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Girls' perceptions of mathematics: an interpretive study of girls' mathematical identities

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Declaration of original authorship

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abstract

This thesis explores girls' perceptions of mathematics and how they make sense of their mathematical identity. It seeks to understand the characterisations girls make of mathematics and mathematicians, shedding light upon their positioning as mathematicians. This is important because there remains a tendency for able females to rate themselves lower than males of a similar attainment, and be less likely to continue into post-compulsory study of mathematics.

This research followed an interpretive paradigm, taking a grounded, case-based approach and using a mosaic of qualitative methods. Fourteen girls from a school in the south-east of England aged 8-9 at the start of the study took part in the research over 15 months. The data collected comprised scrapbooks, concept maps, relationship wheels, drawings, digital photographs, metaphors, group and individual interviews. Data were analysed using open and focused coding, sensitising concepts and constant comparison to arrive at key categories and themes.

The main conclusions of the study are that time taken to explore the diversity of girls' perceptions of themselves as mathematicians provides a powerful insight into their identity formation. Many girls struggled to articulate the purpose of mathematics dominant in their vision of what it meant to be a mathematician. Whilst they recognised a rich variety of authentic mathematical activity at home, this was overwhelmed by number, calculation, speed and processes, with mathematics recognised as desk-bound and isolating. They made sense of their mathematical identity through their characterisations of mathematics alongside interactions and comparisons with others. The girls in the study took a high degree of responsibility for their own development, believing they could improve with ever-greater effort. However, this led to the need for a buffer zone, allowing teachers, family and friends to support the individual in continuing to grow and protecting them from mathematical harm.

This research recommends the provision of safe spaces for mathematical exploration in terms of time, space and collaboration, connecting mathematical study with application and interest, reframing mathematics as a social endeavour and sharing responsibility with girls for their mathematical development. Finally, it suggests the value of practitioners paying close attention to girls' evolving mathematical identities.

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1 Introduction

'I can't do maths!'

So declared one of my colleagues, with an unshakeable belief that mathematics was not for her. How could a capable, articulate, well-educated individual who uses many aspects of mathematics constantly as part of her day-to-day role hold such a deep-seated belief? Where did this idea come from, and how did it become such a core part of her identity? These questions provide the backdrop to the aim of this study, to investigate girls' perceptions of mathematics and how they make sense of their mathematical identity.

Mathematics has long been discussed as a subject in relation to which people have strongly held views, about themselves as mathematicians, their experiences of learning mathematics and the role they do or do not want it to play in their present and future lives. Boaler states: 'Maths, more than any other subject, has the power to crush children's confidence, and to deter them from learning important methods and tools for many years to come' (2009, p. 1). Whilst this is more an assertion to generate debate than an empirically-based statement, the fact that it is frequently cited and in my professional experience causes much nodding of heads suggests that for some, at least, it resonates. In drawing attention to implications for the future, it also hints at a concern that provides the catalyst for this study, that of the potential longer-term effects of children leaving compulsory education without a belief in themselves as mathematicians or at least someone who can do mathematics. Studying students' intentions to continue with mathematical study, Sheldrake, Mujtaba, and Reiss (2015) recently reported on the importance of students' self-beliefs of their subject-specific self-concepts for their attainment and subject choices: girls of a similar ability were found to be both more under-confident in their self-belief, and report lower levels of intention to study mathematics into A-level or beyond, than their male peers, a result confirmed by Smith (2014) in reviewing a wide range of research evidence.

Taking a social learning perspective, learning can be seen as involving identity development rather than simply gaining knowledge (Wenger, 2000). As such, it appears the impact of failing to develop a positive identity as a mathematician can outlast the immediate learning of mathematics that does or does not take place in the primary school. Identity is used as the key construct within this study due to its role as a connective construct, recognising both how 'individuals know and name themselves' and how they are 'recognized and looked upon by others' (Grootenboer, Lowrie, & Smith, 2006, p. 612). Mathematical identity is therefore taken in this thesis as meaning the extent to which an individual recognises themselves and is recognised by others as being a mathematician, with the emphasis within this study being placed on the first of these two ideas. Defining a mathematician is by no means straightforward, and depends upon debates about the nature of mathematics itself set out in Chapter 2. Going back to first principles, being a mathematician could be seen as being someone who can logic and intuit, analyse, construct and generalise, as based on the opening paragraph of Courant and Robbins' (1941) seminal text. For this study it is simply seen as being someone who recognises themselves as being able to do or good at mathematics as they define it.

Generally in national and international terms, gender gaps in mathematics, particularly at average attainment levels, have either declined, evened out or in some cases reversed. In the latest round of international comparison statistics produced by the Organisation for Economic Co-operation and Development (OECD, 2013), girls underperformed boys in 37 of 65 countries. Differences remain at the higher ends of the attainment range, with most able girls lagging behind most able boys (Ganley et al., 2013; OECD, 2013), and also in terms of proportion of girls going on to high-level study, even when they attain in line with their male counterparts . For example, in 2015, 45% of boys in England attained the higher levels in their end of primary school tests, level 5 and above, in comparison with 37% of girls (DfE, 2015c). Basing their statement on the fact that there are greater differences in attainment within than between genders, the authors of the OECD report suggest that gender differences must be acquired and reinforced through social pressures rather than inherent to the genders themselves, and that educators therefore need to explore how the experience of mathematics might be adapted to bolster girls' beliefs in their own mathematical abilities, so as to set the foundations early on for later take up of mathematics. The argument of this thesis is that in order ultimately to work towards improving mathematical identity, engagement and attainment for girls, we first need to understand it in terms that utilise their voice, are readily accessible to practitioners, and reveal some of the factors informing that evolving identity.

1.1 Personal and professional background

My interest in the area of gender and mathematical identity stems from both my present position and my professional background. I am currently, amongst other roles, a mathematics tutor on a range of post-graduate initial teacher training programmes. This brings me into contact with many trainees who have such a strongly-held belief that they are not mathematical that the first term of the programme sometimes seems closer to therapy than to targeted input on subject, pedagogical and curricular knowledge of mathematics for teaching. I have to address their willingness to engage in mathematics and ability to be positive about its study before I can hope to support them in learning to teach it and inspire the children in their care. If one of the challenges for mathematics educators is not only enabling their charges to know more and be able to do more with their mathematics, but to have a greater affinity for mathematics itself (Allen, 2011), then as the mathematics tutor of future teachers I need to work on two levels, and understand factors that might not only affect their own mathematical identities but help them in coming to understand these factors in children.

As I began to read around the topic and uncovered phrases such as ‘maths and me is like oil and water’ (Hobden & Mitchell, 2011, p. 39) in research relating to pre-service teachers, it became clear that my experiences as a teacher-trainer were by no means unique. It is also an unavoidable fact that the majority of recruits to initial teacher training programmes are female (70.2% of postgraduates and 83.2% of undergraduates in 2013-2014 (DfE, 2015a)), and from professional experience men on the programme were less likely to present as disengaged from, anxious about or ambivalent about mathematics than women. My previous career, building on primary teaching, was as a regional and national adviser for the Primary National Strategy, an arms-length organisation working on behalf of the Department for Education and its predecessors. Within this role I visited many, many schools, and was struck by how frequently gender and the underperformance of able girls in terms of progress showed up within their data but was under-discussed and investigated. Within that role I handled national and regional statistics on a daily basis but did not have the opportunity to delve under the surface of those statistics and explore why, for example, some middle and high-attaining girls at the age of 7 did not go on to match the progress of their male counterparts at 11 and beyond. These direct professional experiences led me to want to investigate the factors underpinning these mathematical identities further, and this thesis is the outcome of those investigations.

1.2 Introduction to the context for the study

Much as I am currently employed to work with adults, my primary interest is in helping the mathematical learning and engagement of primary-aged children. Combined with the knowledge that beliefs about mathematics can often become entrenched by the end of primary school (Kelly, 2004; McDonough & Sullivan, 2014), this age-range formed the natural focus for the study. It was set in the context of a primary school, historically successful in the teaching of mathematics but less so in outcomes relating to girls and mathematics, and concerned about the trend of middle- and high-attaining females lacking in confidence in their mathematical ability and making less progress in mathematics than their male peers. This school is located in the south-east of England, a region with overall mathematics attainment at the national level in 2015 but a slightly higher gender gap in higher attaining children favouring boys (a gap of 9 percentage points as opposed to 8 percentage points nationally at level 5 and above (DfE, 2015c)).

The study took place at an interesting time in primary mathematics education in England. At the onset of data collection, schools were beginning to work through the introduction of a new National Curriculum aimed at raising the mathematical attainment of children in England (Gove, 2013). At its close, the group of girls in the study were about to become the first cohort assessed against this new curriculum under the new testing arrangements (DfE, 2015b). This made it a particularly important time to look behind the statistics of international, national and local performance and the rhetoric surrounding the introduction of a new curriculum and examine the formation of mathematical identity as lived by individuals. Interestingly the data cited above regarding the gender gap at the top levels of attainment represent a 4 percentage points increase from 2014 to 2015 (DfE, 2015c), suggesting an urgency to exploring why gender differences for able girls might persist despite much effort and investigation.

1.3 Overview of the research

In order to investigate the sense girls make of their mathematical identities this study explored the perceptions of mathematics and mathematicians alongside factors related to positioning as a mathematician for a particular group of girls in a particular primary school. It sought to give a voice to girls by placing them front and centre of the methodology; the aim throughout was to cast them as active participants in data collection, presenting data in such a way that their voice came through, at times through the medium of drawing, collecting artefacts and digital photography and direct use of their verbal data. Identities are recognised as complex, multiple, social and fluent (Gee, 2001; Thomson & Hall, 2008) and mathematical identity as an under-utilised construct in mathematics education research (Cobb, 2004): this led to multiple data collection methods to mirror the complexity of the construct under investigation. Although divisions between these perspectives can be seen as arbitrary (Grootenboer et al., 2006), there are generally three influential views of identity: psychological/developmental, socio-cultural and post-structural. With its emphasis on the relational self, constructed and situated formation and socio-cultural reproduction and framing, the socio-cultural perspective within a social-constructivist paradigm forms the conceptual framework for this study.

Exploring the role of children as active participants rather than purely the objects of adult-led research has become more of a focus for social science research methods over recent years. From an international perspective, this is in large part related to the United Nations Convention on the Rights of the Child (UNCRC) (Smith, 2011; United Nations, 1989), ratified in the United Kingdom in 1991 (DfE, 2012). Enshrined within articles 12 and 13 of this convention is the right for children to be not only informed about, but also participate within and express their views about decisions that affect their lives. Although this right to be listened to is now increasingly recognised by educators, listening to and recording children’s perspectives on their learning is not typical or common practice in the United Kingdom (Morgan, 2007). Much of the existing research on attitudes towards, perceptions of, and anxieties about mathematics has been either aimed at adults or adolescents or had the feeling of researching 'on' children from an adult perspective (Borthwick, 2011; Smith, 2004; Walls, 2007).

This study adds to the body of research addressing that gap by gathering rich, situated data through a grounded, interpretive case-based approach to shed light on the perspectives of a specific group of girls on mathematics and themselves as mathematicians, and therefore adds to our understanding of factors relating to mathematical identity in relation to conceptions of mathematics and the role of other people. In addition it provides insight into how diversity in girls' mathematics identities and perceptions might be explored.

1.4 Structure of the thesis

This thesis is organised into the following chapters. Chapter 2 reviews the literature underpinning this exploration of mathematical identity. It establishes different perspectives on the importance and nature of mathematics and mathematical study, before exploring mathematics as a social construct. It goes on to consider issues relating to gender and mathematics, before relating these to affective factors in mathematics learning and identity: self-concept and self-efficacy, mathematical resilience, identity and anxiety. It defines key terms, and concludes by setting out the research questions arising from consideration of the literature.

Chapter 3 sets out the methodological approach taken to explore the research questions. The choice of a mosaic of chiefly qualitative approaches (Clark & Moss, 2011) to gain girls' perspectives on factors contributing to their mathematical identity was a key feature of this thesis. Alongside outlining the underpinning epistemological and ontological assumptions and the contribution made by a brief pilot to the research methods, Chapter 3 sets out the data collection and analysis methods in detail.

Chapters 4, 5 and 6 present and discuss the findings of the research, following key themes arising from the analysis of data and addressing the research questions. Chapter 4 (Brussel sprouts and the 'jagoth': characterising mathematics), sets out how the girls in the study characterised mathematics as a subject, drawing out consequences of these characterisations for their own mathematical identities. Chapter 5 (Collaboration, comparison, isolation: the role of significant others in forming a mathematical identity) reports on the feedback that girls received explicitly and implicitly from others, the judgements they consequently made about their own ability, and the world of doing mathematics with or without others. Chapter 6 (It's all down to me: becoming and being 'a mathematician') builds on the previous chapters to present and discuss findings on others and themselves as mathematicians, gendered beliefs about mathematics and issues around resilience and ownership.

Chapter 7 draws together themes from the three preceding chapters into a discussion of key findings in relation to the research questions and implications for practice, proposing a conceptual model encapsulating some of the pressures and buffering factors within the evolving mathematical identity of girls. Finally I conclude the thesis in Chapter 8 by summarising the findings, reflecting upon methodological limitations of the research and impact on my professional practice, and suggesting possibilities for further research.

2 Literature Review

The purpose of this study is to explore girls' relationships with mathematics, their characterisations of the subject and how they construct and make sense of their mathematical identity, framing findings in terms that might support educators. There is a vast amount of literature addressing both the assumptions underlying this stated aim and the background to it, and reviewing this literature forms the focus of this chapter. Gender is addressed both within relevant sections and given its own focus towards the end of the chapter. After setting out the current context in terms of mathematics teaching and learning, the chapter explores a range of features arising from the social constructivist perspective of mathematics learning. It then summarises some of the key debates around gender and mathematics, before examining affective factors including self-concept, resilience and identity and identifying gaps in current understanding.

2.1 Setting the context

This first section of the literature review aims to understand the different perspectives on the nature and importance of mathematics, the curriculum which forms a backdrop to children's mathematical education, and the current picture of mathematical attainment.

2.1.1 Why does mathematics matter?

Being able to draw confidently on mathematical skills, knowledge and understanding within our daily lives is perhaps more important now than it has ever been. As the philosopher of mathematics education Ernest argues, 'Today, virtually all human activities and institutions are conceptualised, regulated and communicated numerically, including sport, popular media, health…' (Ernest, 2002, para. 32). The importance of mathematics is woven throughout and across arenas and careers, from health care, interpreting data in the media and personal finance through to occupations involving estimating, pattern spotting and proportional reasoning (Allen, 2011; Hennessey, Highley, & Chesnut, 2012). This assertion provides a modern-day equivalent of the starting point of the seminal Cockcroft report (1982), that living without mathematics was virtually impossible in the twentieth century. More recently, an international perspective was provided by the Programme for International Student Assessment (PISA), carried out by the Organisation for Economic Co-operation and Development (OECD), stating the negative impact of poor mathematics skills upon people's access to better-paying jobs and the resultant link between distribution of mathematics skills and wealth-sharing between nations: '… people with strong skills in mathematics are also more likely to volunteer, see themselves as actors in rather than as objects of political processes, and are even more likely to trust others' (OECD, 2013, p. 6).

The importance of mathematics and its role within the school curriculum has been the focus of numerous reports focusing on English education over the past decades, both those commissioned by the governments of the day (Cockcroft, 1982; Smith, 2004; Williams, 2008) and by independent societies or political parties in opposition (The Royal Society, 2010; Vorderman, Porkess, Budd, Dunne, & Rahman-Hart, 2011). Despite the disparate agendas and foci of these reports, a common theme is the importance of mathematics both as a subject in its own right and as a tool for economic well-being, international competitiveness and logical thinking (e.g.Vorderman et al., 2011).

In addition to the benefits of its intrinsic characteristics, mathematics can be empowering simply through being seen as socially valuable, as a gatekeeper to success within and beyond education or a marker of intellect (Jorgensen, Gates, & Roper, 2013; Pais, 2011). The corollary is also true, with the danger of reinforcing social inequality for those unable, or perceived as unable, to cope with mathematical ideas (Epstein, Mendick, & Moreau, 2010). For women, the effects of low levels of numeracy are even more marked than for men; even for those with competent levels of literacy, low levels of numeracy are associated with higher levels of depression and poor physical health, being out of the labour market and feeling a lack of control of their lives (Parsons & Bynner, 2005).

Beyond secondary-school qualifications, lack of take-up of mathematically-based subjects and careers, in particular by women, remains a persistent issue across many Western cultures, despite reports across the literature that the gender gap in attainment is small and decreasing (Boaler, Altendorff, and Kent (2011); Huebner, 2009; McCormack, 2014; Piatek-Jimenez, 2008; Sheldrake et al., 2015).

2.1.2 Mathematics attainment – the national and international context

An accurate picture of attainment in mathematics in the United Kingdom remains not only difficult to pinpoint but controversial. In 2015, Department for Education's (DfE) provisional figures show the proportion of children in England attaining a National Curriculum level 4 or above in their final year of primary schooling as assessed by Statutory Assessment Tests (SATs) was 87% (DfE, 2015c), at its highest ever level. This level of attainment was deemed significant at the time, representing expected attainment for children exiting primary school. The headline figure masks variation in performance between children with different ethnic and socio-economic backgrounds and gender. Whilst the attainment of boys and girls at level 4 was similar, in 2014 boys outperformed girls at the higher levels in 2014 by four percentage points, with 44% of boys achieving level 5 or above compared to 40% of girls (DfE, 2014a). In 2015 this gender gap had risen to 8 percentage points (DfE, 2015c).

The relatively positive picture painted by these domestic figures differs markedly from the dialogue surrounding the latest PISA international comparison statistics (OECD, 2013). The result amongst 15 year-olds of the United Kingdom being ranked 26th for mathematics was vilified in the press, for example Gye (2013), with little attention given to the fact that this was in fact an improvement of two places from the previous round of data collection in 2009. In terms of gender, the PISA 2012 results showed that 'Girls in the United Kingdom do not enjoy mathematics, are anxious when asked to solve mathematical problems, and underperform compared with boys' (OECD, 2014c, p. 1), and the gender gap in attainment was found to be similar to the OECD average. A further example is the gender-related difference in the rates of high achievers going on to further study (in 2005/6 for example, 80% of males with A* at GCSE went on to study A-level mathematics as a subject, but only 64% of females (Boaler et al., 2011)). Bringing this data up to date, approximately three times as many boys as girls entered for further mathematics A-level in 2012-2013 (Smith, 2014). Such statistics lead Boaler et al to conclude that 'a very clear picture emerges showing the strong performance of young women, with low levels of participation at advanced levels' (p. 464).

However well school-leavers are doing in mathematics, their understanding and ability to apply their skills is seen as problematic by UK employers. In 2011, 15% of employers in the UK provided remedial training for numeracy (CBI, 2011), seeing their young employees' numeracy skills as inadequate. By 2013, the survey was reporting that whilst businesses perceive an improvement in information technology and literacy skills, numeracy continued to cause concern (CBI, 2013).

2.1.3 The nature of mathematics

At its best, mathematics is a rewarding, compelling and powerful subject. In the words of mathematician Marcus du Sautoy in an interview reported online, 'Mathematics has beauty and romance. It's not a boring place to be, the mathematical world. It's an extraordinary place; it's worth spending time there' (Gold, 2006). Unfortunately this mathematical world is not always recognisable either in portrayals of mathematics in society or the experiences of children in school. The mathematics educationalist Alan Schoenfeld believes that students separate school mathematics from the creative, discovery-oriented discipline of abstract mathematics which it is out of their reach to experience (Schoenfeld, 1989) in their day-to-day mathematics lessons.

Understanding mathematics as a dynamic, evolving entity with which children can form a relationship and therefore identify rather than as a static body of knowledge is a key starting point for this thesis. Stemhagen (2011) conceptualises mathematical philosophy as falling roughly into two categories: absolutism and constructivism. The first of these focuses on mathematics as 'certain, permanent, and independent of human activity' (Stemhagen, 2011, p. 2), the second being more interested in how humans create their own mathematical understanding. Differing views of the nature of mathematics position the subject varyingly as beautiful, pure and reliable or ‘cold, hard and inhuman’ (Ernest, 2014, p. 5), with the latter tied for most people to an absolutist, separated model of mathematics.

The absolutist model of mathematics as universal truth taught through mathematical training is contrasted by Bishop with mathematics as cultural history, best taught through education and incorporating the values of the time, culture and context (Bishop, 1988). Denying this cultural context leads to ‘…the meaninglessness, the rote-learning syndrome, the general attitude of irrelevance and purposelessness,’ (Bishop, 1988, p. 188). A narrow definition of mathematics can be linked with the limited numbers of the population judged, or judging themselves, to have attained mathematical proficiency (Boaler, 2002), and also with cultural values such as rigour, logic and abstraction historically ascribed to masculinity (Harris, 1997). An emphasis on doing, as opposed to learning, mathematics, with a shift towards mathematicians as connection makers and away from performers on tests of knowledge or procedures is seen by Boaler as both important and under-researched, and the same theme is echoed by Mendick (2005) in suggesting that moving away from mathematics equating to a search for a single correct answer to seeing the subject as one of collaborative exploration would be particularly beneficial for the majority of girls.

An alternative to Stemhagen’s two-way conceptualisation of the philosophy of mathematics was suggested by Allen, proposing a move towards democratic mathematics education with a resulting focus on pupil voice, equal participation, collaboration and inclusion (Allen, 2011). Such a model of mathematics education would mean fostering a more collaborative classroom culture with a more prominent role for the students themselves, attempting to move beyond the cycle of teachers recreating the traditional, transmission-based experiences they themselves received. In response to this literature this study aims to contribute to knowledge through exploring how girls experience mathematics, for example in the emphasis they place upon individual accomplishment as opposed to working with others.

Whilst the skills, knowledge and understanding developed by a confident mathematician can be seen as linking increasingly with business and art, no longer residing solely within the world of science and academia (Pinxten & Francois, 2011), this is not necessarily reflected in children and young people’s perceptions of the nature of mathematics. One of the purposes of this study is to discover how girls in the 21st century perceive mathematics, for example whether this will contrast with the findings of Isaacson researching women engaging on a mathematics re-entry programme in the late 1980s, that none of the women had any experiences whilst at school that suggested to them that imagination or creative ability might be used within mathematics (Isaacson, 1990). Adopting a view of mathematics as contingent and created by people rather than independent and observed provides opportunities to explore relationships such as those between the social construction of mathematics identity and gender (McCormack, 2014).

Perceptions of the nature of mathematics are, at least in part, established by the mathematics curriculum and its teaching as experienced by children, in addition to the cultural and home factors explored below. One suggestion is that the commonly-found patterns of interaction around mathematics in school lead girls to see mathematics as a masculine enterprise, with girls preferring 'deep, connected interactions with subjects' and being put off by rote learning (Boaler et al., 2011, p. 473). As Atweh and Cooper (1995) wrote almost twenty years ago, 'if girls and women are not participating as much as boys and men, the possibility arises that the problem may be in the type of mathematics that is dominant in society rather than in the learner themselves' (p. 296).

This section suggests that my study should explore not only how girls recognise and define mathematics as a subject and whether they perceive mathematics to be democratic and collaborative or transmission-oriented and absolute, but the implications of these beliefs for their own self-characterisations as mathematicians. Being a mathematician, as opposed to someone who simply uses mathematics within their daily life, schooling or career, is a problematic notion which is discussed in more depth within the section below on gender.

2.1.4 Mathematics education: purposes and curricula

A brief exploration of purpose and curriculum of mathematics education in England is relevant to this study as it provides the background to the participants' mathematical world, potentially shedding light on the pressures girls face within and beyond their mathematics lessons. At the time of writing, the statutory mathematics curriculum in England has been undergoing a period of rapid change with the introduction of a new National Curriculum (DfE, 2013a). Speaking to the House of Commons, the Secretary of State for Education Michael Gove made clear his intention to raise the expectations of the National Curriculum for mathematics: 'Our new national curriculum is explicitly more demanding – especially in mathematics – it's modelled on the approach of high-performing Asian nations such as Singapore' (Gove, 2013).

