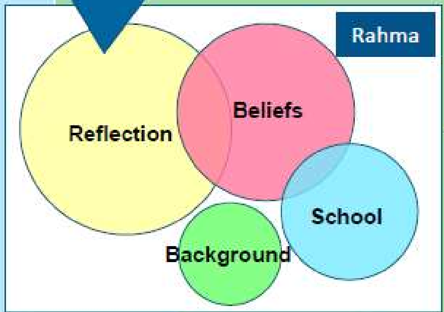


"I always like to reflect on my lessons and try to make it better. I always try and think was it right for my children, was it not, let's change it a little bit. This ['Reflection'] goes with this ['Beliefs'] – because I have really strong thoughts of what makes a good mathematician and how it should be taught in a lesson and what I want to get out of the children - that's helped me to reflect."



"The course was brilliant – just gave you that impetus to carry on, gave you ideas to do, spot on."

"I relooked at everything after your last visit."



"My own self-imposed changes are probably the least because there's been so many other things that have to be put in place that I've had to just go by the wayside with those."

Rakesh: "That was a really good opportunity for me to reflect on what different things have influenced me and how I feel like I've progressed based on different elements."

Findings

Using influence maps as an interview tool provides:

- Depth (e.g. Rahma discussed the connection between her largest two influences)
- Breadth (e.g. Gina talked about an influence she might not otherwise have mentioned)
- Participant empowerment (e.g. Penny added additional circles – 'Courses' refers to professional development courses; 'Research' refers to taking part in my study)

Motivation and interest e.g. Rakesh's reflection

Conclusions

- Deeper and broader responses, giving richer data than using conventional interviewing techniques alone, whilst interesting and motivating for participants
- New insights as to how early career teachers see the influences on their development as teachers of mathematics
- Evidence of how visual data can enhance qualitative research

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