Jo Boaler is a well-respected critic of the type of mathematics studied in both the United Kingdom and America. For her, the mathematics curriculum provides neither links to the real-world of the children's lives nor a basis for further mathematical study: 'In many maths classrooms a very narrow subject is taught to children, that is nothing like the maths of the world or the maths that mathematicians use' (Boaler, 2009, p. 2). Whilst contexts such as those incorporated into mathematical test questions are intended to reflect children's 'real-life', these are often so far removed from actual children's experience as to lead various authors to question exactly whose reality it is that is being portrayed – certainly not the children's (Bonotto & Basso, 2001; Vappula & Clausen-May, 2006). Addressing this issue is by no means straightforward, with teachers often trapped within the 'planning paradox', a tension described by Ainley, Pratt, and Hansen (2006, p. 24). This idea encapsulates the difficulty for teacher that the more they plan from specific learning objectives, the less rewarding and realistic the tasks become, however the taking of engaging, genuine situations as a starting point can lead to learning that is less focused and more difficult to assess. In developing the ideas of purpose and utility as a way of addressing the planning paradox, they see purpose as relating to the perception of a pupil that a task has a meaningful outcome, which may or may not be linked to a real-life scenario. The closely related idea of utility relates to the way in which mathematical ideas are useful; best developed within purposeful tasks (Ainley et al., 2006). Rather than delegating links to real-world situations to word problems, Bonotto and Basso (2001) suggest that 'cultural artefacts' such as receipts, product labels, newspaper weather forecasts or timetables could be used to help children make connections between the taught mathematics curriculum and their daily lives. This mention in the literature of cultural artefacts and their potential role in bridging home and school mathematics led in part to the open-ended data collection methods deployed in this study, allowing children to incorporate cultural artefacts from their own daily lives where they perceived these as related to mathematics.

A contrasting starting point for a mathematics curriculum is that suggested by Bishop based upon a wide range of research carried out across cultures at the end of the twentieth century, observing mathematical activities and categorising these into the six 'fundamental activities' (Bishop, 1988, p. 182) of counting, locating, measuring, designing, playing and explaining. Bishop's suggestion is that these activities appear within the context of every cultural group studied, are enough for mathematical knowledge development, and could provide a basis for curricula which balance familiarity for all cultural groups with the introduction of formal, academic mathematical ideas. Shifting the balance away from capability to include more focus upon awareness of the nature, value and social uses of mathematics has the potential to make the subject more interesting and relevant for those studying it (Ernest, 2014) and more likely to appeal to girls (Burton, 1995). Similarly, making connections between areas of mathematics is not only powerful but requires teachers to be well-informed about how children use mathematics outside the classroom (Masingila, 2002), informing the reasoning behind the research design of this study. Turning the conventional wisdom of home mathematics as an opportunity to consolidate work done in school on its head, reading Masingila's assertion that '…students need in-school mathematical experiences to build on and formalize their mathematical knowledge gained in out-of-school situations' (2002, p. 30) was a formative moment in the development of this study.

It could be argued that alongside mathematical content knowledge, identity formation should be an aim of education. In order to fulfil a future involving mathematics, children and young people need to see themselves as mathematicians, not just achieve assessed levels of subject knowledge. Kaplan and Flum (2012, p. 172) argue 'we hold that in addition to the focus on generative knowledge, and on participation in current communities of practice, education must focus on the adaptive formation of students' identities – promoting students' confidence, agency, and skills in questioning and revising current self-aspects and identifications'. This suggests that practitioners need to understand influential factors upon children's mathematical identities and therefore how these form, and exploring specific children's identity in relation to mathematics therefore forms another key aspect of this study.

2.2 Mathematics as a social construct

The negative connotations of mathematics as a subject appear to be deeply embedded within our culture, with a tendency to define learners as either 'can do' or 'can't do' in terms of their mathematical ability (Jorgensen et al., 2013). Perhaps more worrying still is when lack of capability within and affinity with mathematics is taken for granted, a phenomena reported in the United States not just the UK: 'Adults and children alike joke about being terrible at math, seemingly unconcerned about how this innumeracy hinders full participation in our democracy or the realization of their individual goals, hopes, and dreams,' (Allen, 2011, p. 1). This section forms the backdrop to the affective factors in mathematics learning such as self-concept, resilience and anxiety discussed in section 2.4.2.

Views of mathematics are inextricably linked with the debates about the nature of the subject itself discussed above, with perceptions of mathematics based on absolutism linked with negative attitudes to mathematics (Ernest, 2014). Images of mathematics, both personal and social, are built from a wide range of experiences from seeing classroom displays and listening to parental narratives through to interpreting our own classroom experiences and social talk. Ernest (2014) draws attention to the filtering process between what is intended in the classroom by the teacher and what is actually perceived after filtering through preconceptions, attitudes and beliefs.

2.2.1 Social constructivism and sociomathematics

Constructivist theories focus upon the role of the individual in constructing their knowledge internally (Hansen, 2012). Whilst this has led to many benefits for mathematics teaching and learning such as the use of practical resources to allow children to explore concepts, constructivism is seen as limited by Hennessey et al. due to its reliance on individual construction of knowledge and therefore lack of inbuilt system for exposing and challenging misconceptions (Hennessey et al., 2012). Instead they propose a democratic pedagogy focusing upon argumentation and justification, emphasising understanding why mathematics works the way it does. Based on the work of Vygotsky, social constructivism suggests that purposeful talk and interaction with people are essential for the construction of meaning (McClure, 2012). Moving beyond constructivism, a socio-constructivist perspective takes into account social factors around the learning of mathematics: 'A socio-constructivist perspective on learning is characterized not only by its focus on the situatedness of learning and problem solving but also by the recognition of the close interactions between (meta)cognitive, motivational and affective factors in students' learning' (Op 'T Eynde, de Corte, & Verschaffel, 2006, p. 194). This socio-constructivist perspective is used to frame the present study.

In attempting to explore and model the mathematical lives of children, Walls developed the term 'sociomathematical world' to describe the mathematical dimensions of a child's life (Walls, 2003a, p. 7). Her associated model (reproduced as Figure 2.1) incorporated a wide variety of features of mathematics in the everyday life of the child, and within local and national communities in New Zealand, and attempted to 'define and represent the complex and dynamic social environments within which children experience, internalise and reflect socially constructed meanings about mathematics, about learning and knowing mathematics, and about their mathematical 'selves'' (Walls, 2003a). This model is useful to the present study in that it confirms the importance of acknowledging and understanding the complex, socially-constructed world within which a child's mathematical identity is formed.

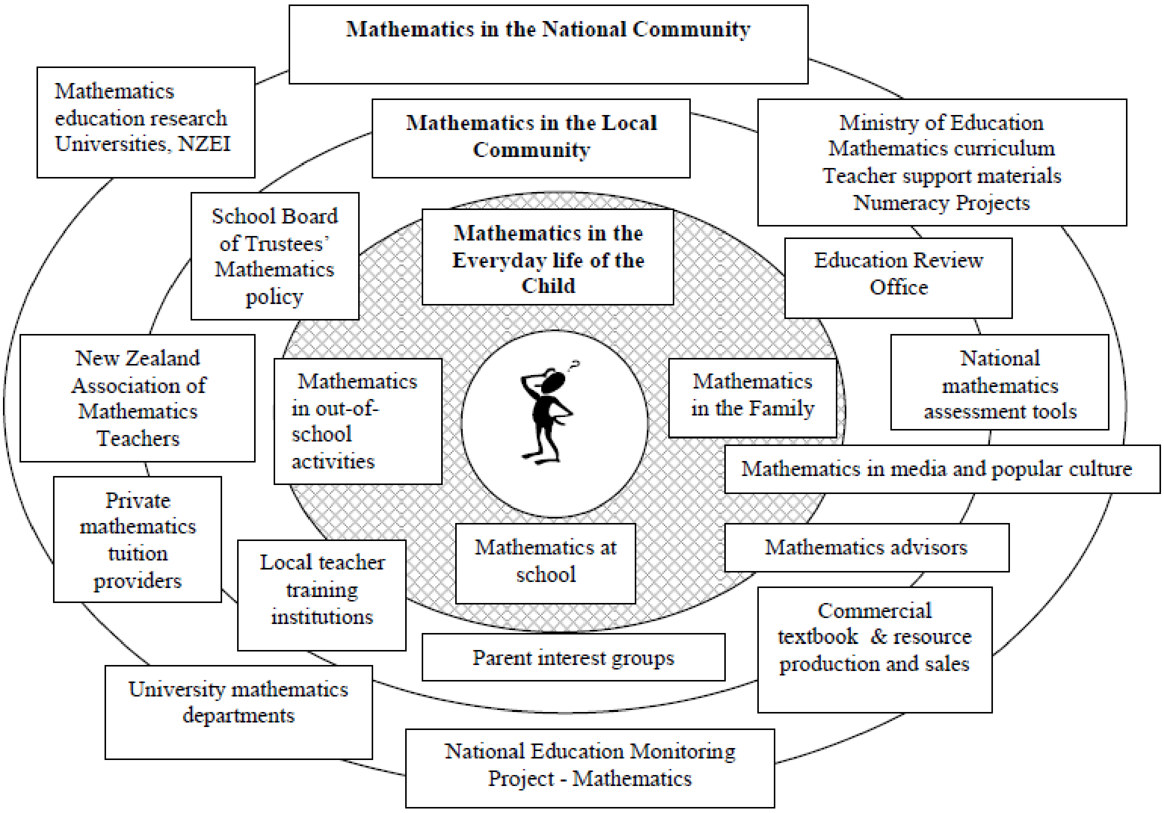


Figure 2.1 The sociomathematical world of the child within its wider context (Walls, 2003a, p. 4)

Acknowledging the social world within which children operate when learning mathematics can be a powerful element of helping them make meaning. In seeing mathematics as a 'socio-cultural story told in a socially negotiable context' (2002, p. 6), Burton challenges educationalists to spend time valuing children's sense-making, giving them opportunities to scaffold each other's learning, collaborate and even regress for a while as a natural part of the learning process. It is hoped that following a research design allowing children to discuss and portray their mathematics within its social context will allow children to contribute to our knowledge by revealing a fuller picture of their mathematical world to the researcher, as well as develop their own mathematical 'story'.

2.2.2 Situated learning and ethnomathematics

Ethnomathematics can be defined as relating to specific, identifiable and idiosyncratic ethnic groups and their distinctive mathematical practices (Pinxten & Francois, 2011), or as simply relating to the mathematics embedded within the lives of any situated group of adults and children (for example families or school communities). Studying Kenyan students' perceptions of mathematics and science use outside the classroom, Masingila, Muthwii and Kimani (2011) see being guided by ethnomathematics as '…recognizing the influence that sociocultural factors have on the learning of mathematics and science' (p. 92). Either way, assumptions of the benefits of linking children's home- and school-lives in terms of mathematics are problematic and require further exploration (Pais, 2011). Considering the place of mathematics outside of the formal classroom was something this research sought to do.

The contrast between formal, academic mathematics and ethnomathematics and its role in children's learning forms the basis of much debate amongst mathematics educationalists. On one hand the sociocultural assumption that '…the adult, teacher or more competent peer should make connections to what the learner already knows by contextualising academic, scientific concepts with the students' every day, familiar and spontaneous concepts' (Rowlands & Carson, 2002, p. 94) is central to criticisms of teaching which excludes children's mathematical background, but on the other the focus on ethnomathematics can become disempowering, denying children access to the abstract power of mathematics and therefore restricting them to their current social context (Pais, 2011). For this reason some educators are wary of an emphasis on ethnomathematics in mathematics education (D'Ambrosio, 1997). In turn Adam, Alangui and Barton (2003) argue for integration of formal, academic mathematics and concepts based within learners' cultures. Taking learners' mathematical backgrounds into account requires interaction (with the teacher framed as manager, guide and facilitator), cooperation (with learners having the power to teach and explain their ideas to others), and 'multimathemacy' – the variety of different cultural insights from both academic mathematics and children's cultural knowledge traditions (Pinxten & Francois, 2011, p. 269). Supporting educators in recognising the insights that can be gained from exploring mathematics originating within girls' own worlds may be a by-product of the evidence gathered within this study.

The two-way relationship between formal and home-based mathematics is explored further by Masingila et al (2011): 'Students gain mathematical and scientific power when their in-school mathematics and science experiences build on and formalize their knowledge gained in out-of-school situations and when their out-of-school mathematical and scientific experiences apply and concretize their knowledge gained in the classroom,'(p. 89). They put forward a powerful argument that in order to maximise students' learning, we need to know not only about how they use mathematics in their everyday lives, but how they perceive that they use it. This literature raises the question for this research of whether there are any commonalities in the type of mathematics included when children are asked to capture examples of mathematics beyond the classroom and in the home, and their portrayal of mathematics as a classroom subject.

Within a situated perspective focusing upon the concept of communities of practice (Wenger, 1998), learning is integrally linked with identity formation: 'learning is a process of becoming' (Vågan, 2011, p. 44). The emphasis is upon social engagement and interaction within and beyond the classroom:

> Rather than as an individual act of knowledge accumulation, learning constitutes active processes of legitimate engagement in collaborative knowledge production. The learner does not operate in a social vacuum but is a part of a more complex community of practice, one in which he or she gradually gains access (Vågan, 2011, p. 44).

Despite the emphasis on the social system and participation within a situated context, this focus on social aspects of learning does not deny the importance of the individual as a meaning-maker who draws on the social world to construct their identity (Wenger, 2009). Wenger goes on to emphasise the importance of the whole person 'with a body, a heart, a brain, relationships, aspirations, all the aspects of human experience, all involved in the negotiation of meaning' (Wenger, 2009, p. 2). Perhaps factors such as relationships and aspirations will emerge within the type of characterisations children make of themselves as mathematicians; this will be investigated within this study. With participation and engagement key aspects of whether or not learners see themselves as members of a community of practice (Lave, 1996; Wenger, 2009), in this case the community of mathematicians, factors affecting that participation and consequences for self-concept and identity are explored next.

2.2.3 Media and culture

Alongside the influences of family members, teachers and classroom experiences, discourses within popular culture have a role to play within the formation of perceptions of mathematics. Over recent years there has been a 'veritable explosion of representations of mathematics and mathematicians in popular cultural texts,' (Epstein et al., 2010, p. 47), providing diverse influences on developing perceptions of mathematics and mathematicians. Exploring the views of over 600 14-15 year-olds and undergraduates, Epstein et al. discuss a range of portrayals ranging from mathematics as pattern and prediction (*Numb3rs*), a code to crack (the film *The Beautiful Mind*), an indication of cleverness (Roald Dahl's *Matilda*) and a source of comfort and safety (*Rainman*, *The Curious Incident of the Dog in the Night-time*). Although it could be questioned how many of these 'popular' texts genuinely feature in the formative experiences of young people, their conclusions that mathematics is positioned as 'other', leading to students feeling release when they no longer had to study the subject, provide much food for thought. One interesting feature is the binary nature of portrayals; people are either gifted mathematical geniuses or not mathematical, rarely simply good at mathematics (Moreau, Mendick, & Epstein, 2010).

Writing more recently, Mendick and Moreau (2014) present a slightly more positive picture, with mathematics being incorporated within popular television such as *The Apprentice* or *High Street Musical*. Despite this they still lament associations between exceptional figures, geeks and geniuses and mathematics, making it hard for children to identify themselves with mathematics.

2.2.4 Mathematics in the home

This research aims to explore girls' perceptions of mathematics as formed and actualised beyond as well as within the classroom with data collection taking place in the home, therefore it is necessary to briefly consider the literature on mathematics in the home and consequences for the study.

One of the key points of interaction between home, school, a child and mathematics relates to the setting and carrying out of homework (Lange & Meaney, 2011), which formed the basis of an ethnographic study set in America positioning homework as a situated social practice (Landers, 2013). How those in their families, friends and school clubs characterised homework impacted children's self-identification as someone who does or does not engage with mathematics homework, with consequences for future participation in mathematical study. An even stronger view of mathematics homework as a source of 'emotional trauma' emerged from Lange and Meaney's exploration of 10-11 year-olds' perceptions of mathematics education (2011, p. 38). The trauma in this case arose from the positioning of the child as mediator between home and school as well as the medium for the homework, with potential longer-term consequences for the child's mathematical agency. It should also be noted that parents themselves might be anxious about the mathematics their children are working on or bringing home as homework (Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015), with knock-on effects on children's confidence.

There can be a disconnect between home and school methods, for example of calculation, and missed opportunities to engage parents in understanding modern approaches to teaching mathematics (Williams, 2008). William's report into teaching mathematics in England also touched on the 'wealth of mathematical knowledge children pick up outside of the classroom' (Williams, 2008, p. 70), and the importance of exploiting this knowledge alongside acknowledging the role of parental attitude towards mathematics. Although some projects aimed at home-school knowledge exchange are provided as examples, it is interesting that the report focuses upon schools holding the key to improving attitudes, with positivity and a 'good grounding' in their power to 'give' to the families and children concerned (Williams, 2008, p. 71). This reinforces a 'uni-directional' view of information flow from schools to parents about their children's mathematics, rather than acknowledging the vast potential of information and support in the home (Baker, Street, & Tomlin, 2003; Hughes & Greenhough, 2006), or investigating mathematics in the home and the related messages children may receive about gender roles (Kelly, 1986), a gap in knowledge this research aims to address. Different approaches acknowledge the anxieties held towards mathematics by the adults around learners, and the need to help them to develop their own mathematical resilience to empower them to fully support their children (Goodall & Johnston-Wilder, 2015).

It is not just homework that provides an opportunity to enrich and extend children's mathematical experiences. A theme reported by successful mathematicians is the inspiration they received from being involved in puzzles, games and problems in the home (Boaler, 2009). Once again the disconnect between home and school mathematics resurfaces, with the subject taught in classrooms bearing little resemblance to children's experience of mathematics in their own lives. Reporting on part of the Home School Knowledge Exchange Project (HSKE) in the UK, Feiler, Greenhough, Winter, Salway, and Scanlan (2006, p. 462) noted the value of using 'formats that do not rely on the written word' to improve communication about mathematics between home and school and allowing an insight into what was happening in the home, for example the use of disposable cameras. This project aiming to develop new methods of exchanging knowledge between school and home found that mathematical activities in the home fell into two main categories (Winter, Salway, Yee, & Hughes, 2004):

1. Those embedded in family activities eg shopping, cooking, going on holiday, dealing with pocket money, or engaging with the working lives of parents;
2. Playing games – both card and board games and those invented by children.

In contrast at school it was unusual to play games and even more unusual to 'engage in the kinds of authentic activity which took place at home' (Winter et al., 2004, p. 68), with school mathematics generally decontextualized or based on contexts introduced by the teacher. This picture is complicated further by the struggle that children have in seeing the kind of activities carried out in the home as being mathematical (Jay & Xolocotzin, 2014). Whilst 8-14 year old children in their study did recognise activities such as counting money in a shop, and in some cases activities relating to baking, Jay and Xolocotzin concluded that 'the descriptions of out-of-school maths resemble the kinds of representations of 'applied maths' that learners see in textbooks and worksheets' (2014, p. 8).

How parents judge their own children as mathematicians is part of a complex picture impacted by their socio-economic status (SES), own experiences of mathematics, and perceptions of what mathematics entails. Some of these experiences may have been less than positive, leading to parents wanting to avoid the same situation being replicated for their children (O'Toole & Abreu, 2005), or lacking confidence in their own ability to support even the earliest mathematical learning (Cannon & Ginsbury, 2008). In studying parental perceptions within an American mathematics project, Mann found that parents 'view mathematical talent in terms of computation ability' (2008, p. 51). Mann speculates that parents may be drawing on their own school-based experiences of mathematics, and focusing on current skills rather than the less tangible concept of mathematical talent. Contributory factors may include lack of emphasis placed on mathematical tasks in comparison with literacy-based activities, alongside parents' lack of confidence in making judgements about mathematical teaching, learning and activities (Muir, 2012). In addition, there can be a knock-on effect of parental mathematics anxiety, with Maloney et al. (2015) reporting a subject-specific link between higher mathematics anxiety amongst parents, lower mathematical learning and higher levels of anxiety amongst their children.

The nature of mathematical interaction in the home may itself impact on children's ability to access and succeed at school mathematics. For example, the use of declarative forms of language in working class households, in comparison with the use of language following a similar initiation-response-feedback model as that deployed within mathematics classrooms may already put certain children at a disadvantage (Jorgensen et al., 2013).

The points raised by this brief review of mathematics in the home point towards the need to gain further insight into what the participants of the study recognise as mathematics in the home, whether factors such as homework, mathematics embedded in day-to-day family activities or puzzles and games feature in their views about mathematics, and whether the views or anxieties of family-members appear to play a part in their own evolving mathematical identities. In addition, this section has raised an interesting question for methodology, that of whether non-verbally reliant data collection methods such as the use of disposable cameras might provide an opportunity to capture the mathematics taking place in the home.

2.2.5 Exploring perceptions of mathematics

Children's perceptions of mathematics must, in part at least, depend upon what they define as being mathematical in nature – this question goes to the heart of this study. Is mathematics carried out within everyday life, and simply recognised as such when it is met in school, or does mathematics not start until '…someone performatively asserts that what students were doing was mathematics' (Pais, 2011, p. 216). Similarly, part of the lack of appeal of mathematical study may be the narrow definition of mathematics as dealing only in numbers (Epstein et al., 2010; Young-Loveridge, Taylor, Sharma, & Hawera, 2006). This latter interview-based study revealed that some children did not appear to have a view about the nature of mathematics at all, leading them to speculate that 'if children don't have a view about what mathematics is, that may make it difficult for them to capitalise on the mathematics they encounter at home and in other out-of-school settings,' (Young-Loveridge et al., 2006, p. 63).

A small-scale project carried out by Grootenboer and colleagues in Australia explored feelings about mathematics amongst 45 9-12 year-olds. Number and calculation were prevalent in their descriptions of what mathematics is about, a finding echoed by Walls (2009), with little focus on measures, geometry, algebra or statistics. Times tables received privileged status in the minds of the children, and examples were exclusively drawn from experiences of mathematics in school, although the reasons for this may be methodological. Perhaps the most interesting finding was that children were well able to 'articulate and discuss their affective responses to their mathematical experiences' (Grootenboer, Roley, Stewart, & Thorpe, 2002, p. 20), contradicting the findings of Young-Loveridge et al. (2006), with a resulting plea from the authors to teachers to discuss feelings about mathematics with children to inform their teaching approach.

An alternative characterisation of mathematics based on a study of ten high-attaining children in England focused upon how children characterised mathematics and mathematicians. The metaphorical labels generated by Kelly (2004) were labourer, mechanic, performer, craftsperson and academic, with labourer and mechanic the most frequently occurring categories, mechanical aspects of mathematics being particularly emphasised by girls.

There is some evidence of links between children's perceptions of the nature of mathematics, and the extent to which they identify with doing mathematics outside school. Drawing on Bishop's (1998) typography of mathematical activity described above when working with Kenyan primary-level students, Masingila et al (2011) found a correlation between those reporting 'broader' activities defined as location, playing or explaining and those who answered positively to whether they had learned mathematics out of school. Girls were also less likely than boys to report they had learned mathematics out of school. Overwhelmingly, views were closely tied to school arithmetic rather than broader views of mathematics as a way of thinking, leading the authors to conclude 'These students may very well be mathematically powerful in their out-of-school mathematics practice, but they may not count that as mathematics due to the disconnection between the discourses of everyday and school' (Masingila et al., 2011, p. 106).

An attempt to portray perceptions of mathematics through the eyes of the children was made by Borthwick (2011), using analysis of children's drawings of mathematics lessons created by primary-aged children in the UK. Themes arising included perceptions of mathematics as a solitary activity, dominated by number and calculation. A similarly limited view of mathematics was found by Ashby (2009) in his small-scale study of 7-8 year-olds, where children displayed difficulties in making connections between the work carried out on paper in mathematics lessons and its practical applications, with the exception of working with money. Also worrying was the lack of self-belief shown by many of the children, together with an association of mathematics with cleverness – children perceived that not only did you have to be clever to do mathematics, but mathematical ability was a defining feature of cleverness itself. The combination of these two factors, lack of understanding of the point of mathematics together with assumption of the likelihood of failure, provides a powerful disincentive to effort and further study: 'Human nature does not favour futile endeavours; if a difficult task appears to have no purpose, then few will continue to follow it through,’ (Ashby, 2009, p. 8)..

A similar drawing methodology to that deployed by Borthwick was utilised by Picker and Berry a decade earlier (Picker & Berry, 2000). They asked their 12-13 year-old participants to draw mathematicians and write a commentary to explain their drawings, with striking results. Across all five countries involved, children had great difficulty in explaining why anyone might want to hire a mathematician, either leaving the question blank, stating that they didn’t know why anyone would wish to do so, or referring to asking for help with their homework. Alongside themes of mathematicians with special powers (like wizardry), images were dominated by drawings of mathematics teachers, with a common theme of small children powerless before authoritarian and threatening teachers. Picker and Berry (2000) concluded that there is a greater distance between children and mathematics than with any other subject, with children therefore reliant upon societal stereotypes for their references on the role and nature of mathematics.

This concept of distance, or a disconnect between mathematics and children’s real lives, resonates across the literature. In analysing the responses of 215 children asked to explain what mathematicians do, Rock and Shaw (2000a) found that not one respondent provided an example drawn from outside the life of the classroom. They drew the conclusion that teachers should stress the role of mathematics, ‘making connections to children’s everyday lives to help them learn to value mathematics,’ (p. 554). Perhaps this top-down discourse, pleading the importance of mathematics in children’s lives rather than trying to draw upon the mathematics which is already there, contributes to the very sense of distance that Rock and Shaw are trying to overcome.

This section suggests the need to consider not only whether previous findings such as the association of mathematics with school arithmetic, teachers and cleverness, the narrow definition of mathematics as number and calculation and emphasis upon mechanical aspects of mathematics amongst girls are replicated within my study, but how best to investigate these perceptions. The studies employing a creative methodology giving opportunities for children’s voices to be heard through drawings and the use of metaphor alongside more traditional interview-based methodologies seemed to gather more in-depth data on perceptions of mathematics, pointing towards a need for further research trying out and reflecting upon these approaches.

2.2.6 Stereotype formation

Once established, stereotypes can be challenging to overcome and have a significant impact on children’s perceptions of themselves and others. In particular, stereotypes such as men being better at mathematics can threaten girls' perceptions of themselves as mathematicians, with stereotype threat being defined by Ganley et al. (2013) as the phenomenon of specific groups being affected by 'an unconscious fear of confirming a negative stereotype' (p. 1887), in particular in relation to test outcomes. As Georgiou, Stavrinides, and Kalavana (2007, p. 339) state, 'a stereotype ceases to exist only when reality proves it wrong'; children may underestimate their abilities in specific areas due to perceived social bias rather than due to a particular lack of ability. Simply being aware of negative stereotypes surrounding girls and mathematics may lower girls' performance (Martinot & Désert, 2007), although these authors suggest that gender differences in stereotypes emerge beyond the primary age range rather than being held by young children, who are more likely to be optimistic about their own gender. This is a complex area, with a difference between stereotype 'awareness' and 'endorsement' (Martinot & Désert, 2007, p. 457), and the possibility of stereotypes being mitigated against by positive role models, again raising the question of whether such role models are available to children of primary-school age; many studies of the effects of stereotypes have been conducted with older students or in laboratories rather than with school-age children (Smith, 2014).

Mathematicians in popular culture are frequently male and white, leaving a lack of positive female role models (Moreau et al., 2010). Young people realise these are stereotypes, but do not have alternative images to use instead of these stereotypes (Epstein et al., 2010). Reacting to the news that for the first time in over 70 years since its inception, the Fields Medal mathematics prize, the most prestigious prize awarded to mathematicians, had been awarded to a woman (Iranian Maryam Mirzakhani), Oxford University's Frances Kirwan commented on the stereotypical portrayal of mathematics as a male preserve, despite the contribution of women made over centuries (Kirwan, 2014, cited in Sample (2014)).

In addition to the lack of female role models, Moreau et al. (2010) suggest that we should ensure that children have a role model or vision for how mathematics might be used in the future: '…wider representations of mathematicians should include representations of research and non-elite mathematicians and people doing mathematics, such as school or university teachers of mathematics, market research or medical statisticians, engineers and technicians, nurses, etc, as well as of people who do mathematics as a hobby' (Moreau et al., 2010, p. 35). This prompted a research design for this study incorporating opportunities to explore children's perceptions of mathematics within people's lives.

Teachers may also have a role in stereotype formation, with Middleton and Spanias (1999) reporting that patterns of teacher attribution are different for boys and girls. Whereas failure in girls is attributed to lack of ability, effort and task difficulty, failure in boys is more typically attributed only to lack of effort, reinforcing the stereotype that boys are naturally more able. This stereotyped view of mathematics may be exacerbated by the 'thin' knowledge of children that many teachers hold, knowing them from their performance within the classroom rather than tapping into the rich knowledge-base of those in the home, the accumulated 'funds of knowledge', using the term coined by Moll, Amanti, Neff, and Gonzalez (1992) and used to underpin the approach taken within the HSKE research introduced above. Whilst exploring the views and stereotypes held by their teachers is outside the scope of this study, it aims to address some of the gaps in our knowledge of girls' perceptions of mathematics by exploring the extent to which a particular group of girls hold and/or endorse stereotypical views of mathematics, have a vision for how mathematics might be used in the future and have access to female role models, alongside looking for patterns in these views set alongside individual self-perception as a mathematician.

2.3 Gender and mathematics

Gendered identity can be positioned as being socially constructed, with social constructionism seeing gender characteristics and dispositions as dynamic rather than taken-for-granted and stable concepts (Gordon, 2007). There has been a long-standing, high-profile debate about the nature and extent of gender-related differences in mathematics (Leder, 2007; Leder & Forgasz, 2008; Walden & Walkerdine, 1982; Walkerdine, 1998; You, 2010). This debate has focused not only on attainment but considered post-compulsory study, occupational choices, patterns in confidence and attribution of success, societal factors, classroom socialisation processes and differing learning styles. The underlying focus has shifted from a deficit model targeted at how females' attainment can become more like males, towards a focus on how mathematics is taught and learnt to empower all students to meet their potential (Leder, 2007). Discussion of gender-related differences are also framed by the nature of mathematics as a subject discussed above. Given that women tend to value 'connected' knowledge developed through contextualised experience, intuition and creativity, with males more comfortable with logic, rigour and abstraction, females may be more disadvantaged than boys by an approach to teaching mathematics that fails to provide a context and makes little sense to them (Boaler, 1997).

Typically, the literature reports gender differences in attainment which have historically favoured males but are diminishing over time (Boaler et al., 2011; Boaler & Irving, 2007; Herbert & Stipek, 2005; Huebner, 2009). There are a small number of dissenting voices, for example Choi and Chang (2011) found significant gender differences in attainment of middle-school students, and Penner and Paret (2008) suggest that the tendency of statistical methodologies to focus on mean attainment scores obfuscates significant differences at the extremes of attainment, for example underrepresentation of females in higher attainment bands for young children. Two particularly significant themes arise from reviewing the literature in this area.

The first of these is a disparity in representation within post-compulsory study and take-up of mathematics-related careers, with lower participation rates by females (McCormack, 2014; Mendick, 2005; Piatek-Jimenez, 2008; Reid & Roberts, 2006), with these disparities persisting over time, for example Hyde, Fennema, Ryan, Frost, and Hopp (1990), Sheldrake et al. (2015). With mathematics as a gatekeeper subject as established above, this puts women at a disadvantage in terms of career choices, influence and earning potential (Herbert & Stipek, 2005). The picture is even more complex still, with Ceci and Williams (2010) reporting a wide range of evidence that when females do choose STEM-related careers, they tend to opt for those that are less mathematically-intensive, being over represented in subjects such as psychology, sociology and veterinary science and underrepresented in careers relating to engineering and physics, particularly at the highest level. One possible reason is the phenomenon explored by both Mendick (2005) and Piatek-Jimenez (2008) of the difficulties females, even able mathematicians, have in identifying themselves as mathematicians. The female undergraduate mathematicians who were the subject of both studies positioned themselves on the non-mathematical side of binary oppositions, identified mathematicians as being 'different', and 'did a great deal of work in their interviews to deny the possibility of their being thought 'mathematically able',' (Mendick, 2005, p. 204); they tend to prefer application of mathematics rather than mathematics as an end goal. Reasons for this denial are speculative and under-researched, but may include stereotypes of mathematics as masculine and mathematicians as obsessed with their work and 'misfits in society' (Piatek-Jimenez, 2008, p. 638), developing the theme of binary oppositions further. Gendered differences in binary constructions around mathematics, mobilising ideas of mathematics around logic and masculinity, often favouring the esoteric rather than everyday mathematics, may form a barrier to viewing oneself as a mathematician amongst females favouring language, everyday application and context over abstraction (Mendick, Moreau, & Hollingworth, 2008).

These themes follow through into identities at all ages. In a report to the White House, Boaler (2014, p. 1) discussed the girls who believe that in terms of belonging to the mathematics classroom they 'just do not fit in', linking this in part to a lack of role models but also to the procedural forms of knowledge most valued in mathematics classrooms. This lack of role models is deep seated and historical, resulting from the build-up of two thousand years of social conditioning as set out in a review of the gendering of mathematics by Harris (1997). Harris' argument is that this search for role models has contributed, in part, to the overlooking of the context and application of women's mathematics in their working lives.

The second theme relates to the differences between mathematical attainment, perceptions of mathematical ability by children and adults, and children's confidence levels. Research consistently finds gender differences in children's confidence levels in mathematics, with girls either less confident or declaring themselves less able in mathematics even when operating at a similar level to boys (Frost & Wiest, 2007; Georgiou et al., 2007; Herbert & Stipek, 2005; Kurtz-Costes, Rowley, Harris-Britt, & Woods, 2008; Lubienski, Robinson, Crane, & Ganley, 2013; Piatek-Jimenez, 2008). Furthermore, evidence suggests that gendered gaps in self-perceptions of mathematics competence emerge both at a young age and 'earlier than or independent of any gap found in actual achievement' (Herbert & Stipek, 2005, p. 278).

Gender-related differences in perceptions of mathematical ability have far-reaching consequences. Over many years, society's fascination with 'who is better' at mathematics (McCormack, 2014) has been fuelled by the plethora of studies either reporting or denying differences, contributing in turn to stereotypes regarding girls and mathematics and the potential for girls doubting their own mathematical ability due to social bias and discrimination (Mendick, 2005). Taking a gender role socialisation perspective, Choi and Chang (2011) suggest that girls are not encouraged to excel in mathematics to the same extent as boys, with consequent impact on future grades and career choices. This arises not only from girls' negative perceptions of themselves as mathematicians, but from adults who have formative influence on their lives, not least parents and teachers. Various studies have made this link, for example Kurtz-Costes et al. (2008), who found that the more girls perceived that adults viewed girls as good at mathematics, the higher their own ratings of girls' abilities – where they believed that adults viewed boys as better than girls in mathematics and science, they held poorer mathematics and science self-concepts. Parents have been found to underestimate the mathematical ability of girls whilst overestimating that of boys, particularly significant as parental judgements have been found to be strong predictors of children's own perceptions of ability (Herbert & Stipek, 2005). Teachers can also fall prey to assumptions about gender, with their expressed commitment to equality in achievement not necessarily matched by observed differences in their perceptions of ability, behaviour and attitude (Jones & Myhill, 2004). In the case of girls and mathematics, being passive and compliant can be offered as an explanation for underachievement by teachers (Jones & Myhill, 2004).

Investigating affective factors in Kindergarten-aged girls' and boys' mathematics achievement, Lubienski et al. (2013) found evidence that gender differences (in confidence rather than actual performance) were greater for children from high SES backgrounds. They found that teachers tend to conflate girls' compliance with mathematics proficiency, and rate boys' proficiency higher than similarly achieving girls. Given the damaging consequences of perceptions of low attainment leading to lower academic reputation, self-image and future opportunities, understanding these early factors is essential, with Penner and Paret (2008) recognising the tendency of gender inequalities in early childhood, alongside those of race or class, being reinforced.

It is worth noting the suggestion of Leder (2007), supported by Lubienski et al (2013), that differences in attainment may themselves be related to the assessment used: the consequence of girls tending to favour verbally-based, problem-solving approaches whilst most assessments including the statutory end-of-key stage tests undertaken in the UK are based upon more individualised, traditional tasks may be that boys are relatively over-assessed. Girls and boys may also respond differently to quite subtle differences in teaching approaches and activity design within mathematics, for example Fennema, Carpenter, Jacobs, Franke, and Levi (1998) found that girls tended to benefit from opportunities to develop their own algorithms and use more concrete calculation and problem solving strategies than boys. Although there has been significant attention given to researching gender differences in preferred learning styles in mathematics, the results of this research remain tentative and complex, with detailed discussion beyond the scope of this review. Common themes arising from research tend to centre around the preference of females for verbally-mediated learning situations, both in terms of tackling problem-solving and in preferring collaborative, group-based contexts as opposed to individualised, competitive classrooms (Boaler et al., 2011; Boaler & Irving, 2007; Frost & Wiest, 2007). This focus on group work may be important precisely because of the preference of females to favour applications rather than abstraction, with the opportunity provided by discussion to think about topics in depth and increase understanding, a feature less important to boys tending to focus on speed and task completion (Boaler, 1997).

Gender differences in approaches to mathematics can begin very young, well before children reach the age of formal schooling (Klein, Adi-Japha, & Hakak-Benizri, 2010; Penner & Paret, 2008). One example is provided by Boaler (2009), suggesting that the higher level of play with construction materials such as building blocks amongst boys has an impact on them developing better spatial ability, with a resulting impact on subsequent mathematics performance. Klein et al. (2010) suggest that these enhanced spatial abilities become increasingly important for complex problem-solving tasks later in children’s school careers. Basing their results on association tests and self-report measures of nearly 250 6-10 year-old children, Cvencek, Mentzoff, and Greenwald (2011) claim that the cultural stereotype in America that mathematics is for boys presented as early as the second grade (7-year-olds), further claiming that these stereotypes influenced self-concept even before differences in achievement began to emerge. Although many different early years role-play scenarios provide opportunities for incorporating mathematics, including areas traditionally populated by girls, adults need to help children to interpret and discuss their experiences in order to see mathematics embedded in their play (Parks & Blom, 2013).

Positive features of recent research which have informed the approach taken by this study include the move requested by Dweck (2007) and You (2010) away from identifying gendered differences in mathematical ability towards exploring how the mathematical abilities and confidence of all can be fostered, and the suggestion by Leder (2007) that it is time to move away from considering females as a homogenous group towards exploring the complex picture influencing their mathematical identity, confidence and ultimately their willingness to participate in formal or occupational mathematics beyond the end of compulsory study; recognising the diversity of females and the consequences for their mathematical positioning. This positioning of identity as complex, multiple, situated and evolving is explored within the section on identity formation below, and is an area in which this study aims to contribute to existing knowledge through a grounded, open-ended approach.

There are various consequences of this section for the present study. The literature reviewed on gender and mathematics suggests a need to explore the extent to which girls identify themselves with mathematics and mathematicians, or whether they see mathematicians as 'other' and/or male. Tied in with this avenue for exploration is the question of whether their data will suggest they associate mathematics with identifiable role-models, and the extent to which influential others including teachers and family members appear to shape their mathematical self-perceptions. Finally, the section has posed the questions of whether girls see mathematics embedded within their home lives, play and individual interests, and whether the contradictions between girls' characterisations of themselves as mathematicians and their actual attainment apparent within the literature are present within the particular group of girls studied.

2.4 Mathematics and the affective domain

As Meyer and Koehler succinctly point out, 'Students bring more to the mathematics classroom than just their books and pencils. They also bring a wide assortment of skills, prior knowledge, work habits, attitudes, and beliefs,' (Meyer & Koehler, 1990, p. 60). The section discusses some of the key affective factors in mathematics education, leading towards the key idea for this study of mathematical identity. The affective domain and its role in mathematics teaching have been studied in depth over the last 40 years. Links between learning and concepts within the affective domain such as beliefs, attitudes, emotions and more recently values are found to be complex and contested (Grootenboer & Hemmings, 2007); for every study finding a link, there is another suggesting there is no significant correlation or that the causal direction flows from attainment to attitude or vice versa (Törner, 2014).

The term attitude can be defined as ‘a positive or negative response towards mathematics that is relatively stable, similar to what some might call dispositions,’ Hemmings, Grootenboer, and Kay (2011, p. 692). The importance of these dispositions should not be underestimated, as they underpin not only children’s approaches to learning mathematics, but affect the likelihood of continuing with post-compulsory study or mathematics-related careers and may even be as important as content knowledge (Wilkins & Ma, 2003). In fact, Wilkins and Ma (2003) found that student beliefs about the nature of mathematics, as opposed to their attitudes towards the subject which declined, were fairly stable over their time at secondary school, suggesting that investigating and securing children’s beliefs about the nature of mathematics before they leave primary school is a worthwhile focus to pursue. There are dangers in assuming that learners in a particular group or reacting to mathematics in a particular way have a homogeneity of beliefs or reactions. In discussing the idea of ‘quiet disaffection’, Nardi and Steward (2003, p. 345) warn of the dangers of linking disaffection with mathematics as deviance and therefore only noticing those proving disruptive. Instead, dependent upon their personal situation, classroom experience and individual self-concept, tedium, isolation, tasks based on rule following, elitism and depersonalisation (summarised as T.I.R.E.D) may all impact not only affective beliefs around mathematics but engagement and outcomes.

2.4.1 Self-concept, self-efficacy and mindsets

Children and young-people’s self-efficacy in mathematics, defined as ‘the conviction that one can successfully execute the behaviour required to produce the outcomes’ (Bandura, 1977, p. 191), is integrally linked with how long they will persevere with a task and the effort they are willing to expand, with self-efficacy generally seen as an important predictor of mathematics achievement (Alsawaie, Hussien, Alsartawi, Alghazo, & Tibi, 2010). In fact the key authority on self-efficacy Bandura, writing with Locke (2003), reflects that beliefs about personal efficacy are more important than any other ‘mechanism of human agency’ (p. 87). This study follows Chmielewski, Dumont, and Trautwein (2013) and Schweinle and Mims (2009) in seeing self-efficacy as domain specific, relating to a child’s self-perceived confidence in achieving success within a specific task or context, as opposed to the wider concept of academic self-concept, ‘a person’s perceptions of his or her abilities and competences’ (Chmielewski et al., 2013, p. 927). Academic self-concept is developed through social comparison alongside actual performance, with school organisation structures such as grouping and tracking having an impact on children’s developing ideas about themselves as mathematicians (Chmielewski et al., 2013).

Children learn a lot more than mathematics itself within their lessons (Grootenboer et al., 2002). They also develop beliefs about themselves as mathematicians, with the resulting knock-on effects on confidence, self-concept and arguably outcomes. How children value mathematics is linked to the extent to which they see themselves as capable in mathematics, which according to Middleton and Spanias (1999) is in turn linked to their attribution of success. There may be gender differences here, with Middleton and Spanias (1999, p. 70) reporting that 'girls tend *not* to attribute their success to ability but *do* tend to attribute their failures to lack of ability, exactly the attributional style that leads to failure'. Linking to the idea brought into the public consciousness by Dweck (Dweck, 2000, 2007) of fixed and growth mindsets, Middleton and Spanias (1999) suggest that success tends to be an oversimplified concept in mathematics learning, often seen as being related to a whole problem or test rather than more usefully as relating to steps taken to address a problem or learning gains. The beliefs children hold about their own intelligence and the nature of that intelligence are integrally linked to their self-esteem. Valuing learning, relishing challenge and seeing errors as a positive part of learning are all more likely to lead to improved self-esteem than being told they are intelligent (Dweck, 2000), alongside believing that intelligence is malleable and can be increased through effort rather than fixed and finite. This type of fixed-ability thinking is particularly prevalent in England, where 'ability is a pervasive discourse… particularly in mathematics where ability-grouping practices are commonplace' (Marks, 2014, p. 39). Such co-constructed beliefs about ability impact not only on self-esteem but also on pupils' future attainment (Hodgen & Marks, 2009; Marks, 2014) and permeate discourses around mathematics. As Lee (2009) observes, in contrast to a growth mindset within which learners believe that their learning can grow in response to effort, those with a fixed theory of learning take as their starting point that they can learn only a finite amount.

Gender differences in mathematical self-concept have been reported by a wide range of research, both looking specifically at issues to do with gender, and focusing on attitudes more generally, for example Ashby (2009). He found marked gender differences in attribution of success and failure, with girls believing they had been lucky when they succeeded, in contrast to boys associating success with their own ability and effort. This emerging self-concept may be important, as suggested by Cvencek et al (2011), with children having a reduced interest in future courses or careers incompatible with their self-image. Their study explored two possible developmental sequences:

- Me = girl, girls ≠ math, therefore me ≠ math; or
- Me = girl, me ≠ math, therefore girls ≠ math (p. 775)

concluding that their data suggested the first of these as the more likely. It was beyond the scope of their study to explore the origins of these ideas, leading the authors to suggest the need for further exploration of the kind of input related to mathematics children encounter in the real-world and the sense they make of these encounters. These gender differences in mathematics, specifically in the UK, were confirmed by the latest PISA results, which revealed that the UK has a gender gap in mathematics self-efficacy among students performing equally in mathematics that is statistically significantly above the OECD average (OECD, 2014b). Internationally, PISA results show that ‘even when girls perform as well as boys in mathematics, they tend to report less perseverance, less openness to problem solving, less intrinsic and instrumental motivation to learn mathematics, less self-belief in their ability to learn mathematics and more anxiety about mathematics than boys, on average; they are also more likely than boys to attribute failure in mathematics to themselves rather than to external factors’ (OECD, 2014b, p. 18). There is, however, significant variation in gender issues by country, for example with a higher proportion of boys than girls believing they are simply not good at mathematics in Qatar and Jordan, and a significantly higher proportion of girls than boys in Thailand believing in their own ability to learn and use mathematics (OECD, 2014a).

Amongst the range of affective factors, self-concept is closely linked to confidence, how certain a child is of their ability to learn mathematics and do well at mathematical tasks (Meyer & Koehler, 1990). This in turn affects their willingness to try new ideas and persist when tasks become difficult. Confidence was researched extensively using statistical methods by the series of Fennema-Sherman studies beginning in the late 1970s, with results indicating that gender differences in confidence were identified even when there were no corresponding differences in achievement, with females reporting lower levels of confidence at both middle- and high-school levels (Meyer & Koehler, 1990). These results were brought up to date by Nagy et al. (2010), who studied over 8000 children in Australia, the US and Germany and concluded that boys have a more favourable mathematics self-concept than girls, that self-concept is a greater predictor of future choices and career aspirations than achievement, and that these gender-related differences persist over time. These differences persist in England to this day, with Sheldrake et al. (2015) finding that although gender was not a significant influence on attainment within GCSE mathematics, girls were more under-confident than boys and boys reported higher intentions to study mathematics into Year 12 and at university, suggesting a relationship between confidence level and intentions to pursue more advanced mathematics.

Confidence is a contested concept, with ‘no agreement on what confidence is, how it can be recognised or measured’ (Burton, 2004, p. 357). Whereas the teachers in her study tended to recognise confidence through pupil behaviour, seeing it as well-defined, pupils linked it with how they felt in specific situations, providing a more nuanced view. Interestingly they saw confidence as being collaborative (as opposed to their teachers’ views of confidence as an individual attribute often linked to traditionally masculine classroom behaviours). Whilst these findings were based on Burton’s study of A-level students and their teachers, her assertion that low-achievers are often labelled as low-ability, with confidence used as an indicator, resonate with the researchers' experience of primary classrooms and provide the backdrop to the present study. In their review of research, Nunes, Bryant, Sylva, and Barros (2009) found that at least four factors impacted upon the mathematical self-confidence of individual children: their mathematical competence, others' perception of their ability, gender (with girls reported again as showing less confidence than boys) and verbal ability. Mathematical confidence is a key attribute, motivating children to persevere because they believe that ultimately they will be successful: low confidence 'can result in reduced effort or even mathematics avoidance because students do not consider that they can succeed and therefore avoid expending what they perceive would be a wasted effort' (Parsons, Croft, & Harrison, 2009, p. 55).

A final key question in the literature around affective factors and mathematical learning relates to the nature of the relationship between the two; does success lead to increased confidence and self-efficacy, or vice versa? Grootenboer and Hemmings (2007) report the relationship as being cyclical or reciprocal, with affective factors such as mathematics confidence significantly predicting mathematical performance. This is portrayed in the 'success cycle' developed by Ernest (2011) shown as Figure 2.2.

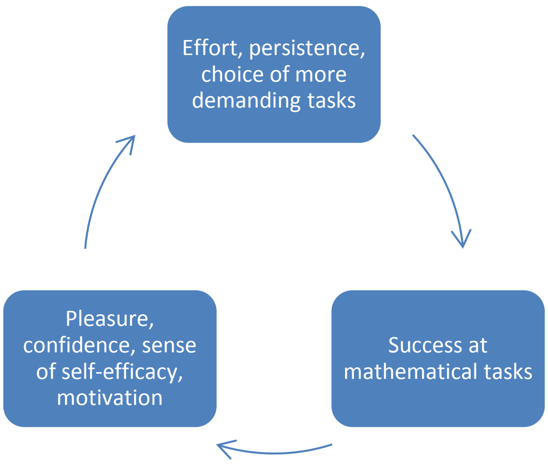


Figure 2.2 The success cycle (Ernest, 2011, p. 110)

This model has been called into question recently by international data suggesting that children in Eastern Asian countries self-report very low confidence level in mathematics, despite outperforming those in other countries who have a higher self-reported confidence level (Mullis, Martin, Foy, & Arora, 2012). Much of the research into self-concept and self-efficacy is quantitative in nature, leading to a gap in our understanding of how children themselves perceive both mathematics and themselves as mathematicians, and how their characterisations of mathematics and themselves in relation to the subject shed light upon their mathematical identity.

2.4.2 Mathematical resilience

A related idea linking self-concept, self-efficacy and the formation of mathematical identity is that of mathematical resilience, or 'a learner's stance towards mathematics that enables pupils to continue learning despite finding setbacks and challenges in their mathematical learning journey' (Johnston-Wilder & Lee, 2010b, p. 38). Resilience can be seen as an outcome of the relationships between a learner, other people and the subject being studied (Hernandez-Martinez & Williams, 2013), placing importance both on the learner's perceptions of mathematics as an academic domain, and upon the social context around their mathematical learning. Resilience can be the difference between the child who gives up when they become stuck or feel overwhelmed, and the one who is able to meet challenges, be confident and develop a 'growth mindset' (Dweck, 2007). According to Johnston-Wilder and Lee (2010b), common features of current mathematics teaching which threaten pupils' mathematical resilience include:

- Mathematics as a chameleon – the discontinuity between school and 'real world' mathematics
- An over-regard for speed in calculation
- Making mistakes being seen as a sign of carelessness or stupidity
- The assumption that there is 'one right way' in mathematics
- Dependence upon short-term memory

Mitigating beliefs and approaches or 'protective factors' (Hernandez-Martinez & Williams, 2013, p. 47), by contrast, include seeing mistakes as part of the learning process, discussion and reflection, not worrying about being right, ownership of progress and adopting a growth mindset (Bell & Kolitch, 2000; Johnston-Wilder & Lee, 2010b). Also key are collaborative working and a school ethos based upon effort and improvement as opposed to feats of memory or divorcing of mathematics from reality (Johnston-Wilder & Lee, 2010a). Being resilient was also found by Bell and Kolitch (2000) as valuing the role of persistence and struggle in overcoming mathematical difficulties; it is okay to find mathematics difficult. In turn, mathematical resilience is key not only for overcoming feelings of helplessness and anxiety but also to increase the likelihood of interest in further mathematical study (Goodall & Johnston-Wilder, 2015). Extending the discourse around resilience beyond that focusing on the individual, the same researchers have also explored resilience in the context of developing a mathematically resilient community (Lee & Johnston-Wilder, 2011). Not only did this research reinforce the importance of collaboration in developing mathematical resilience, with members of the learning community actively involved in overcoming barriers to learning, it suggested the value of using research techniques incorporating pupil voice to shed light on how resilience might be improved.

Resilience can also be seen in relation to gendered attitudes towards mathematics, in particular 'mathematical courage, risk-taking behaviour, and a resistance to the stereotype of women's silence and passivity in the learning of mathematics' (Bell & Kolitch, 2000, p. 238). Whilst this study does not set out to capture resilience per se, the literature suggests that it is so integrally linked with self-concept and dispositions towards mathematics that it should be used as a sensitizing concept (Charmaz, 2014a) both within data collection and data analysis.

2.4.3 Identity formation and mathematical identity

Through the literature reviewed to this point, how children and girls in particular identify with mathematics and as mathematicians has been a recurrent theme. This study sets out not so much to analyse how identity is formed – as will be seen it is recognised as complex and fluent – but to explore the idea of mathematical identity as a construction that girls can express and informs and is informed by their actions, beliefs and interactions.

Identity as a focus for improving understanding of the processes involved in learning mathematics has gained momentum in recent years (Grootenboer & Zevenbergen, 2008), although it has been characterised by Cobb (2004) as being underdeveloped as an explanatory construct within mathematics education research. This points to an opportunity for contributing to knowledge through using mathematical identity as a concept to frame enquiry into girls' perspectives on mathematics.

Identity can be explored from a psychological, socio-cultural and post-structural perspective (Grootenboer & Zevenbergen, 2008), alternatively seen as psychoanalytic, sociocultural or discursive by George (2009). She allows that people may develop a positive, negative, or weak mathematical identity through their experiences whilst learning mathematics. The socio-cultural perspective is the most helpful for this study, balancing a focus on the individual and their interactions with others and society at large (Grootenboer et al., 2006).

Identity itself is a disputed term relating to the 'way the self is represented and understood, both by the individual and by others' (Osborn, McNess, & Pollard, 2006, p. 419). This thesis follows a mathematics educationalists' definition set out by Grootenboer et al. (2006) of identity as 'how individuals know and name themselves (I am: a teacher, a student, good at maths…), and how an individual is recognised and looked upon by others' (p. 612). In this way identity is seen as a 'unifying and connective concept' (Grootenboer & Zevenbergen, 2008), bringing together ideas such as affective qualities, cognitive dimensions of learning and life histories. The emergence of ability is a key feature of developing a mathematical identity (Walls, 2009).

Delving deeper into the literature around identity formation, this thesis draws upon the summary of Thomson and Hall (2008) in seeing identity as:

- Social (in other words, formed in the company of or through interactions with others, rather than in isolation)
- In formation (rather than being fixed, identity changes over time and in response to context, although is not necessarily determined by these contexts)
- Multiple (we think about ourselves and act differently depending upon social circumstances and observer), for example Gee (2001)

This view of identity provides an opportunity to explore the kind of diversity in individual positions towards mathematics explored above. Part of the formation of mathematical identity must relate to the beliefs that individual children have about themselves as mathematicians, or the stories they tell themselves to make sense of their world. In his article exploring thought as story or narrative, Bruner (2004) takes a constructivist approach to narrative: the view that in both the sciences and the arts making sense of the world is the main job of the mind. So the stories that we tell ourselves are a fundamental part of our existence – there is power in a child's 'self-story' that believes themselves to be, or not be, a mathematician. He goes on to share his belief that 'life is never free of precommitment. There is no innocent eye, nor is there one that penetrates aboriginal reality. There are instead hypotheses, versions, expected scenarios' (Bruner, 2004, p. 709). This idea links to that deployed in their research by Hobden and Mitchell (2011) based on the work of Kilpatrick, Swafford, and Findell (2001) of a productive disposition towards mathematics: 'the tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics' (Kilpatrick et al., 2001, p. 131). Developing their ideas through a review of pre-kindergarten to 8th grade mathematics in the United States, the authors identify five interwoven elements of what they term 'mathematical proficiency' (p. 116):

- Conceptual understanding
- Procedural fluency
- Strategic competence
- Adaptive reasoning
- Productive disposition – the habitual inclination to see mathematics as sensible, useful and worthwhile, coupled with a belief in diligence and one's own efficacy.

The idea of a productive disposition is developed by Pollard and Filer (2014) as the stance towards learning children adopt when meeting a new challenge. The stories that children tell themselves about mathematics and about themselves as mathematicians, based on their experiences and interactions, will have a profound impact upon their attitude towards and engagement with the subject. Whilst mathematical resilience and the idea of a productive disposition towards mathematics discussed below are closely linked ideas, resilience can be positioned as a construct arising from a variety of factors including beliefs about mathematics, teaching and the nature of the subject itself (Johnston-Wilder & Lee, 2010a). It would be possible to have a productive disposition and yet still not be mathematically resilient; however, it would be difficult to be resilient without having a productive disposition. In deploying this understanding of productive dispositions to investigate breakdown of mathematical learning of pre-service teachers, Hobden and Mitchell (2011) found that alongside being taught by teachers lacking subject knowledge and empathy, the poor perception of their own ability amongst pre-service teachers was a key factor in the breakdown of their mathematical learning. Perhaps similar factors are at play in the lack of willingness or desire amongst academically able females to carry mathematics forward into compulsory study, the seeds of which may be sown before the end of primary schooling?

Factors influencing the formation of mathematical identity are many and various, frequently independent of explicit intention, and include factors both within and beyond the immediate school environment (Kaplan & Flum, 2012). The implications of this overview of mathematical identity and its formation include the need to explore:

- The role of significant others (Pollard and Filer, 2014)
- The influence of the teacher as a key dimension of the classroom community and therefore potentially a key influence upon children's developing identity (Grootenboer & Zevenbergen, 2008)
- The specific nature of the discipline of mathematics and how it is perceived by children
- The gendering of mathematical identity

In reminding us that the role of the teacher is temporal, Grootenboer and Zevenbergen (2008) point out that mathematical identities endure beyond defined schooling, claiming that 'the goal of learning in the mathematics classroom is the development of students' mathematical identities – their relationship with the discipline of mathematics' (p. 248). This statement presupposes that mathematics is a living entity with which children can develop a relationship, and the extent to which this is true for the girls in the study will form a key area of investigation.

2.4.4 Mathematics anxiety

Alongside attitude towards mathematics, mathematical anxiety formed one of the foci of the increase in research around affective factors in mathematics education in the 1960s and 1970s (Zan, Brown, Evans, & Hannula, 2006) and remains a focus of attention to this day. Defining mathematics anxiety as 'an unpleasant emotional response to math or the prospect of doing math' (2010, p. 1860), Beilock, Gunderson, Ramirez and Levine go on to note that mathematics anxiety is more common in women than in men. Based on observations of primary children who are academically capable but struggle with mathematics in Texas, Stuart (2000) comments on the irony that mathematics, often seen as logical and intellectual, seems to generate such an emotional reaction. Failing to embrace the difficulty in mathematics as enjoyable, rather than a source of negativity, may link to the characteristics of those who define themselves as being a non-mathematician (Epstein et al., 2010). Anxiety might also be mitigated against by an approach to teaching and learning mathematics that accepts emotions as part and parcel of mathematical problem solving, with Stuart (2000) recommending the use of cooperative group work and informal writing in mathematics journals to reduce anxiety, and Op 'T Eynde et al. (2006) going as far as suggesting that we should teach children how to cope with accompanying emotions alongside mathematical problem solving skills themselves.

The causes of and contributory factors towards mathematics anxiety are outside the scope of this study. Mathematics anxiety is a complex issue, with subtleties such as differences in the way that mathematically-anxious children approach tasks having a knock-on effect on mathematical competence (Lyons & Beilock, 2012). Factors such as testing, emphasis on speed in mathematics lessons despite the knowledge that speed inhibits mathematical thinking (Boaler, 2014), perceptions of ability levels and the teaching approach have all been the focus of study (Taylor & Fraser, 2013), with clear links to the notion of fixed and growth mindsets discussed above. Whilst not a key focus of the study, the literature reviewed above regarding the mismatch between actual and self-perceived ability may well suggest that anxiety is a reflection of identity rather than ability, and is therefore an important emotion to be aware of when conducting research into girls' perceptions of mathematics.

2.5 Conclusion and research questions

The limiting discourse of mathematics as something which is 'other' for a high proportion of our children, situated in school with set procedures and rules (Masingila et al., 2011) and belonging to those who are more confident, competent and more often than not male, can only disenfranchise the less confident and more collaborative members of our primary classrooms. Whilst the literature upon the nature of mathematics and affective factors in mathematics education is extensive, there remains the intractable issue of low levels of mathematics take-up beyond compulsory study, particularly amongst females, the disparity between attainment levels and reported confidence and efficacy amongst females, and the tendency of people in general and girls in particular to deny being mathematical as part of their identity. Whilst these bigger issues provide the background to rather than the focus of this study, the question of how girls identify with mathematics is an important one. Arguably, identifying positively with mathematics is important because it provides the foundation on which engagement is based. Understanding this identification is thus significant and forms the focus of this research.

The literature reviewed reveals the need for this study in addressing persistent gaps in our understanding of girls and mathematics. Whilst we have substantial knowledge of gender differences in attainment, confidence, approaches to mathematics and attitudes, the persistent gender gaps in post-compulsory study, reported reticence even amongst able female mathematicians to identify as such and mismatch between actual attainment and self-efficacy in mathematics suggests there is a need to further understand how girls perceive mathematics and mathematicians and how they construct their mathematical identity in relation to these perceptions. Using identity as a lens, it is hoped that this study will make a meaningful contribution to knowledge by allowing a particular group of girls to reveal their mathematical worlds, relationships and positionings.

Themes emerging from the review of literature, combined with the author's professional experience as reported in Chapter 1, led to the following research questions which in turn informed the development of the research design and methodology as set out within the following chapter:

1. How do girls perceive mathematics?
    a. How do they characterise mathematics?
    b. What mathematics do they recognise as part of their daily lives?

2. How do girls make sense of their mathematical identity in relation to:
    a. How they characterise mathematicians?
    b. The role of other people?
    c. How they position themselves as mathematicians?

These questions feed into the key purpose for the study, to draw out the implications of these perceptions and constructions of mathematical identity for educators.

3 Methodology and methods

3.1 Introduction and key concepts

The purpose of this study was to explore girls' relationship with mathematics and how this might lead to later disengagement with mathematics, drawing out implications for educators. The study sought explanations of why some girls do not see themselves as mathematicians, and to illuminate this issue through exploring the following overarching research questions arising from the literature review:

1. How do girls perceive mathematics?
2. How do girls make sense of their mathematical identity?

These questions were compatible with an open-ended, exploratory and grounded approach set within a social-constructivist, interpretive paradigm, aimed at understanding the processes that might lead some girls to part company with mathematics rather than testing a pre-existing theory. Identity has been shown in the preceding literature review to be social, in formation (rather than fixed) and multiple, depending upon context. Given this complexity, the study used a broad range of chiefly qualitative methods including drawings and photography, scrapbooking and group and individual interviews, to build up a picture of the girls and their mathematical identities as they form beliefs which may stay with them for life. The literature review has provided framing around gender and mathematics, and thus rather than taking a comparative approach this research sought to deepen understanding of how a particular group of girls appeared to make sense of their mathematical identity.

An interpretive paradigm embeds certain ontological and epistemological assumptions which influence what methods of data collection and analysis are appropriate. This chapter clarifies these assumptions to provide a rationale for the choices that were made. It also explains the challenges linked to adopting this approach and how these were managed.

3.2 Exploring perceptions of mathematics: ontological and epistemological stance

In carrying out any social research, the first step is to establish the philosophical stance, guiding principles and underpinning rationale: the model framing the research (Silverman, 2010). This section explores the key ideas of subjectivity, constructivism and interpretivism as a backdrop to setting out the methodological rationale and research approach. It takes its definitions from Cohen et al (2011) of ontological considerations relating to the nature of reality and epistemological considerations as defining how we can or should come to know this reality.

3.2.1 Subjectivity

Positioning on subjectivity and objectivity relates to both the ontological questions of what is real and what can be known about this reality, and epistemological considerations of whether the researcher can attain an objective, knowable truth or simply present their subjective interpretations of any given situation. Generally, research methodology textbooks position objectivity and subjectivity at two ends of a continuum, with realists at one end suggesting there is an objective, external and knowable reality and idealists taking the stance that reality is constructed by individuals or groups, and therefore we can only ever discern meaning that people, including ourselves, assign to their lives (Savin-Baden & Howell Major, 2013).

This research is based on a subjectivist conception of social reality, assuming that the social world exists but is differently construed by different people as opposed to being externally imposed on individuals from without (Cohen et al., 2011). Subjectivity was seen as providing an illuminating lens informing the process of inductive reasoning – uncertainty brought with it the opportunity for richer exploration of the multiple layers of perspectives and identity formation. Although interpretations of patterns in the data were confirmed with the participants where possible, ultimately this thesis presents my interpretations of the data.

3.2.2 Constructionism and social constructivism

After setting out the overall worldview framing the research, the next level to be considered is the conceptual framework (Silverman, 2010), in this case the social construction of reality, an idea consistent with interpretivism as discussed below. The language throughout the research literature around constructionism and constructivism has been inconsistent (Crotty, 1998). Bryman (2012) simply states that constructionism is often referred to as constructivism, and sees the two terms as equivalent. Savin-Baden and Howell Major (2013), on the other hand, list them as two distinct philosophical paradigms with subtly distinct features. Social-constructionism is seen as an argument that 'the world is produced and understood through interchanges between people and shared objects and activities' (2013, p. 62). Research focuses upon dialogue and negotiation, and reality is not entirely external – instead individuals make and experience meaning together. On the other hand, constructivism is based on the idea of reality as a product of one's own creation – an 'internal construction where individuals assign meaning to experiences and ideas'(Savin-Baden & Howell Major, 2013, p. 63). This places the emphasis on gathering data on how individuals construct knowledge, and how their meanings are presented and used, and aligns with an inductive, grounded model of data collection looking for patterns of meanings.

Creswell's positioning of social constructivism as a 'worldview' in which the goal of the researcher is to 'rely as much as possible on the participants' views of the situation being studied' (2009, p. 8) leads to open-ended questioning with careful listening, and social and historical negotiation of meaning. This final interpretation of social constructivism, emphasising individual meanings constructed through interaction with others in a historical and cultural context, is the stance taken within this research, hence the choice of data collection methods set out below.

3.2.3 Interpretivism

The epistemological position underpinning the research design interlinks with the aim of the research – exploring perceptions and identity. Taken at its simplest level, within a positivist design the assumption is that the procedures used in the study of natural science can be applied to studying and explaining human behaviour (Bryman, 2012; Cohen et al., 2011). On the other hand, an interpretivist stance assumes that the role of the social scientist is to 'grasp the subjective meaning of social action' (Bryman, 2012, p. 30) with an emphasis on building understanding of the processes and actions of individuals, albeit within a social context, and interpretations of their behaviours. The interpretivist approach 'looks for culturally derived and historically situated interpretations of the social life-world' (Crotty, 1998, p. 67): how girls perceive themselves as mathematicians is examined in their own environment, using their language and context as the backdrop for interpretations of meaning. The interpretive researcher positions theory as emergent, grounded, and multifaceted rather than universal and normative (Cohen et al., 2011). The focus is upon exploring how people think and interrelate, how their worlds are constructed, and what understandings and perceptions they have about the world (Basit, 2010; Thomas, 2013), and in the case of this research, how they come to perceive and construct mathematics, their relationships with it and its role in their current and future lives. Whilst rooted in an interpretive paradigm, this research acknowledges the existence of absolute measures, for example as measured by assessments of mathematics attainment.

The interpretive paradigm is often characterised by a reciprocal and dynamic link between data collection, data analysis and theorising, beginning with a more general exploration of a topic or theme and then modifying explorations as patterns and fruitful lines of enquiry emerge (Robson, 1993). The implications of this stance for my research will be explored in more detail in the section on constructivist grounded theory below.

3.3 Methodological rationale and research approach

The stance taken above regarding ontology and epistemology in turn informed the decision-making process underpinning the chosen methodology. This section addresses how the research was designed in order to better understand and conceptualise how the girls perceived and constructed mathematics and their own mathematical identities.

3.3.1 Constructivist grounded theory

Given the aim of this study, grounded theory with its emphasis upon inductive, data-based reasoning, emergent design and theory generation seemed a natural starting point. However, since its intellectual origins within pragmatism and symbolic interactionism, grounded theory has become a contested method (Charmaz, 2014b).

Grounded theory can be seen variously as a distinct research approach, overarching paradigm, collection of tools, strategy for data collection and analysis or way of thinking about social reality (Charmaz, 2001, 2014b; Creswell, 2009; Savin-Baden & Howell Major, 2013; Strauss & Corbin, 1998; Taber, 2013), and a key decision to make when considering its use is whether to see it as a complete and inflexible research approach, or a way of thinking about social processes. These differing views of grounded theory have evolved over time. They can be characterised as classic based on the work of Glaser and Strauss (Strauss & Corbin, 1998) within which constant comparative analysis of data reveals pre-existing patterns; evolved or modified (Mills, Bonner, & Francis, 2006; Savin-Baden & Howell Major, 2013) based on the subsequent systematic approaches developed by Strauss and Corbin through the 1980s and 1990s, or constructivist following the work of Charmaz, the first author to describe her work as constructivist grounded theory (Mills et al., 2006). In constructivist grounded theory the researcher and researched become inductive co-constructors of knowledge, in which the researcher should immerse themselves, representing and evoking the participants' experiences within their writing (Savin-Baden & Howell Major, 2013).

This study followed the constructivist stance towards grounded theory, with the grounded theory strategies seen as 'tools rather than prescriptions' (Charmaz, 2001, p. 6397) and the researcher positioned as a product of prior knowledge and experience. The following guiding principles were applied:

- Literature was seen as a useful voice contributing to the construction of theory and providing potential points for departure (Taber, 2013)
- Research questions and data collection strategies evolved as patterns emerged from the data and its analysis
- Data collection began with open-ended, inductive inquiry (Charmaz, 2014b)
- Coding was carried out as data was collected rather than using preconceived codes
- Memos were written as a key tool to support constant comparison of data and identification of core variables
- Conclusions were seen as 'interpretive renderings of a reality' (Charmaz, 2014b, p. 6397) as opposed to objective reporting, with the checks and balances on quality set out below.

The strength of this approach for this research is the opportunity it provides to allow for emergent patterns and lines of enquiry whilst maintaining a rigorous approach to data analysis.

3.3.2 Interpretive case-based approach

Early studies of affective factors in mathematics education focused upon quantitative measurement. One limitation of such an approach is the risk that important information may not be elicited by pre-set questionnaire-based items, which can fail to draw out the differing experiences and perceptions of the respondents (Meyer & Koehler, 1990). These challenges can be solved by deploying a case-based approach, chosen above other approaches due to its ability to shed light on abstract ideas and principles through the situated study of real people and situations (Cohen et al., 2011).

There are various definitions of case studies, for example ‘a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence’ (Robson, 1993, p. 147). Silverman (2010) allows for case-study research with an aim of adding to knowledge about a phenomenon rather than remaining within the bounds of the case itself. The most natural setting for a grounded approach is provided by Merriam (1988): an ‘interpretive case study’ which seeks to develop conceptual categories or theories, moving past description or refining of existing theory towards construction or suggesting relationships between variables. ‘A case study researcher gathers as much information about the problem as possible with the intent of interpreting or theorizing about the phenomenon’ (Merriam, 1988, p. 28). This approach allows for the interpretation of meaning based on inductive analysis of data, aligning with the interpretive nature of this study, and allows for the use of sensitizing concepts (Charmaz, 2014a) such as productive disposition, self-concept, resilience and identity formation guiding inquiry.

The argument for broadening tools for gaining insight into children’s perspectives on mathematics has underpinned much study, for example (Ashby, 2009; Borthwick, 2011; Masingila, 2002; McDonough & Sullivan, 2014; Tan & Lim, 2010; Walls, 2003a, 2009). Although this research has qualitative data collection at its heart, it draws on quantitative data where this supports the process of building a fuller picture of the participants and their mathematical lives. Qualitative data collection methods such as scrapbooks, group interviews, visual methods and pupil interviews were supplemented by the use of numerical information such as mathematics assessment levels to shed light on emerging themes and contextualise the data (Brannen, 2005).

Given that this research took place in the context of a professional doctorate with its focus on enhancing professional practice, the advantages of case study with its ‘face-value credibility’ and reporting format which is accessible to the audience and provides illustrative examples the reader can identify with (Demetriou, 2013, p. 257) are worth noting, and guided the approach taken within the presentation of results. This study:

- Was bounded by time and activity;
- Involved the collection of detailed information drawing upon a variety of data collection methods and taking place over a sustained period of time;
- Made use of a context providing contextual conditions ‘highly pertinent to the phenomenon of study’ (Yin, 2009, p. 18), in this case a group of high-achieving but less confident girls in a school concerned about a gender imbalance.

It is therefore positioned as a grounded, interpretive case study, drawing on the tools of constructivist grounded theory set out above to develop understanding of the perceptions a group of girls have of mathematics and the consequences for girls’ relationship with the subject.

3.3.3 Listening to children: pupil voice, pupil perspectives and the Mosaic approach

‘If children’s ‘voice’ is being sought, then children have to be positioned as participating subjects, knowers and social actors, rather than objects of the researcher’s gaze,’ (Smith, 2011, p. 14). The United Nations Convention on the Rights of the Child (United Nations, 1989) was a catalyst for pupil consultation and participation in research relating to their education gaining traction, as opposed to children being purely the object of research (Flutter, 2007; Kellett, 2005; McIntyre, Pedder, & Rudduck, 2005). An approach based on researching pupil perspectives involves assuming that children are competent and have the expert knowledge about their own childhoods (Dockett, Einarsdóttir, & Perry, 2011; Kellett, 2005), whilst acknowledging that children’s competence to communicate their views will be subject to the same constraints as adults (for example children of lower socio-economic class may be disenfranchised if data collection methods are not carefully planned (McIntyre et al., 2005)) and change over time. It was noticeable over the course of the study as children moved from Year 4 towards the latter stages of their time in primary school that their confidence and agency grew, not only in communicating their views but in developing skills they could draw on in future research of their own. This may also have been linked to their developing trust in myself as the researcher and understanding of the nature of the project.

A distinction can be drawn between pupil voice and pupil perspectives, although sometimes these terms are used interchangeably. Pupil voice research can be seen as inviting children to discuss their views on school matters, generally with a view to teacher development and school improvement (Flutter, 2007; Houssart & Barber, 2013; Rudduck & Flutter, 2004). A further example can be seen in the work of Lee and Johnston-Wilder (2011) in investigating the development of a more mathematically-resilient community of secondary-aged girls, with the involvement of student ambassadors, questionnaires and journals used alongside field notes and discussions used to build understanding of the topic. In suggesting that researchers should be realistic about their potential to instigate and sustain change, Warwick and Chaplain (2013) suggest it may be more appropriate to emphasise pupil perspectives rather than pupil voice. Capturing children's perspectives includes the following underlying assumptions:

- There are a range of complex and interacting factors influencing learning, not all under the control of the teacher
- Pupils may have views on these factors which differ significantly from those of other children or adults
- Empirical data should be collected to gain pupil perspectives
- The process should include reflecting upon the potential significance of research findings (Warwick & Chaplain, 2013)

To this list I would add the importance of research involving children being of benefit to the children themselves, involving some kind of reciprocity between the participants and researcher (Sikes, 2004). A drawback of pupil voice research occurs if pupils perceive no positive impact of sharing their views, particularly when findings are 'uncomfortable' for teachers (McIntyre et al., 2005). For these reasons this research is positioned as pupil perspectives research, with the focus upon children's perceptions of mathematics in their lives rather than upon classroom practice.

One researcher genuinely attempting to research views of mathematics from the child's perspective is Fiona Walls. She points out the 'noticeable omission of learners' perspectives in recent evaluations of numeracy project effectiveness', (Walls, 2003a, p. 1) although she acknowledges that within her research, which deployed interviews with children and parents, questionnaires and children's drawings, there are constraints upon how we can interpret children's ability to speak willingly and communicate their own ideas as well as their conscious awareness of the ideas she was interested in. This research attempted to overcome these limitations by adopting what might be termed a 'Mosaic' of approaches.

Developed to investigate the perspectives of three- and four-year old children, the Mosaic approach is based on the principle that children not only have a right to be heard but also that drawing on a wider range of communication tools such as drawing or taking photographs can in turn serve as a 'springboard' for further talking, listening and reflecting (Clark & Moss, 2011, p. 6). The Mosaic approach essentially comprises gathering documentation through a multi-method approach, and piecing together this information for dialogue, reflection and interpretation by participants in the process.

‘Listening’ is framed as not only giving children opportunity to articulate their perspectives and experiences, but to communicate through photographs, drawings and actions. The notion of building a picture through multiple methods of data collection then piecing these together underpinned the research design of this study and was particularly important when tapping into a complex concept such as mathematical identity.

3.4 Gathering data

Studies exploring perceptions of and attitudes towards mathematics have often been aimed at adults, adolescents or pre-service teachers (McDonough & Sullivan, 2014) or employed quantitative methods not originally developed for use with primary-aged pupils (Houssart & Barber, 2013; Walls, 2003a) such as rating scales. Having established within the review of literature that beliefs about mathematics are a valid and worthwhile construct to investigate, as Ruffell, Mason, and Allen (1998) summarise ‘there remains the problematic process of tempting people into revealing them’ (p. 17). Reviewing approaches taken to studying attitudes to mathematics, alongside strategies such as rating scales they list approaches such as asking children to respond to open-ended probes (I like learning mathematics when…), producing diagrammatic representations of themselves, take part in group interviews or listing what they thought mathematics was about. Drawing on the literature reviewed, all these methods and more were considered alongside the development of scrapbooking as an open-ended method of initial data collection.

3.4.1 The pilot project

A limited pilot study was carried out in the summer of 2013 at a large primary school in south-east England. The purpose was to try out and refine data collection plans, in particular the strategy of putting digital cameras into the hands of children and asking them to keep scrapbooks incorporating photographs taken of ‘mathematics’ in the home and anything else that showed ‘mathematics’.

The site for the pilot study was chosen for convenience. The middle attaining class of three in Year 5 were invited to take part after discussion with the head teacher and class teacher, and both boys and girls were involved. Full ethical processes were followed to gain informed consent (see Appendix 1 for University of Reading ethical approval form).

The pilot was launched with 32 children, who borrowed cameras for approximately 10 days on a rolling programme. The project was launched through discussion of a short presentation (Appendix 2), then children brainstormed ideas for what they could include within their scrapbooks. Overall 18 scrapbooks were handed in, five of which did not have permissions paperwork from both parents and children. Of the 13 scrapbooks remaining, on the day I went in to conduct informal group interviews, 10 children were available.

From an informal analysis of the scrapbooks and group interviews, the following pointers for the main study emerged. On the positive side, the use of cameras worked well, and children happily combined their photographs with their own written and drawn entries. Their scrapbooks clearly had the potential to provide insight into their perceptions of mathematics. Two contrasting examples illustrate this point (Figures 3.1 and 3.2):

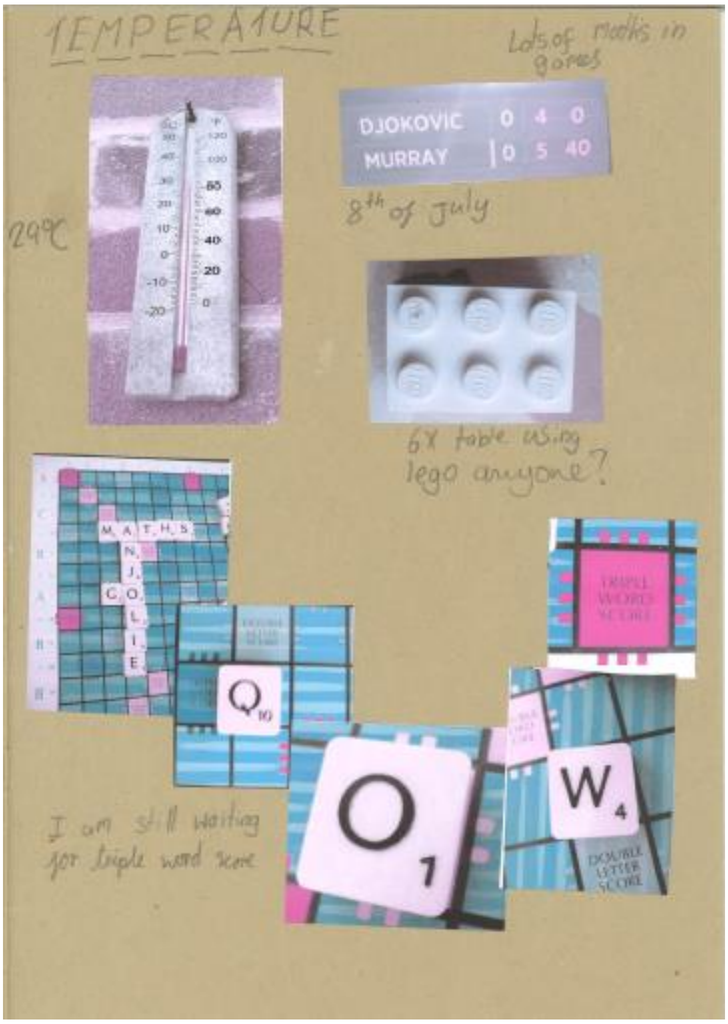


Figure 3.1 Entry to scrapbook, female, June 2013

This kind of entry showing a range of interpretations of mathematics including games, arrays and measures was in stark contrast to those such as Figure 3.2, in which a child has chosen to include extensive examples of times tables to represent mathematics.

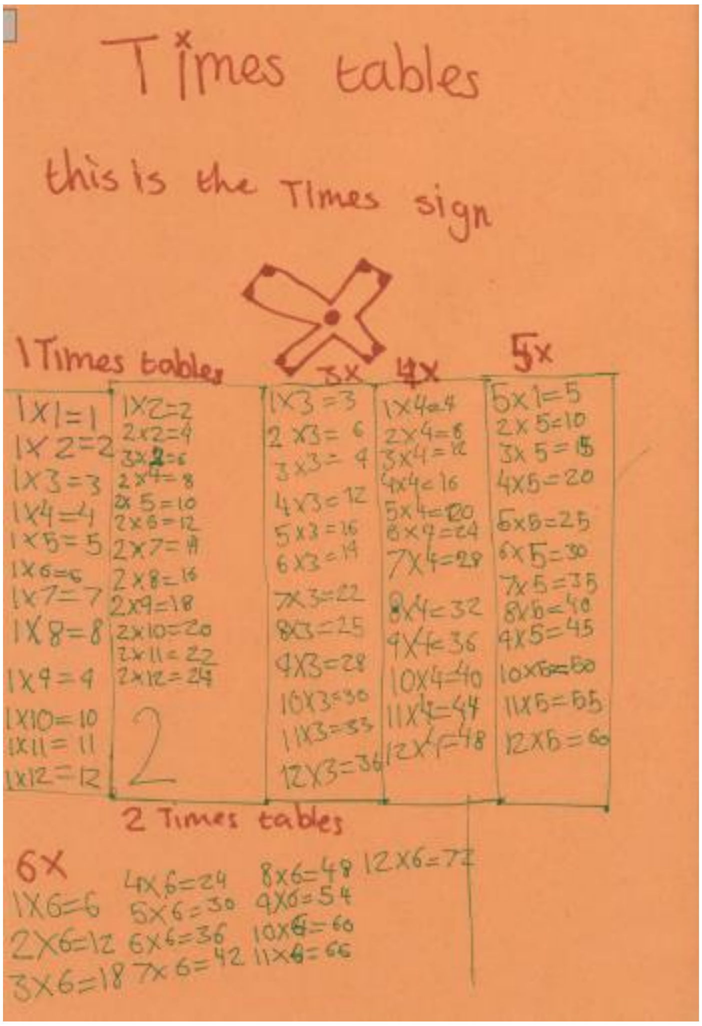


Figure 3.2 Entry to scrapbook, male, June 2013

Within the group interviews children were enthusiastic, engaged, and more than capable of articulating their views about their scrapbooks, the mathematics they contained, and the processes of the research. In terms of planning the main phase of data collection, the pilot was invaluable and the lessons learnt included:

1. The permissions process would be key, including good communication with the class teacher as gatekeeper and possible face-to-face meetings with parents to gain their trust;
2. Trying to manage the process of using cameras and selecting and printing photographs with the whole class was unrealistic, for a researcher not based on the school grounds. It would be necessary to be selective about which children were involved in the study;
3. The research design would need to allow for quality time for children to explain the rationale behind their choice of photographs to include and other entries to their scrapbooks, along with multiple sources of evidence to build a picture alongside the scrapbooks.

These lessons informed the details of data collection methodology set out below. In combination with the reasons set out in the introduction and literature review around gender and mathematics, they also supported the decision only to collect data from girls within the main phase of the study due to the ability of the data to shed light upon girls' perceptions of mathematics without the need of comparison and confirmed the value of the selected data collection methods to tap into the area of interest.

3.4.2 Contextualising the case: the school and participants

In case-study research, the choice of location for the study is key in terms of its ability to illustrate the features of interest (Silverman, 2010). The choice of school location for the study was purposive; I knew the head teacher well, having worked together within initial teacher training programmes and visited the school on many occasions. Through this relationship I became aware of the pattern over several years of boys, particularly at the higher end of the attainment range, outperforming girls. In discussion with the head teacher, the following themes were identified (see Appendix 3):

- Girls entering school with the pre-conception that 'boys do maths'
- Girls being under-confident in mathematics in comparison with boys, regardless of ability
- Girls being less willing to put themselves forward or have a go at mathematics unless they were certain they were right
- Observable differences in classroom behaviours towards mathematics, for example differences engaging in mathematical tasks in the early years foundation stage (EYFS) through to girls' unwillingness to ask or answer questions
- Peer pressure amongst the boys to do well at mathematics
- Girls being under-represented historically in the high attaining group for mathematics

Additionally the school, a one-form entry primary school located in the south-east of England, was in reasonable travelling distance and keen to become better informed about how they might guard against gender-based differences in confidence and attainment in the future.

Mathematics at the school is taught within mixed-attainment groups, apart from the weekly withdrawal of the highest-attaining pupils for smaller group teaching by the mathematics subject leader. Over time the gender of children within this group had become very unbalanced, leading to a situation where the majority of the members, the highest performing children in each junior class, were male. This selection policy was revised in 2014, so that the highest attaining boys and girls in each class were identified and the gender balance was equal. The head teacher reported that the running and make-up of this group is something the school struggles with each year, as it can be seen as an 'elite'. The decision to ensure that the genders are balanced has led to some girls taking part in the group who in the words of the head teacher ‘perhaps shouldn’t be in there, and struggle’ (see Appendix 3, discussion with HT). In this document the group is named ‘HAG’ (high-attaining group). Its real, more imaginative name cannot be used in order to preserve anonymity.

As stated in the school prospectus, the ethos of the school involves promoting positive attitudes to mathematics, emphasising mathematics that is enjoyable and relevant, developing mental agility and maintaining high expectations (School Prospectus, 2015). This was a particularly interesting location for studying gender and mathematics, as mathematics in the school has two extremely strong female mathematical role models – the head teacher and mathematics subject leader, both of whom have a strong grounding in and love for mathematics. The school follows the National Curriculum (DfE, 2013a), and was graded ‘good’ by the Office for Standards in Education (OfSTED) inspection process in 2013 (OfSTED, 2013). Within this report progress in mathematics was deemed ‘good’, with attainment including the proportion of children with above-average attainment much higher than the national average. In the academic year 2013-2014 the school had 3% of children eligible for free school meals, 7% of pupils learning through English as an additional language, and 6% of pupils with a statement of special educational needs or on School action plus (DfE, 2014c). Figures have been rounded to the nearest whole number to preserve anonymity.

The age of the children involved in the study was given careful consideration. Two of the early researchers in the field suggested that girls make the decision to disengage with mathematics at around 12-14 years of age (Burton & Townsend, 1986). However, at least some of the reasons for this disengagement appear to emerge much earlier. McDonough and Sullivan (2014) found that children had not only developed beliefs about mathematics but could clearly articulate them by the age of 8-9, reinforcing Kelly’s (2004)findings that children had made the decision mathematics was not pertinent to the world beyond school by the end of their primary years. In fact evidence suggests that gender gaps in mathematical confidence are already significant by the time children become seven (Lubienski et al., 2013). In order to respond to the data collection methods, children needed to be able to communicate in written form and verbally, operate cameras and select images digitally and work independently. As key gatekeepers, it proved immensely helpful that the class teachers were experienced, willing to facilitate data collection, and enthusiastic about the research aims. These considerations led to the selection of girls in Year 4 aged 8-9 at the onset of the research, a cohort of 14.

In terms of mathematical attainment, at the start of the study the girls ranged from National Curriculum level 3a (slightly above the average attainment expected by the end of Year 4) to level

4a (around the expected attainment for a child exiting primary school) – in other words all were of at least average attainment, as judged by teacher assessment (see Table 1).

Over the course of data collection individuals were absent for specific activities, however none withdrew from the study (names are pseudonyms).

Participant	Mathematical attainment at start of Year 4 (teacher assessment)	Mathematical attainment at end of Year 5 (teacher assessment)	Attended high attaining withdrawal group (HAG)	Received pupil premium
Jasmine	3b	4a		
Aimee	3a	4a		√
Alice	3a	4a		√
Emily	3a	5c		
Lauren	3a	4a		
Mackenzie	3a	4b		
Poppy	3a	4b		
Tilly	3a	4a		
Hetty	4c	5c		
Skye	4c	5c		
Millie	4b	5b		√
Polly	4a	5b	√	
Sally	4a	5b	√	
Taylor	4a	5b	√	

Table 1 Background participant information

3.4.3 Data collection methods: building a picture

Operating within an interpretive paradigm and exploring identities which are multiple, dynamic and socially-constructed demanded multiple approaches to gathering rich, situated data. The research combined approaches, using my analysis and interpretation of child-generated artefacts such as scrapbooks to frame questions and lines of enquiry, and children's own diagrammatic representations of mathematics, photographs, scrapbooks, metaphors and drawings to prompt discussions within group interviews and individual pupil interviews. Each of these methods formed an element of the mosaic being used to build a picture of the girls' perceptions of mathematics, as illustrated in Figure 3.3.

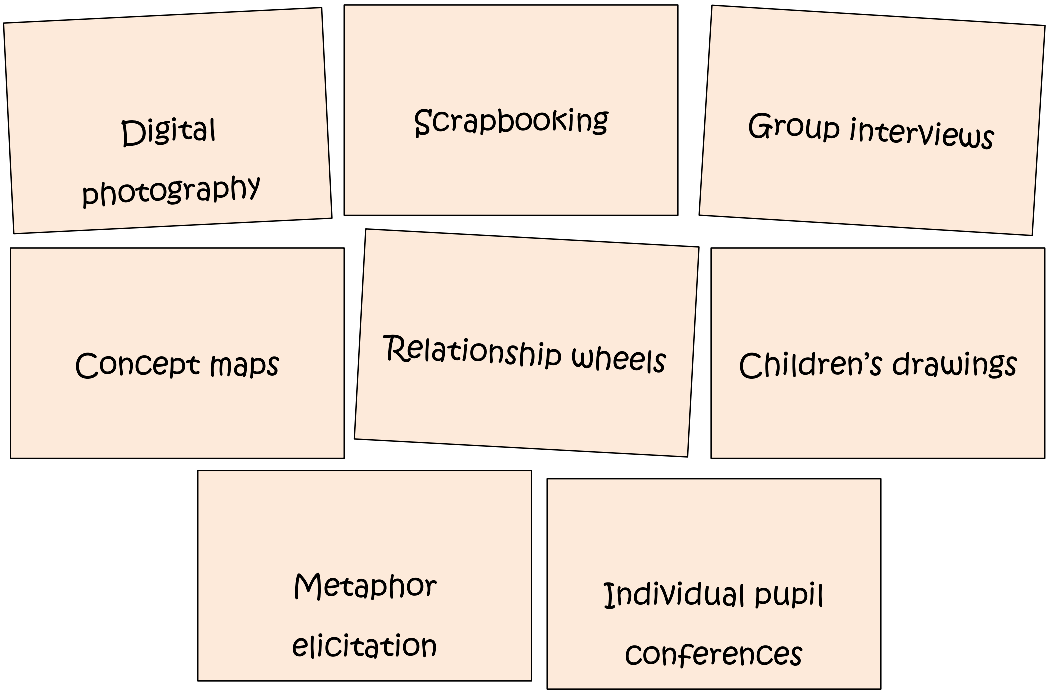


Figure 3.3 Multiple methods of data collection

These tools are explained below roughly in the order they were deployed, with group interviews discussed alongside pupil conferences as the two verbally-based data collection methods.

3.4.3.1 Digital media – photography

The increased availability of digital technology provides an opportunity to listen to children in new ways (Morgan, 2007), and putting cameras into the hands of children was a key element of my methodology, informed by the increasing prevalence of participatory photography and photo-elicitation or photovoice in health and social justice research as well as education, for example Warne, Snyder, and Gadin (2012). Photovoice aims to empower participants through giving them control of data collection and reducing reliance on language-based communication (Harkness & Stallworth, 2013; Kaplan, Miles, & Howes, 2011; Nelson & Christensen, 2009). Whilst there are potential limitations of an approach incorporating digital photography, for example poor quality of images, factors skewing selection of images and challenges with analysis (Cohen et al., 2011), I decided the advantages in terms of providing an engaging way to involve children in data collection outweighed these potential problems. Similar to the methodology deployed by Jay and Xolocotzin (2014), part of the role of photography was to bridge the gap between activity carried out at home and at school.

Using funding provided by the researcher's institution, 10 Fujifilm digital cameras were purchased and based at the school for the duration of the study. They were specifically chosen to be robust for use by children, shockproof and waterproof. Cameras were used by children in two ways:

1. From the beginning, girls took it in turns to take home cameras to take pictures of ‘mathematics’ to include within their scrapbooks (see Appendix 4 for full guidance). They were encouraged to be selective in which photographs they printed, avoiding images which included identifiable images of people. These photographs were discussed within the group interviews at the end of the first term of data collection.
2. Later in the study, guidance was updated to ask children to start including photographs of ‘mathematics’ in the school grounds. They selected just three photographs to put onto one page which summarised what mathematics meant to them, and these were used as a basis for discussion within individual pupil interviews.

Alongside the potential to generate evidence not necessarily available via other means, and provide distance from children’s experiences to allow for reflection, a third more pragmatic reason for using photography is that it is easier to involve participants in visual research as they see taking photographs as fun (Rose, 2013). Keeping this in mind, along with the age of the participants, they were given as free rein as possible to enjoy using the cameras, with the open-ended prompt of taking images of anything to do with mathematics. It was hoped this would provide an insight into what the children perceived as constituting mathematics or mathematical activity that was richer than could be discerned through questioning. Throughout the study decisions about which images were selected, printed and included within scrapbooks were left to the children, although the rationale for why I was asking them to take photographs of mathematics was discussed. Children utilised free time within the school day to print their photographs, using computers and a printer in the computer suite and paper and ink provided by the researcher.

3.4.3.2 Documentary methods – scrapbooks

The idea of using scrapbooks as a strategy for exploring the girls’ perceptions of mathematics arose from a number of sources, not least my experience of working with primary-aged children. There are few instances of scrapbooks or journals being used within mathematics education research. Those that do exist tend to focus on the use of journals as a tool for children to explore and explain their developing understanding of an area of mathematics (Coles & Banfield, 2012; Kostos & Shin, 2010; Wolfe, 2013). In this context, writing and drawing about mathematics proved a useful tool for children to document their learning, consider patterns and summarise thinking (Coles & Banfield, 2012). Recently the keeping of scrapbooks has emerged within the growing field of visual research with children and young people; they provide a method accessible to children at a range of levels of literacy and development and allow participants to ‘play’ with different ideas and identities without the presence of the researcher (Bragg & Buckingham, 2008, p. 118), making them a pragmatic tool in data collection when the researcher is not based on site.

Within their research, Bragg and Buckingham (2008) utilised the term 'diaries' with the children, and admitted that this may have had an impact on both the style and gendering of the responses. Working with younger children, Kostos and Shin (2010) preferred the word 'journal', defining it as 'an ongoing record that people use to record their thoughts, occurrences, experiences and observations' (Kostos & Shin, 2010, p. 225). I decided to use the term 'scrapbook' hoping this would emphasise the idea of piecing together impressions of mathematics through inclusion of a range of artefacts, writing, drawings and photographs.

The purpose of the scrapbooks was to provide an opportunity for children to record what mathematics was to them, place their photographs, and use as a prompt and support when discussing their ideas. It also extended the time available for them to engage with the research beyond the confines of direct interaction with myself. This method of data collection aimed not only to provide insight into which areas of mathematics children recognised in their daily lives and their characterisations of mathematics, but to shed light upon their emerging mathematical identity.

Introducing the idea to the children without dictating the contents they should contain was challenging; any examples were likely to skew what the children included. Having trialled this approach, I used one slide within the launch presentation as a prompt to encourage them to incorporate images, artefacts, their own photographs, writing or drawings as they saw fit (Figure 3.4) in order to share with me their perceptions of mathematics. Although chosen to be as bland as possible, all images carry meaning and in hindsight the inclusion of images such as measuring equipment and dice may have been unwise.

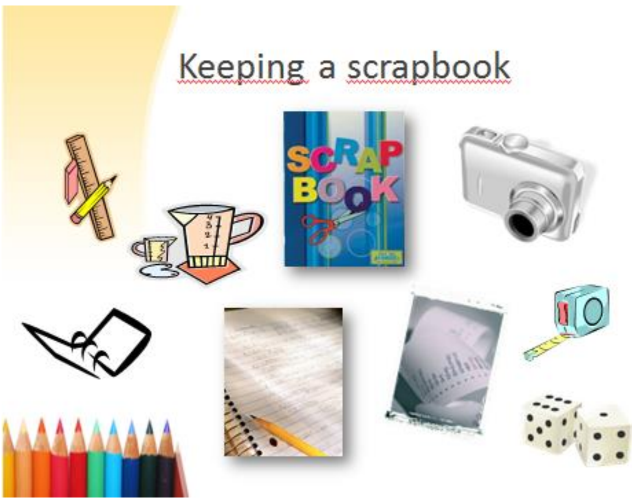


Figure 3.4 Image from launch presentation

Children were first given the scrapbooks, A4-sized with coloured unlined sheets, at the same time the cameras were distributed. At first the girls had many questions about the scrapbooks, including whether they could talk with people about them (yes) and whether they had to do things in them every day (no).

Over the course of the research I learnt to be relaxed about the scrapbooks – I had taken a decision to place ownership of these into the hands of the children, and had to accept whatever they wanted to represent in them, however extensive or minimal.

3.4.3.3 Image-based research – concept maps, relationship wheels and children's drawings

In order to investigate further the girls' mathematical identity and factors within its development, a range of short activities were carried out to gather 'responder-generated' visual data (Prosser & Loxley, 2008). These were inspired by the methods employed by visual researchers (Prosser, 1998; Prosser & Burke, 2011) and confirmed as effective tools more recently by mathematics education researchers (McDonough & Sullivan, 2014). Visual methods have gained ground in recent years as a method for exploring research questions, possibly due to their potential to generate a different range of evidence from that available by more conventional means, and to stimulate talk (Rose, 2013). Whilst there are potential limitations in using these visual approaches, for example the dangers of drawing conclusions from just one visual task (McDonough & Sullivan, 2014) and challenges of interpreting complex data and the requirement that children can respond visually, the use of a range of approaches was put in place to mitigate against these limitations. Strategies used for analysis are discussed below.

Concept mapping is based upon constructivist understandings of learning (Prosser & Loxley, 2008), and 'can be used as a tool to articulate children's perceptions, promote reflection, and generate and communicate complex ideas on a range of topics' (Prosser & Burke, 2011, p. 265). All 14 girls were present for the concept-mapping activity, which took place in a spare classroom during mathematics lesson time in September 2014 and aimed to tap into what the girls believed mathematics as a subject to comprise. To introduce the activity children were shown a simple concept map representing food, based on the work of Georghiacles and Parla-Petrou (2001) cited in Prosser and Burke (2011). After this they worked in pairs to generate a concept map for English to check that they understood how concept maps worked, then individually to represent mathematics. Emphasis was placed on labelling the lines between ideas to show relationships as well as the nodes, and children were encouraged to include anything they thought of when they thought of mathematics. Although they were asked to work individually and were spread around the room, they were in fairly close proximity leading to some influence on each other's ideas.

Relationship wheels were chosen as a data collection tool for their potential to shed light upon the influential figures in the formation of children's mathematical identity. This is similar to the word-wheel technique deployed by McDonough and Sullivan (2014) in which participants were asked to place the question ‘what is maths’ in the centre of the word wheel, surrounding it with their responses. This was adapted to an activity where children placed themselves in the centre, and were asked to put anyone they would link with mathematics around the spokes of the diagram (see Appendix 5 for blank proforma), explaining why they were there. They were encouraged to illustrate the sheets if they wanted to, and when some girls asked if they were allowed to show objects or animals rather than people, this was accepted. All of the girls were present for this activity.

Children’s drawings have been used by various researchers as a method for capturing children’s perceptions, feelings and beliefs (Mitchell, 2006). They provide an opportunity for children to communicate ideas they may not be able to articulate in words in a way that is fun and non-threatening (Merrimam & Guerin, 2006). At the turn of the century, Picker and Berry (2000) asked 12-13 year olds across 5 countries to draw a picture of mathematicians at work, a strategy echoed by Rock and Shaw (2000a), and more recently Borthwick (2011) asked children in Key Stages 1 and 2 to draw a picture of their mathematics lessons. These studies found that drawings provided fascinating insights into children’s perceptions of mathematics. In reviewing recent studies deploying the use of children’s drawings to understand key issues in their lives, Leitch (2008) stated the importance of following up the creation of images with opportunity for children to explain their responses, with the researcher aiming to hear the child’s ideas about what is happening in the images. This informed the final phase of data collection, the pupil interviews explained below.

In this case, children were given the simple instruction ‘Draw yourself doing mathematics. You could also annotate your picture to show what you are thinking’. The activity took place immediately after the metaphor elicitation task – when children finished one task they could move straight onto the second. All 14 girls were present, and the activity took place within the normal classroom with the teacher present. For all of the activities described in this section I was present having introduced the activity, but took a passive role whilst the children completed the activities, avoiding interaction where possible.

3.4.3.4 Metaphor elicitation

Metaphor elicitation has been employed as a tool for investigating beliefs and attitudes within different disciplines, including mathematics (Özgün-Koca, 2010; Rehner, 2004) and the field of second language learning (Fisher, 2013), and was thus considered as being a valuable strategy for the study. It allows young people to ‘articulate current beliefs and attitudes towards mathematics by comparing mathematics to more concrete items that they were familiar with outside of the classroom' (Rehner, 2004, p. 66). Metaphor can be seen as allowing the bringing together of incongruous ideas (Fisher, 2013), and within Fisher's research it was the process of generating and articulating metaphors, as well as the outcomes of the metaphors themselves, that was revealing, allowing participants to express beliefs they may have been previously unaware of and therefore unable to articulate in a more traditional questionnaire or interview approach.

Özgün-Koca (2010) deployed metaphor to explore attitudes, beliefs and emotions towards mathematics amongst 120 school students in Turkey. She found that some prompts, such as colour, led to references to emotions, whereas others such as asking children to respond to prompts such as 'if mathematics was a kind of transportation vehicle it would be…' (p. 6) led to insight into participant beliefs about the nature of mathematics, leading her to recommend using a range of prompts.

Although studying simile and metaphor is not included in the National Curriculum in England until Years 5 and 6 (DfE, 2014b), the class teacher confirmed that all children would be familiar and confident with these terms, and this was borne out during the activity introduction, when all children were able to give examples of both.

The metaphor elicitation task took place with the whole class during lesson time. The purpose was to shed light on the research questions 'How do the participants characterise mathematics?' and 'how do they position themselves as mathematicians?' Children were seated in mixed-attainment, same or mixed-gender pairs but encouraged to work individually. After a brief introduction, a poem was explored (see Appendix 6) which illustrated the use of simile and metaphor to describe a book and set the context for the activity. Children were then given a pro-forma (see Appendix 7) with a series of prompts to complete: if mathematics was …

- … a food
- … a kind of weather
- … a colour
- … an animal
- … a vehicle

…it would be … because ….

Emphasis was placed on the importance of explaining why particular responses had been chosen, and children were allowed to illustrate their ideas. For practical reasons this piece of data collection was conducted with the whole class, however the boys' work was not analysed or included within the study.

3.4.3.5 Verbal methods – group interviews and pupil conferences

Interviewing is used throughout social research as a key strategy for investigating participant perspectives. As Kvale and Brinkmann (2009) point out: 'If you want to know how people understand their world and their lives, why not talk with them?' (p. xvii). Many researchers have employed interviewing techniques to gain insight into the views of participants about mathematics, such as Young-Loveridge et al. (2006), who interviewed six- to 13-year olds using questions such as "What if a spaceship landed on the field, and the people came into your school and wanted to know what is this thing called maths that you kids do, what would you tell them?" (p. 57). A limitation of this approach is that children can only respond with ideas they are already aware of, and the results may be subject to response or social desirability bias (Bryman, 2012) whereby participants look for what the researcher wants and respond accordingly. Children can be eager to please unless the researcher takes steps to mitigate against this kind of bias through making questions clear and non-leading and avoiding becoming overly friendly with participants (Warwick & Chaplain, 2013). More recently McDonough and Sullivan (2014) provided a range of prompts and activities such as drawings created by the participants, photographs, personal dictionary procedures and word-wheel responses as a stimulus for discussion, aiming to create a more rounded view of children's beliefs about mathematics than could be achieved with traditional interviewing techniques.

Two different types of interviews were deployed within this study. The first, semi-structured group interviews, came after the first term of girls using the digital cameras and scrapbooks to build up a picture of mathematics in their lives, and the second, individual pupil conferences, came at the end of the study after other data collection methods were complete.

Group interviews took place with groups of five, five and four girls respectively. The first was conducted in the classroom whilst the rest of the class were outside, and the other two in the music room during 'finishing off' time. All three lasted approximately 25 minutes, and were digitally recorded and subsequently transcribed. Children were seated in a circle with the researcher to take advantage of one of the benefits of group interviews, that despite being inevitably artificial they are more similar to a normal classroom discussion than other techniques. The group interviews were semi-structured, with guiding topics and prompts (see Appendix 8) but with the flexibility to pursue lines of enquiry stimulated by responses and the 'interplay of perspectives' (Warwick & Chaplain, 2013, p. 70). By this point in the study, the girls had begun data collection and brought along to the interview their scrapbooks, frequently referring to the contents and helping to keep my questions and their responses grounded through the use of photographs and artefacts (Bryman, 2012). The main purpose of the group interviews was to establish whether the scrapbook methodology was generating rich data.

A danger of group interviews is the potential for group dynamics to take over and assertive members of the group to dominate (Warwick & Chaplain, 2013): rules such as turn-taking and listening were established at the beginning, and in one group it became necessary to establish the use of a 'special pen' which children held when they wanted to talk.

The individual pupil conferences were held after the other methods of data collection, and used the range of data gathered as a stimulus. The main purpose was to probe further the second group of research questions, around how the girls position themselves as mathematicians and what factors influence these perceptions and their self-efficacy. The interviews also provided an opportunity to probe further what was shown in previous drawings or photographs created by the children, particularly useful when images or writing were indistinct. Following the advice of Thomson and Hall (2008), the interviewer and child sat next to each other rather than opposite, with the range of data including drawings, photographs and scrapbooks spread out on the table. Thus these became the focus of the early stages of the discussion, helping to put the children at their ease using prompts such as 'tell me about your picture' and 'could you say a little more about…'.

Interviews took place in an open room immediately opposite the classroom, which was sufficiently quiet to provide a calm environment but familiar to the children and overlooked by adults and other children moving around the school. A schedule was used to provide sufficient structure to cover key topics, whilst allowing flexibility to allow emergent lines of enquiry (see Appendix 9). Interviews lasted approximately twenty minutes, and were digitally recorded and subsequently transcribed.

3.4.4 Timescale

Although not longitudinal in focus, as there was not a primary concern to map change of time (Bryman, 2012), data collection points were spread over approximately one calendar year. This was chiefly for practical reasons: firstly, to manage data collection alongside a full-time job, secondly to allow for the multi-layered data collection to run its course, and finally to ensure the participants were not disadvantaged through time spent interacting with the researcher and gathering data rather than in lessons or relaxing, engaging with hobbies or doing homework. An additional benefit was to allow for the analysis and comparison of themes over time. The data collection events are set out in Table 2.

Phase	Date	Who	What
Pilot	May 2013	Year 5 children	Pilot launch Keeping of scrapbooks

	July 2013	Year 5 children	Focus groups
Main	April 2014	Year 4 girls	Launch of research project Ethical approval obtained
	May-July 2014	Year 4 girls	Initial scrapbook data collection Cameras given out
	July 2014	Year 4 girls	Group interviews
	July 2014	Head teacher	Informal interview to gather background data
	September 2014	Year 5 girls	Concept mapping of mathematics
	October 2014	Year 5 girls	Second phase scrapbook data collection
	February 2015	Year 5 girls	Relationship wheels
	March-May 2015	Year 5 girls	Final phase scrapbook data collection
	May 2015	Year 5 girls	Metaphor elicitation and drawings
	June 2015	Year 5 girls	Individual pupil conferences

Table 2 Schedule of data collection

3.5 Working with participants

The research involved working with a wide range of gatekeepers, teachers, and child participants, along with communicating with parents and other members of the school community. The implications of insider research, the role of the children and ethical issues are explored next.

3.5.1 The role of the researcher: insider research and reflexivity

The role of the researcher within an interpretive paradigm can be seen along a continuum – at one extreme there is a direct participant observer, involving themselves 'in all aspects of the lives of those being investigated', and at the other is a non-participant observer remaining aloof at all times (Warwick & Chaplain, 2013, p. 67). In reviewing different approaches to studying attitudes to mathematics, Ruffell et al. (1998) position the relationship between the researcher and the researched as crucial, not least how the researcher is perceived by the children.

Although not strictly an 'insider researcher' (Alderson & Morrow, 2011) as I am not employed or based at the school, I was a known 'face', having visited on numerous occasions within my role in initial teacher training, and even taught this particular class on one occasion. This brought with it the advantage that I was a trusted member of the school community, which alongside the positive endorsement of the head teacher undoubtedly was an influencing factor in 100% of parents agreeing to their children's involvement in the research. The disadvantage was the risk that I was seen in a position of authority and power, with the concomitant risk of social desirability bias –

would the children simply tell me what I wanted to hear? Steps to minimise this were taken throughout the study, including taking time to establish a trusting research relationship which can minimize children's tendency to try to supply the 'right' answer (Harcourt & Conroy, 2011), but its inevitable effects are acknowledged and discussed within the section on quality.

A distinction can be drawn between reflection upon the processes involved in a study and reflexivity, the ability not only to consider the researcher's position and its influence upon the study and its findings but to acknowledge that the researcher is 'both integral and integrated into the research' (Savin-Baden & Howell Major, 2013, p. 76). In my case my background involves being: female; a former primary-school teacher; educated; passionate about mathematics and its importance; involved in initial and in-service teacher education; white and middle class; a parent. Any and all of these will have shaped my interpretations of data and affected my interactions with participants throughout the research process (Creswell, 2009); they cannot be changed but they are acknowledged within the process of data interpretation and analysis.

3.5.2 Children as active participants

Children in research can be positioned as leaders of participant action research at one extreme, and objects of adult-led research at the other. Although this research is not completely participatory as much of the power lay with the researcher, the aim matches that articulated by Pascal and Bertram (2009), that there should be 'mutual respect, active participation and the negotiation and co-construction of meaning' (p. 254) and concurs with the view that research with children does not have to have been initiated by them in order to be meaningful (Anderson, 2015). Throughout, the girls were encouraged to take ownership of when they took the cameras home, the extent to which they engaged in collecting materials for their scrapbooks, and what they did and didn't want to include or discuss.

A key question is whether research with child participants should be treated the same as or differently from research with adults. If they are seen as 'competent social actors', does this necessarily imply they do not need special 'child-friendly methods' (Dockett et al., 2011, p. 71), or do approaches need to be tailor-made to support pupil participation? There can be a danger in assuming children will prefer methods such as painting, drawing or playing as a way of communicating their beliefs. In conducting a range of studies with children Dockett et al. (2011) found that often children preferred what they saw as being adult research approaches such as structured interviews. The range of data collection tools used in this research was designed to provide both familiar, 'child-friendly' methods and more traditional data-collection techniques.

As with any research involving active contributions from participants, self-efficacy is important. For children to contribute actively and honestly to research, they have to believe that they have something important to say, and that they will be listened to (Lee & Johnston-Wilder, 2013).

3.5.3 Ethical considerations

Ethics within educational research involve making choices 'on the basis of moral and ethical reasoning' throughout the research process (Basit, 2010, p. 56). The aim was to develop an 'authentic research relationship' with children (Harcourt & Conroy, 2011, p. 49). Key steps in this process were:

- Dedicating time to establishing a research relationship, and thinking about the exit strategy at the end of the research (we agreed I would revisit the girls before they left primary school)
- 'informing' children carefully and thoroughly, for example through talking through my role at the University and motivations for undertaking the study
- Re-affirming initial consent and the right to withdraw at the beginning of each new encounter with the children (Harcourt & Conroy, 2011)
- Understanding that there may be times when individuals prefer not to engage with the researcher or a data collection method

Specific ethical procedures were approved by the University Research Ethics Committee (see Appendix 1). All ethical procedures were designed to be accessible to children (see, for example, smiley-face consent forms – Appendix 10) and parental permission was sought. Included within the British Educational Research Association guidelines is the statement that researchers must 'seek to minimise the impact of their research on the normal working and workloads of participants' (BERA, 2011, p. 7). This was one of the greatest challenges for this research and required constant review, along with an acceptance that the information children recorded in their scrapbooks over particular periods of time might be minimal.

Voluntary informed consent and right to withdraw

From the beginning, the girls needed to understand the nature of the research, its purpose, and exactly what would happen to them and their data (BERA, 2011). Initially this was achieved through meeting, explaining the research and answering any questions. Children then had an information leaflet (Appendix 11) and consent form (Appendix 10) to discuss with their parents and return. Gaining informed consent was an evolving process; when it emerged that it would be beneficial to interview individual pupils and conduct additional data-gathering activities, children received an additional consent form asking them to confirm their willingness to continue.

Before the research began, parents and carers received a letter outlining the research and inviting them to an after-school meeting to find out more (see Appendix 12). During this meeting they received a copy of the children's information leaflet, an information sheet and accompanying 'opt-in' consent form (Appendix 13). They also received an update letter in July 2014 and a further update in March 2015 giving them opportunity to opt-out of permission for their child to take part in the pupil conference.

Permission was sought from the head teacher for the research to take place and to be interviewed for background data about the school context. This was updated in March 2015 to gain permission for children taking photographs in the school grounds and individual pupil interviews (see Appendix 14 for an example). Throughout, the research supervisor and head teacher were consulted on the evolving ethics of the research.

The right to withdraw was set out within all of the paperwork detailed above and reiterated at the beginning of all data-collection activities. It was respected throughout, for example on one occasion when a child decided not to continue with completing the scrapbook at home as she was finding it difficult to fit in to her hobbies.

Openness and disclosure

The BERA guidelines (2011) state clearly any subterfuge in research must be carefully considered and justified. The dilemma within this research was whether to reveal to the children the specific focus on girls and mathematics and reason behind it. There is some disquiet in the literature that studying mathematics and gender can perpetuate stereotypes (Georgiou et al., 2007; McCormack, 2014), and also that alerting girls to gender differences in mathematics makes them more likely to respond negatively (Martinot & Désert, 2007). However, the need to build an open and authentic research relationship with the children along with the benefits of enabling them to reflect upon the questions being explored were more persuasive and the agenda was shared from the start.

Privacy and confidentiality

Confidentiality was maintained through changing identifying details, keeping data separate from names, and storing hard copies in a locked cabinet and electronic data on a password-protected computer. As predicted by Alderson and Morrow (2011), some children actually wanted their work acknowledged. Because this would have made them identifiable, to help children feel they had ownership of the data they were invited to provide their own pseudonym.

Visual methods

The need to preserve the anonymity of participants can be challenging set alongside the benefits of rich, situated visual data (Prosser & Loxley, 2008). Parameters were established around the use of digital photographs, including avoiding the inclusion of any photographs of identifiable people (for example, through avoiding pictures of faces). In using digital photography with children researchers should also be conscious of how the images will be shared and published (Anderson, 2015); in this case images were uploaded onto the secure, password-protected network of the school and researcher's laptop.

3.6 Analysis and interpretation

The range of data collection methods deployed within this study led to a large amount of visual, text-based and transcribed data, with the associated challenges for analysis. Despite the variety of data, the same basic approach was taken throughout, informed by Charmaz (2014a), which involved initial coding for topics and themes using constant comparative analysis, followed by focused coding to follow routes identified by initial coding and synthesize key themes.

A key issue within qualitative data analysis is the use of theory and lines of inductive versus deductive reasoning. In this case the reasoning was essentially inductive, proceeding on the basis of deriving principles from analysis and interpretation of the data rather than deductive, beginning with a stated argument and looking for supporting evidence (Thomas, 2013). As discussed earlier no researcher is free of pre-conceived ideas, and as Silverman (2010) points out it makes no sense to reinvent the wheel by pretending theories do not exist. Instead the data analysis was conducted using the idea of 'sensitizing concepts', which give 'starting points for initiating your analysis but do not determine its content' (Charmaz, 2014a, p. 117). These were derived from topics covered within the literature review and included the notion of productive disposition, self-concept, resilience and gendered identity formation, informed by the original research questions around how girls perceive mathematics (the areas of the curriculum they recognise within their lives and how they characterise the subject) and how they make sense of their mathematical identity (how they position themselves as mathematicians and what factors may affect this positioning). Although software packages are available to support qualitative data analysis, I chose to do this by hand, thus allowing me to maintain a global view of the data and the stories that were emerging (Evans, 2013) and stay close to the data.

3.6.1 Analysing interview data

Data from the group interviews conducted early in the study and the individual pupil interviews at the end of the data collection period were transcribed. Hesitations were recorded using ellipses, and occasional notes were included to indicate significant features such as a particularly raised or quiet volume, laugh or questioning tone (see Appendix 15 for an example transcript). Initial coding followed the guidance set out by Charmaz (2014a) to code line by line and keep codes simple and precise, coding for action to define what is happening in the data rather than for topics or types of people. In particular, coding was carried out using 'gerunds', the 'ing' form of the verb, which helped me to avoid 'leaping beyond participants' meanings and actions' (Charmaz, 2014a, p. 121) through keeping close to the actions and words of the participants. For example, three consecutive codes for lines within Millie's transcription were 'Doing maths quickly', 'knowing facts' and 'getting stuck'.

This initial coding of the transcript data led to a large number of codes or temporary constructs (Wilson, 2013). As each new transcript was read and coded, the list of codes was increased and amended through a process of constant comparison. The whole set of data was then re-read against these codes, noting where in the data they occurred. This allowed a review of which codes recurred most frequently, which were interesting but rare or unique, and began to provide insight into the themes emerging from the data. The next step was to carry out a process of 'focused coding', determining the 'adequacy and conceptual strength' (Charmaz, 2014a, p. 140) of the initial codes and identifying those that occurred most frequently, were most interesting or surprising or presented as an anomaly. The focused codes arising from the interview-based data were:

- Making and receiving judgements
- Looking to the future
- Seeing or not seeing the relevance of mathematics
- Characterising mathematics
- Characterising mathematicians
- Personal relationships with / reactions to mathematics
- Displaying resilience and perseverance
- Being influenced by others
- Working with / without others
- Using skills
- Having choice and helplessness

To analyse the frequency with which each focused code occurred as well as the distribution (for example, was an idea mentioned six times by one child or once by six children), colour coding was used to identify where each idea was located (see Appendix 16 for the focused coding analysis). A further part of the process was writing memos after analysing each transcript and at various points throughout the rest of the data analysis as key themes began to emerge. As predicted by

Charmaz (2014a) these memos allowed me to capture thoughts and comparisons, crystallize questions arising from the data and record hunches. See Appendix 17 for an example of a memo written after initial coding of one of the girls' transcripts.

3.6.2 Concept maps, relationship wheels and metaphors

Although these were diverse forms of data, the same essential process of 'reading' and becoming familiar with the data, initial coding, constant comparison across all fourteen sources of the same type of data, and focused coding in order to draw out key themes applied in each case. Particular analytical tools were then employed to shed light on emerging patterns. For example, the concept maps were each read in turn and coded. This long-list of codes was then analysed, and the codes clustered together into the overarching themes of:

- Content
- Context
- Labour
- Artefacts
- Affective factors (attitudes and emotions)
- Activities

There were a couple of codes which did not naturally group together such as mathematical tests and the role of creativity, which were noted as rare but interesting codes. Because the concept maps chiefly revealed information about the type of content children considered to be part of mathematics, a numerical analysis was carried out to further examine the mathematical content (see Appendix 18), revealing for example that the concept maps were dominated by reference to calculation and number. Silverman states that 'an apparently simple count of apparently basic features can raise a number of interesting issues' (2010, p. 244) and this was found to be the case both here and within the relationship wheels.

Because of the nature of metaphor, the metaphor elicitation task required analysis which could take into account both literal and figurative interpretation. An analysis was carried out to list and tally each child's responses in terms of food, weather, colour, animal and vehicle and whether these responses carried positive or negative connotations (for example mathematics being a lorry 'because it is big and hard to carry' (Lauren) versus mathematics being a lorry because it is 'long and I find maths long which is good' (Millie)). Initial coding, constant comparison and focussed coding as described above revealed the recurrent themes of features of size and speed across the data, mathematics having many parts, children's changing relationships with the subject and dissonance within the same statement (when children both did and did not like mathematics). See Appendix 19 for examples of analysis.

The relationship wheels were analysed in a similar way, with an initial analysis of who was included within each child's data followed by focused coding of emerging themes. Unexpectedly the verbs incorporated within the relationship wheels emerged as a potential line of inquiry, such as 'helps', 'teaches' and 'has faith' suggesting a key theme of needing or receiving support, along with the absence of anyone other than known individuals, and these were used as the basis for a numerical analysis of the relationship wheels. Appendix 20 presents the data on which this analysis was based.

3.6.3 Drawings and photographs

Drawings and photographs can be notoriously difficult to analyse (Merrimam & Guerin, 2006; Prosser & Burke, 2011). Thomson and Hall (2008, p. 160) point out that when discussing their drawings with the child participants in their study of self-portraits, they had already made a reading of the data 'startlingly at odds' with those of the child, leading them to conclude that 'adults can read visual texts in ways that are perhaps not very enlightening'. This led to a dilemma within data analysis illustrated by the photographs selected by Emily reproduced in Figure 3.5.

Figure 3.5 Emily's selected photographs

As the researcher and analyst my reading of the first photograph suggested that she saw mathematics as a collaborative activity carried out with friends, the second that mathematics led to future aspirations and career choices, and the third that it was a never-ending subject. However, the individual pupil conference suggested that Emily had taken the first because she liked taking photographs of feet, the second because we could ask how many bars there were, and the third because you could fill it with 'sums' and also the class had recorded calculations in the circle whilst doing a science experiment on the playground. Which of these analyses is more pertinent to answering the research questions? On the one hand the design of the research aimed to capture the pupil perspective. On the other, the whole point of using visual data such as drawings and photographs is that they allow children to reveal subconsciously held views or beliefs which are different to those revealed by methods based on speech or the written word (Thomson, 2008).

This dilemma was resolved by using member checking (Merriam, 1988) to discuss the images with the girls concerned. Using questions and prompts such as 'I noticed that' and 'tell me about' allowed me to check my initial impressions and coding of the drawings and photographs against the girls' interpretations and responses. Where these are contradictory, my interpretation is presented within the results chapters along with the accompanying evidence and transcript extract. The interviews confirmed some themes apparently arising from other data sources, strengthened others, and occasionally revealed red herrings.

3.6.4 Scrapbooks

Although originally conceived as the primary source of data collection, the scrapbooks ultimately were used chiefly to prompt discussion within the group and individual interviews. Initially these were analysed by a simple listing of the contents. These lists were then coded using the same process described above, with constant comparison against each new scrapbook. To gain a different perspective a short memo was written articulating impressions of each scrapbook, and an analysis of the curricular content of the scrapbooks was carried out. These differing analytical approaches revealed themes such as the rehearsal of school mathematics, involvement of a variety of extended family members, frequent inclusion of contrived questions and word problems, self-marking and associating mathematics with number and calculation.

3.7 'Quality' in qualitative research

It is open to debate whether the quality concepts developed for quantitative research such as validity, reliability and generalizability can or should be applied to qualitatively-based research. These are sometimes seen as not applicable to qualitative research where suggested concepts include credibility or trustworthiness (in place of internal validity), fittingness (in place of external validity) and auditability in replacement of reliability (Brannen, 2005). This leaves a dilemma of which concepts to draw on when making claims about the quality of a grounded, interpretive case-study incorporating chiefly qualitative data. Being framed as a grounded, interpretive case study, quality is discussed using the same terms as within Merriam's (1988) text: internal and external validity and reliability.

3.7.1 Validity

Internal validity essentially explores whether the findings 'capture what is really there' (Merriam, 1988, p. 166). Merriam goes on to point out that what is being observed is 'people's constructions of reality, how they understand the world' (p. 167), and that there are various strategies which can be deployed to ensure internal validity. The approaches he suggests and their use within this study are set out in Table 3.

Approach	Deployment within the study
Multiple sources of data	Key method for ensuring internal validity (for example scrapbooks, group interviews and individual pupil interviews, metaphors)
Member checking	Deployed within pupil interviews
Long-term or repeated observations	Data collection points were spread out over one year
Peer examination	Not used within this study: the study used member checking rather than introducing potentially conflicting voices from external 'experts'
Participatory modes of research	Participants were involved in shaping the evolution of the research and reviewing findings
Researcher's bias	Discussed in section 3.5.1 above

Table 3 Approaches to ensuring validity

The key element of ensuring internal validity was using multiple sources of data, establishing a chain of evidence for claims (Yin, 2009), and guarding against social desirability bias through building trusting relationships over time.

One of the dangers of taking an approach based on capturing pupil perspectives is that only the more confident and articulate pupils' voices might be heard (Flutter, 2007). The range of data collection tools set out above sought to allow the voices of all girls to be heard by deploying individually-based techniques such as pupil interviews, scrapbooks and metaphor elicitation as well as group interviews. A second danger can be 'enculturation' (Ruffell et al., 1998, p. 13), children reporting back what they have picked up from teachers or learned to say about their feelings. This led to the avoidance of relying solely upon asking children how they felt about mathematics in favour of analysing what was revealed through their photographs, metaphors and scrapbook entries.

In turn, external validity relates to generalisability, or the 'extent to which results may be assumed true for other cases' (Savin-Baden & Howell Major, 2013, p. 473). Rather than aiming for generalisation, this study aimed to generate useful concepts and 'working hypotheses' (Merriam, 1988) which might inform future practice as well as contribute to debate and theoretical understanding of this area.

3.7.2 Reliability

Given that reliability is generally seen as denoting that 'the research process can be repeated at another time on similar participants in a similar context with the same results' (Basit, 2010, p. 69), reliability is a problematic idea within social science research; because there are differences between people and over time, replicating the same study would inevitably lead to different results. Instead, the emphasis is on ensuring that all procedures have been ‘scrupulous, honest and precise’ (Basit, 2010, p. 70). To this end the data collection methods have been explained in detail, and the data analysis procedures following a grounded, constant comparative method are set out below and supported by accompanying evidence throughout the appendices.

Using visual research methods including photography posed particular challenges for validity and reliability. Rasmussen (2013) points out that when examining an image produced by a child we tell ourselves a story, which will be based on our preconceived notions of the child’s environment and development. The child’s story may well be different. Rather than trying to establish which story is truer, Rasmussen suggests that ‘stories that can never be understood independently of the context of which they are part and independent of the decoding perspective lying behind the photo’s reception’ (2013, p. 444). The approach taken here heeds the warning that all cameras are socially located and ‘’see’ from a particular, socially constructed viewpoint’ (Banks, 1998, p. 18); this was tackled through pupil interviews to discuss the origins of the images and acknowledged within data analysis.

3.8 Summary and key emerging themes

The final stage in data analysis involved extending constant comparison across the range of data collection tools, piecing together the analysis and looking for ‘saturation’, or the point at which ‘gathering fresh data no longer sparks new theoretical insights, nor reveals new properties of these core theoretical categories’ (Charmaz, 2014a, p. 213). The focused codes from across the analyses were put into a grid, and compared with the original research questions. This led to the following emerging themes which are examined in detail within Chapters 4, 5 and 6 respectively.

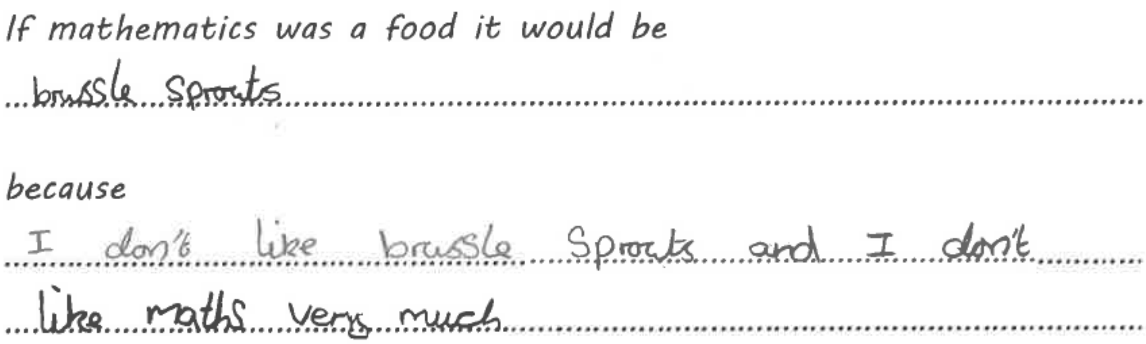
Chapter 4 explores the themes arising from analysis of children’s characterisations of mathematics, including the prevalence of number, speed and size, their tendency to see mathematics as involving contrived questions, and dichotomies in terms of right and wrong, hard and easy. The role of significant others including the feedback they provide and its impact on children’s self-concept is explored within Chapter 5, alongside key emergent themes of support, collaboration and isolation: although it began as a sub-question, the role of other people in relation to the girls’ mathematical identities emerged as such a strong theme it demanded a chapter in its own right. The data showed that children’s characterisations of mathematics and their relationships with others and feedback they received on their mathematical development both fed into their developing mathematical identity, alongside deeply held albeit contradictory beliefs about what it means to be a mathematician and whether mathematicians are born or ability can develop over time. These findings, alongside the ownership girls took of their own mathematical development, form the focus of Chapter 6. The implications of perceptions and identity constructions for practice are addressed within the subsequent discussion.

4 Brussel sprouts and the 'jagoth': characterising mathematics

If mathematics were an animal it would be a Jagoth (mix of jaguar and a sloth) because sometimes it comes quickly (jaguar) and sometimes it comes slowly (sloth).

Hetty, metaphor elicitation task.

At the heart of this study was trying to understand the process by which children, and subsequently adults, come to identify with the phrase 'I can't do maths'. The first line of questioning aimed to investigate how a particular group of girls perceived mathematics as a subject. Perhaps if, as teachers, we could understand how they characterise the subject of mathematics, along with which areas of the mathematics curriculum they do or do not recognise as being present in or relevant to their everyday lives, we could start to re-engage them with the world of mathematics and self-belief in themselves as mathematicians. Across all forms of data collection, it quickly became apparent that far from being 'objective, fixed, pure, abstract and wholly logical' (Ernest, 2014, p. 5), mathematics was seen as a living, subjectively-perceived being; the girls were able to express strongly held views not only about their capabilities within and relationships within mathematics, but about the subject itself. As the metaphor above and the extract from Poppy's metaphor below (Figure 4.1) illustrate, most of them had no difficulty in characterising mathematics using metaphor, drawn images and the written and spoken word; mathematics conjured up images in their minds which they were willing and often keen to share.


If mathematics was a food it would be

brussle Sprouts

because

I don't like brussle Sprouts and I don't

like maths very much

Figure 4.1 Extract from Poppy's metaphor elicitation task

The main data sources for this chapter are the scrapbooks that children kept throughout the research period, concept maps, drawings, metaphors and the individual interviews which provided an opportunity to probe the thinking behind the information they had provided elsewhere.

4.1 Contrived questions and purposelessness

One of the striking features across all methods of data collection was the tendency of children to strive to find a purpose for their mathematical understanding and endeavours, without having a clear vision of what this purpose might be.

Mathematics was frequently characterised as being about answering questions, often word problems which seemed to have little connection with any realistic use of mathematics. The explanation accompanying a photograph of a child's safety gate at Tilly's house (Figure 4.2) provides perhaps the most extreme example:

Figure 4.2 Extract from Tilly's scrapbook

This paints a worrying picture of mathematics as a subject within which children need to 'accept the ridiculous problems they are given' whilst 'learning without reality' in the mathematics classroom (Boaler, 2009, p. 45). Tilly's entry is not an isolated example, with several children incorporating what I am characterising as 'contrived questions' into their scrapbooks or justification of photographs. Polly chose to pose the following question in her scrapbook, which typifies the kind of word problem frequently deployed within mathematics lessons: 'If I had 389 books and 92 of them are non-fiction, how many books do I have?' The same phenomenon recurs within Poppy's scrapbook, within the label accompanying her image of a calculator, a valid mathematical tool in its own right (Figure 4.3).

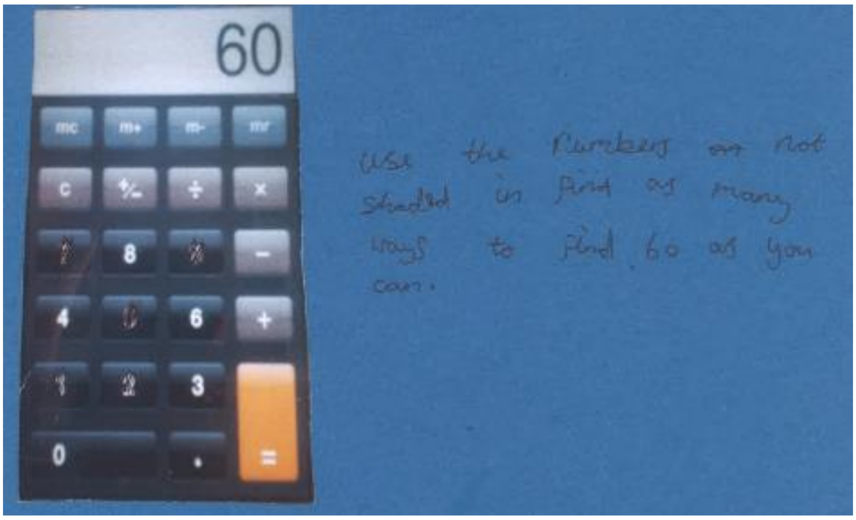


Figure 4.3 Example of a 'contrived' question

Aimee chose the photograph shown in Figure 4.4 as one of her 'special three', picked out to represent what mathematics meant to her.

Figure 4.4 Aimee's chosen photograph

Whereas I wondered whether she had chosen this photograph to illustrate an aspect of measures, or proportionality, or even grouping in 4s, she explained (and proceeded to annotate on the photograph) that she could use it to set a question of 1 + 1 then multiply this by 2. Why anyone would want to do this is not immediately obvious.

The word 'question' appeared no fewer than 87 times across the 14 pupil interviews, almost always introduced by children when discussing how they could pose mathematics questions for each other or how they dealt with question posed by parents or the teacher. Attempting to explore this phenomenon further, I had the following exchange with Alice (throughout my words are represented in italics):

I’ve noticed that quite a lot of things that people are saying, there’s quite a lot of questions and answers. Do you think that… that’s what maths is like?

Not exactly, because … some are questions, maths questions, practically everything is a maths question.

Two of the most frequently occurring areas of mathematics represented within drawings and scrapbooks were times tables and fractions, with times tables in particular ubiquitous throughout all methods of data collection. The following conversation was triggered by discussing a photograph of lists of times tables written out by Aimee whilst everyone else was reading.

Is it important to know your times tables?

Yes.

Why?

Because if you were like in a shop, and you give the shopkeeper too much money, you’ve got to work it out quickly, just in case they give you the wrong change, like too much or too little.

Ok, and do you need your times tables to do that?

Yes.

How do you use your times tables?

Because… say if you had £1.90 that you needed to pay and you had a £2 coin, you would have to like use your ten times tables to say 90 to 100 is ten so I know that…

In this case number bonds and subtraction as difference are probably the more relevant concepts, however there seemed to be a desire amongst the girls to justify the importance of times tables, on which they spent so much of their time. When the same question was posed to Lauren, she responded:

Yes, because if you don’t, you can’t do much, like… if you don’t know your times tables, … I don’t know what you can do… just if you’re trying to… work out money, and if… you only have £6 and it’s double the price your times tables might help you with doubling and halving, not just knowing your doubles and halves… it can help you with quite a lot of things… it can kind of help you with time… because, if you… if you need to… I’m not actually sure.

Fractions are another area of mathematics that occurred frequently throughout the different data sources, but not always with understanding of why they are important or how they might be used. This is a revealing response from Mackenzie:

> *Ok. So do you think fractions are an important part of maths?*
>
> Well, yes. But a couple of other things are more important than fractions. Like, times tables, or like addition, subtraction, centimetres, metres and all that. But you can use fractions for some things… like… erm… … nothing's coming to me.

Mackenzie is determined to find a purpose for the mathematics which she finds so difficult, but somehow it seems to elude her.

Reading and analysing the scrapbooks led to wanting to probe how children thought mathematics might be used within the world of work. This question drew some fascinating responses, which are summarised in Table 4 and suggest a limited vision of the purpose of mathematics as related to potential future careers. Question marks indicate where children used a questioning tone, perhaps looking for affirmation of their suggestions.

Millie	Baking, buying stuff
Aimee	Shopkeeper, police officer (to calculate how many people have been arrested)?
Alice	Working in a shop
Emily	Mathematics is in every job, for example being a vet
Mackenzie	-
Tilly	Hairdresser
Sally	Working in a bank… teacher… someone who works in a shop
Poppy	School bursar (dealing with money), being a teacher
Hetty	Being a doctor?
Skye	Shopkeeper, estate agent (dealing with money)
Lauren	The best jobs, eg engineer, being a teacher
Taylor	One that uses money?
Polly	Running a company (dealing with money)
Jasmine	Being an architect, 'I can't think of any'

Table 4 Mathematics in relation to the world of work

The girls seemed to find it easiest to articulate how being able to deal with money might relate to the world of work, similar to the findings of Ashby (2009) and Jay and Xolocotzin (2014) that children most easily associated money with real-life application. Measures also featured in terms of hairdressing, baking and being an architect, with Lauren in particular seeing mathematics as a 'gatekeeper' subject necessary for access to all the best jobs, echoing the viewpoint of Jorgensen et al. (2013). This limited vision of mathematics in the world of work is perhaps unsurprising amongst children who were only 9-10 years old at the time of the interviews, and begs two further questions: do they have a clearer idea of how other subjects such as English or science might be used, and how will these ideas evolve over the next few years as they move into and through their secondary education?

There were some contrasting voices able to portray how mathematics was relevant to their daily lives or might be useful in the future. Hetty, who identifies as loving mathematics but 'not really' being a mathematician, portrayed mathematics as being like an ambulance, because 'it comes to the rescue when you need it'. This theme is echoed by Tilly ('If mathematics was a kind of weather it would be spring time because it's when it leads up to something, eg summer, and maths leads up to anything'), and Sally who states that mathematics as a kind of weather would be sunny because 'it can turn to anything'. Taylor, a confident mathematician attending the high attainers' group (HAG), showed a real insight into realistic applications of mathematics. Not only could she invent word problems using realistic scenarios, but she recognised how to use mathematics to solve problems arising naturally in her day-to-day life (Figure 4.5).

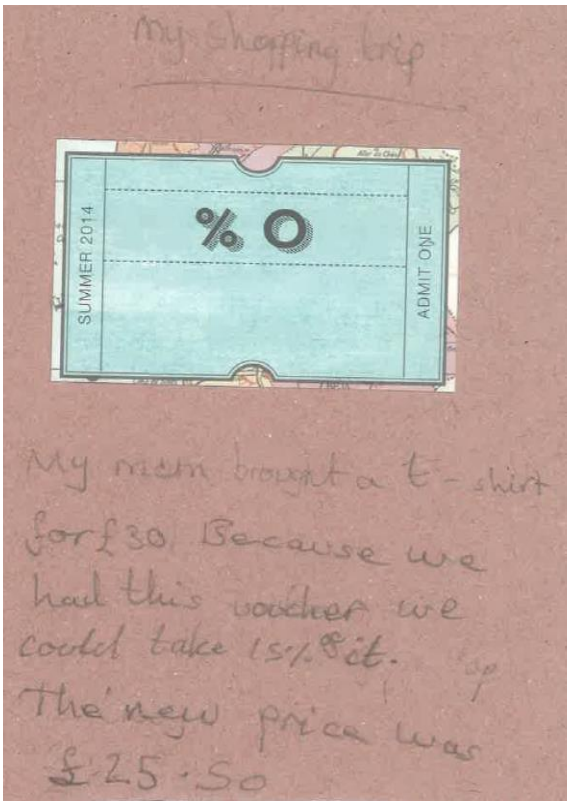


Figure 4.5 Extract from Taylor's scrapbook

One of the broadest ranges of mathematics represented within any of the scrapbooks was Hetty's, with mathematical topics ranging from angles, reading scales and shape properties to finding fractions, working out prices and reading Roman numerals. Like Taylor, rather than inventing contrived contexts for using mathematics, Hetty recognised how mathematics was embedded within her daily life (Figure 4.6).

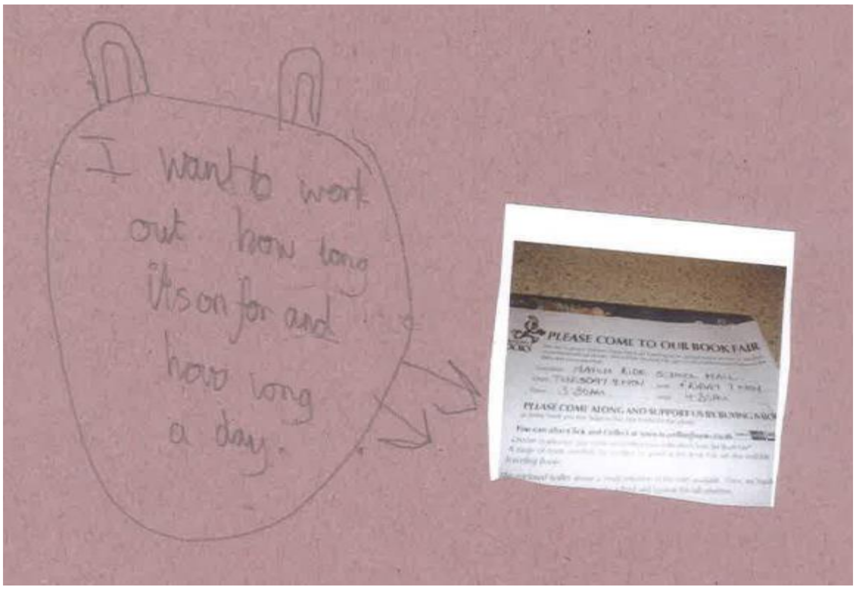


Figure 4.6 Extract from Hetty's scrapbook

Interestingly, all three of the children attending HAG provided evidence of seeing genuine applications of mathematics within their scrapbooks. Whether being a member of the group opened their eyes to mathematics in daily life or whether being more tuned into mathematics was a contributory factor to higher attainment and therefore group membership was impossible to discern.

Another source of purposeful mathematics for children came where they linked the subject with their own hobbies. At the time of the research, 'loom bands' were particularly popular amongst primary-aged children, and featured in various scrapbooks. Using loom bands involves sorting and grouping, counting and recognising patterns in order to create bracelets and other pieces of jewellery, and these featured within the scrapbooks of 4 children. These kind of authentic activities were also found to take place in the home within the Home School Knowledge Exchange Project (Winter et al., 2004), but not to be replicated within school. A second key link was that made with music, as shown within Jasmine's scrapbook (Figure 4.7).

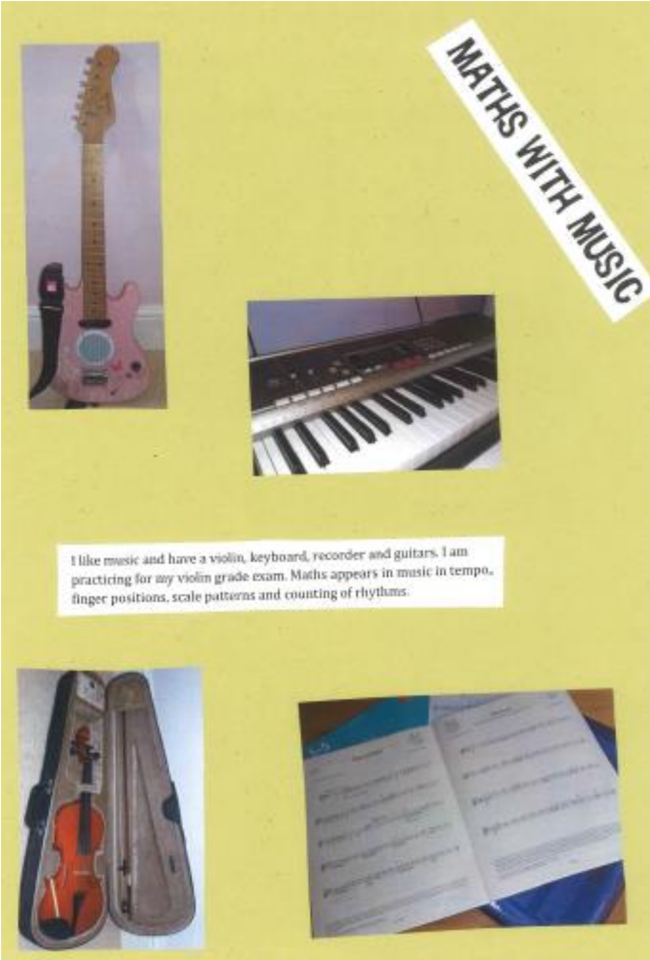


Figure 4.7 Jasmine's scrapbook

Links have long been made between mathematics and music, with the role of ratios and pattern frequently cited as linking concepts (Vaughn, 2000). The question of whether mathematics featured within music was discussed at some length within one of the group interviews early in the research. After discussing links with music for some time, Lauren plucked up courage to ask the other group members to make the link for her which she just couldn't see (note how Lauren also contrasts mathematics with 'normality', echoing the findings of Moreau et al. (2010)):

Lauren	For music… how would… why would… because I was thinking music was to do with maths, but I don't actually see how it is, because when you look at it, it just… it isn't anything to do with maths, it just seems normal?
CF	*Let Jasmine tell you her ideas.*
Jasmine	I think maths appears in music in tempo, finger position, scale patterns and counting a rhythm.
	Transcript of Group Interview 3, July 2014

Polly also saw links between mathematics and music, although she had to fight to convince family members that these links were real and therefore she could include music within her mathematics scrapbook (Figure 4.8):

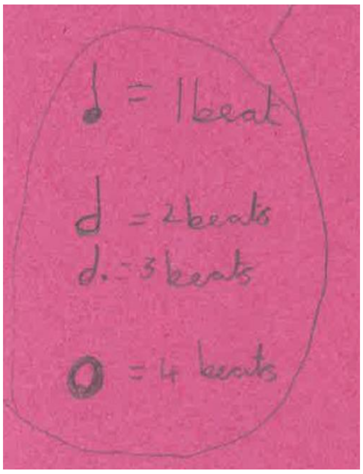


Figure 4.8 Extract from Polly's scrapbook

> I showed my mum my scrapbook, and she said Polly, music isn't to do with maths, and so I had to explain it to her and I said mum, a crotchet equals one beat, that equals two beats, that equals three beats and that equals four beats, and she said 'why don't you write that in otherwise I'm going to get really confused when you ask me about it?'

However, these voices were in the minority, with analysis of data leading to the conclusion that for many of the group mathematics existed in isolation from other subjects or real-world applications.

4.2 Size, speed and substance

Perhaps unsurprisingly, given the findings of previous research (Walls, 2003b), speed was a key factor in the girls' characterisations of mathematics, as well as in their discussions of themselves as developing mathematicians, explored within Chapter 6. Several children associated mathematics with speed, influenced by examples of classroom practice where they were challenged to cover as many questions as possible in a short space of time:

> The first one is… we were doing division, and we had a sheet, and we had two minutes to do it, as many as we can, and I got up to here… it was less than two minutes, I did six division questions, then I did the rest another time on my own. We had to just… it was kind of trying to help you get as quick as you can with your maths.
>
> Alice, interview transcript

Somehow speed of moving through material became, for some children, a higher priority or indicator of success than developing understanding. Mackenzie refers to her sadness that she isn't getting enough work done when discussing the impact of getting stuck, rather than seeing grappling with mathematics as a learning opportunity as recommended by Dweck (2000). This becomes part of her self-image and what allows, or prevents her, from enjoying mathematics:

> … my sequence work I'm enjoying that and going really fast. And some work I'm really really slow, that's like some work that I don't enjoy, or don't get it, or anything, so…
>
> *Is it a problem to take it slow?*
>
> Well, sometimes it is, and sometimes it's not. Because sometimes when you are going slow, you're concentrating and everything. But sometimes you need to hurry up and like get it done. Yeah.

The contrast between speed and understanding is beautifully articulated by Taylor, one of the highest attaining children:

> *What do you think most people think about maths?*
>
> I don't think lots of people like it very much.
>
> *Do you know why?*
>
> Erm, because… because if you find things quite hard, and then you are often told to like hurry up, it's not… you don't really like it. You just find things really hard, then everyone else around you gets it, and then you're told to hurry up and you can't, because you don't… like understand everything.

This appears to be exactly the kind of focus on speed rather than understanding warned against by Boaler (2014) in her plea to the Whitehouse. Interestingly Polly, who does characterise herself as a mathematician and is one of the higher attainers, is more comfortable with speed as an aspect of her mathematical learning. 'If mathematics was a vehicle it would be a car, because a car goes at a steady speed and to get a question right you need to go at a steady speed.' With an over-regard for speed being cited as one of threats identified to pupils' mathematical resilience (Johnston-Wilder & Lee, 2010b), this might indicate that Polly displays the 'protective' approaches necessary to mitigate against this threat (Hernandez-Martinez & Williams, 2013).

Alongside speed, children often characterised mathematics in terms of its size. This seemed to be a particular feature for those children self-identifying as poor at mathematics or not being a mathematician. Perhaps the most striking example is that provided by Lauren (Figure 4.9), who sees mathematics as a constant struggle.

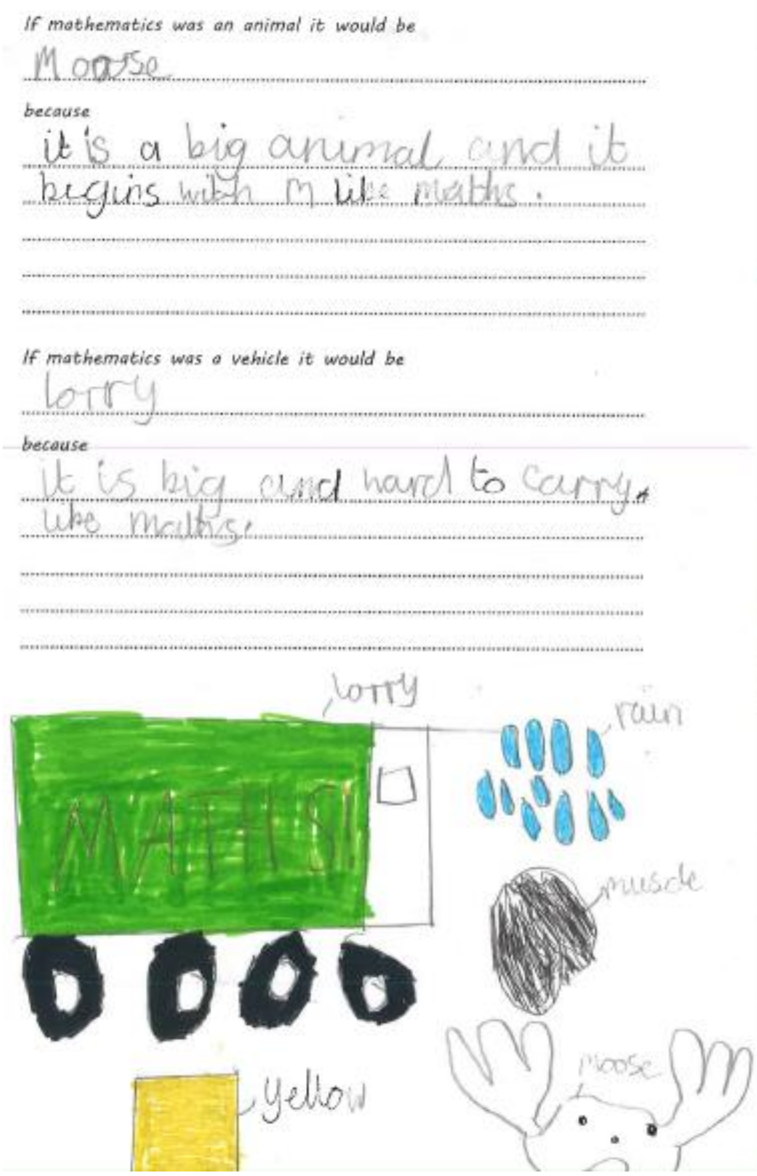
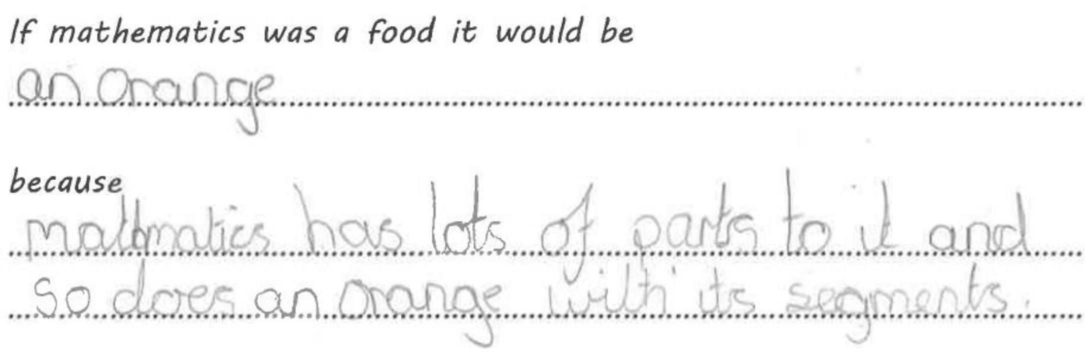


Figure 4.9 Metaphor elicitation task, Lauren

A different take on the 'size' of mathematics was provided by Polly who likened mathematics to spaghetti, as both can go on forever. Whether this was a positive or negative feature of mathematics through her eyes was unclear. Rather than focusing upon size, three of the children revealed images of mathematics as being multi-faceted. Sally, one of the highest attaining mathematicians, wrote (Figure 4.10):


If mathematics was a food it would be
an Orange

because
mathmatics has lots of parts to it and
So does an Orange with its segments.

Figure 4.10 Extract from Sally's metaphor elicitation task

The other two children who saw mathematics in this way, Hetty and Jasmine, both shared certain characteristics, including an ability to recognise mathematics throughout their daily lives and hobbies.

Characterising mathematics as being about knowing facts and remembering things featured in the majority of children's minds, although there was no particular pattern in whether this was a feature for more or less confident mathematicians. Times tables featured strongly here, with children using their knowledge of times tables as a proxy indicator for how good they were at mathematics as a whole, echoing the 'privileged status' afforded to times tables within the findings of Grootenboer et al. (2002). Mackenzie stated that whilst she is 'bad' at some of her times tables, she has to work on them and is 'getting there' through working at home and at school. For Tilly, knowledge of times tables was integrally linked with being an effective mathematician:

> *And what kind of person do you think is good at maths. Is there a particular kind of person?*
>
> I think… anyone that can automatically know their tables, that will really help them, because it helps them in anything, I just think if you know all your tables, then… you'll be able to do most of maths.

This is backed up by Alice's unprompted question, drawn on the back of her metaphor elicitation task (Figure 4.11):

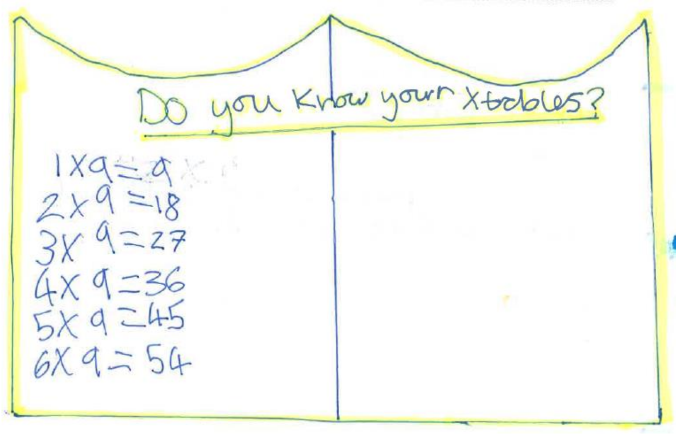


Figure 4.11 Image drawn by Alice on her metaphor elicitation task sheet

This assumption of times tables knowledge being fundamental to success in mathematics directly contradicts Boaler's viewpoint of times tables, in which she asserts that understanding number structure and being able to reason and look for pattern is much more important for leading mathematicians than knowledge of number facts (Moors, 2014).

For Lauren, not only is mathematics something that can be 'known', but the knowing of mathematics is integrally linked to future career prospects:

> And… it makes you get a better job… it makes you do more things, because if you want to be a teacher if you know maths then you can be a teacher, you can be like engineer, and all sorts, if you know maths. But if you're not the best at maths, then you'll have to find something else.

A range of artefacts (as opposed to photographs, drawings or writing) were included within the girls' scrapbooks, in particular receipts (for example Figure 4.12) and other items related to money and food, such as extracts from menus or recipes. They also included a page torn from a Su Doku puzzle book, a weather forecast printout, a Paris travel guide, playing cards and a 'Fish' phonecard.

Figure 4.12 Receipts in Sally's scrapbook

Physical artefacts were present in 8 out of the 14 girls' scrapbooks. Whilst it is hard to see a pattern in the data, for example they were present within the scrapbooks of both the least positive girls about mathematics (Lauren and Mackenzie) and the most positive (Hetty), there were differences in terms of attainment. There was a wide range of artefacts within the three highest attaining children's scrapbooks (Taylor, Sally and Polly), with no artefacts within the four lowest attaining girls' books.

4.3 Number and calculation: a narrow view of mathematics

The tendency of children to see mathematics as being focused on number and calculation is well-established in the literature (Ashby, 2009; Borthwick, 2011; Picker & Berry, 2000) and was undoubtedly reflected in the data. Three examples from the scrapbooks are shown as Figure 4.13:

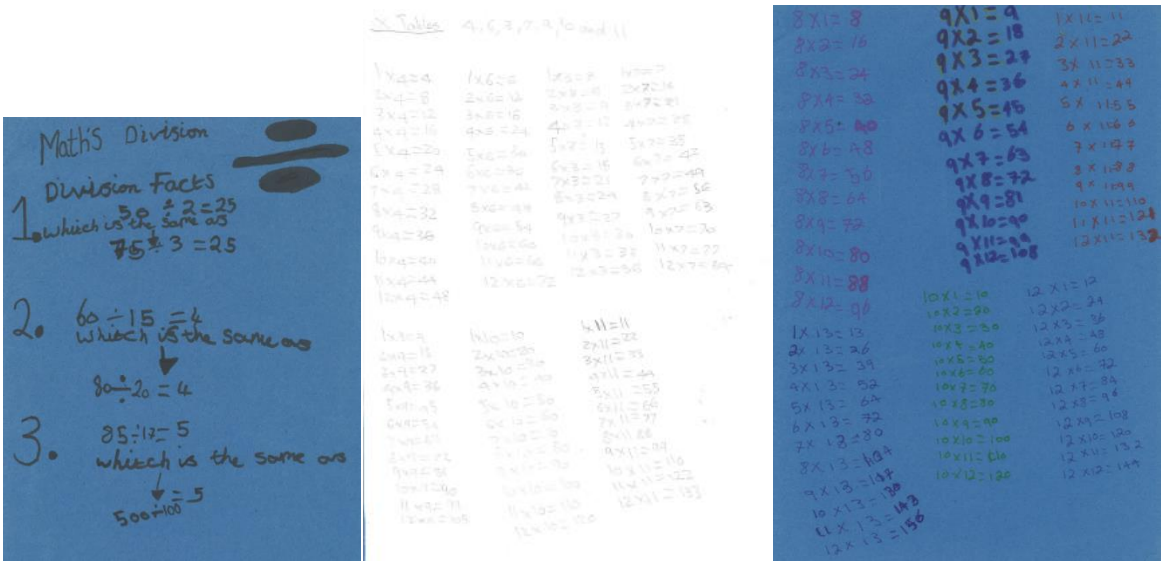
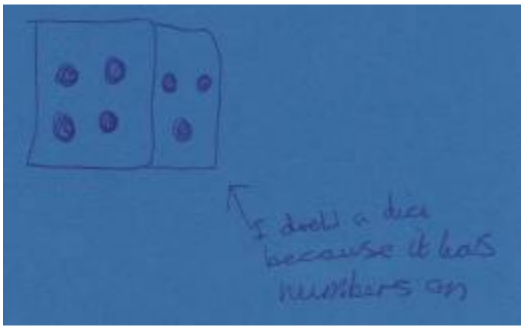


Figure 4.13 Number and calculation in Alice, Emily and Aimee's scrapbooks

An analysis of the children's concept maps portraying mathematics revealed that out of 228 references to mathematical content across the 14 concept maps, one hundred (44%) related to calculation, with a further 10% and 8% referring to number and place value and fractions respectively. This categorisation used the National Curriculum (DfE, 2013a) as its basis. To a certain extent this may reflect the emphasis placed on curricular areas within the English education system, for example the tests being developed at the time of writing for first use of 2016 (coincidentally the year in which the case study girls will be taking their end of year 6 statutory assessment tests) will follow a distribution of 75-85% of marks for number, ratio and algebra, with only 15-25% focused upon measurement, geometry and statistics (DfE, 2015b). What is perhaps more surprising is that children were so determined that mathematics was about number that they went to great lengths to justify the inclusion of artefacts or other activities under the guise of number. Whereas lead mathematicians celebrate the importance of games and puzzles as a key aspect of mathematical development (Boaler, 2009), and number puzzles (Su Dokus) and cards were present within the scrapbooks of more confident mathematicians Sally, Polly and Taylor, Mackenzie and Emily both felt they had to justify drawing dice in their scrapbooks (Figure 4.14):



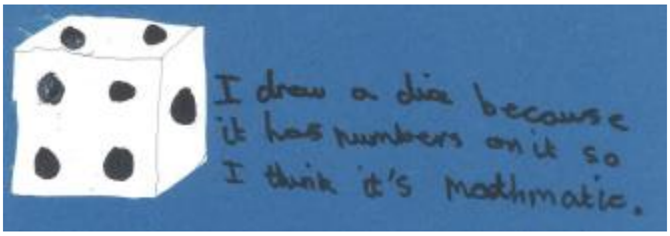


Figure 4.14 Extracts from Mackenzie and Emily's scrapbooks

The same happened when rulers, telephones and thermostats were included within the scrapbooks, each of which was justified because it included numbers rather than out of a recognition that measurement and communication are fundamental aspects of mathematics.

Let's have a look at your photographs. This is the hopscotch grid isn't it. So tell me about that photograph and why you chose it.

I chose it because… it's got numbers on, and numbers are to do with maths… you can erm… you can count up in like 3s or something, because it goes in singles… then you can count up in 2s, if you go…

Skye, transcript of pupil conference

The dominance of number was reinforced within the scrapbooks themselves, with the vast majority of content-based examples falling under the category of number, calculation and fractions. The most prevalent area outside of number and calculation was measures, primarily money and time but with temperature, length, capacity all featuring (see examples from Mackenzie and Hetty's scrapbooks in Figure 4.15).

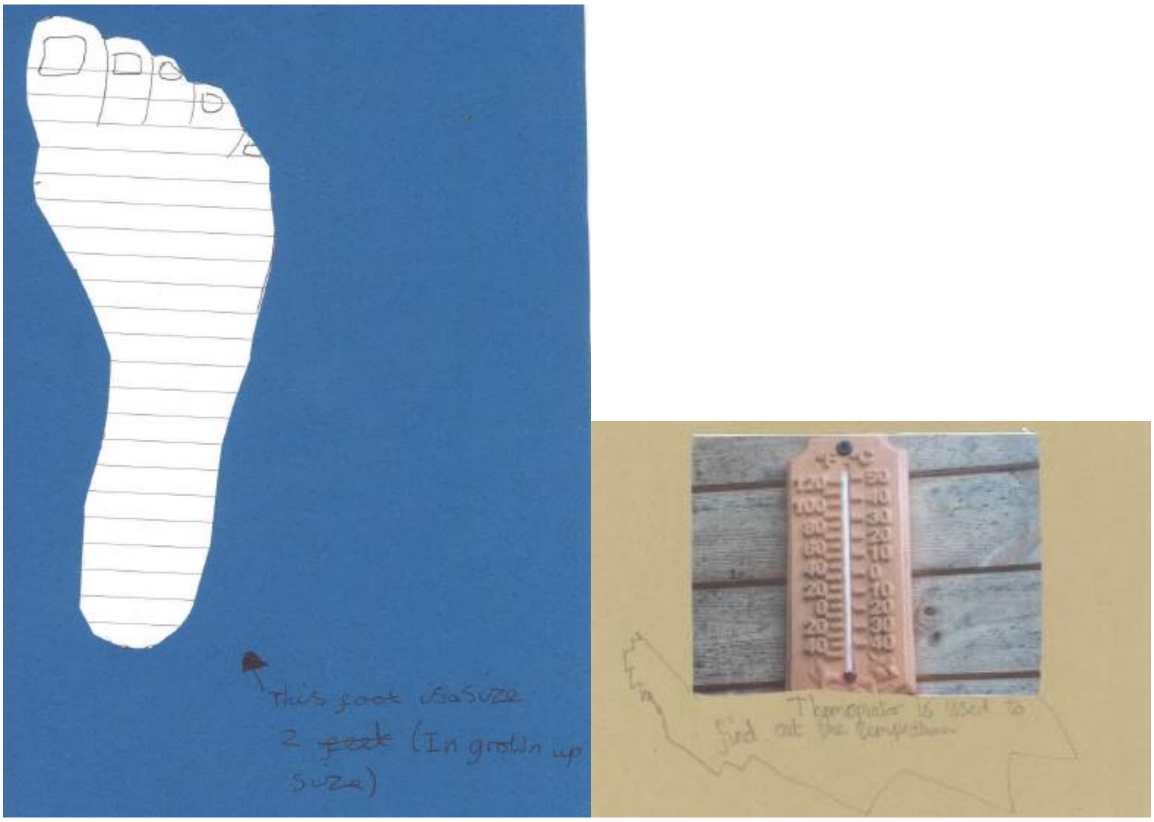


Figure 4.15 Examples of measures

Interestingly, any content recognisably linked to algebra was entirely absent within both scrapbooks and concept maps. Data handling (or statistics as it is known within the English National Curriculum (DfE, 2013a)) received sparse mention, an exception being within Polly's scrapbook when including an example of weather forecasting statistics, and Jasmine's which included grouping and sorting different tools in her father's workshop. However, nowhere was this pattern more apparent than within children's drawings of themselves doing mathematics.

Eleven out of fourteen of these drawings were exclusively related to calculation, primarily times tables. Whilst two of the remaining three did not show specific mathematical content, the pupil interviews revealed that in both cases the girls had been imagining themselves doing calculations. The remaining example included a mixture of fraction and decimal equivalents, and one example of measures. Emily's drawing is typical (Figure 4.16):

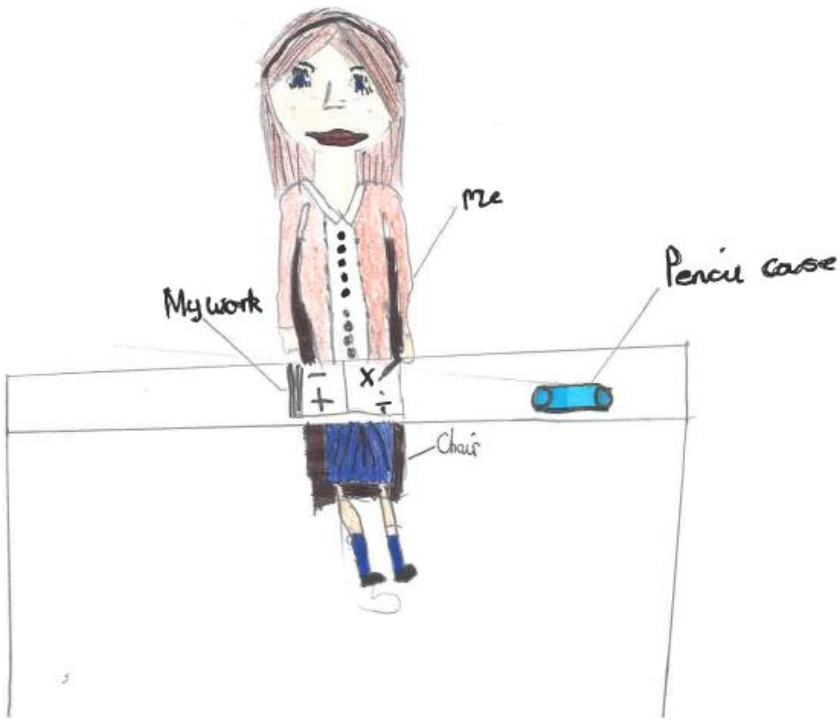


Figure 4.16 Emily's drawing of herself doing mathematics

Associating mathematics with number, and in particular with closed calculations, may be one of the reasons why girls dissociate with the subject. There is some evidence to suggest that girls do better in discussion-based, open-ended and project-based approaches, with gender gaps opening up within more traditional, procedural approaches (Boaler & Irving, 2007; You, 2010). Over the course of the data collection period the class were engaged in both learning procedural calculation methods and solving non-routine problems commensurate with the statutory national curriculum (DfE, 2013a); determining which of these tended to dominate was outside the scope of the study.

4.4 The where and the how: deskwork and tools

Two of the more physical aspects of perceptions of mathematics were apparent when analysing the range of data collected. The first is the tendency of children to see mathematics as an activity to be carried out at a desk. This may have been a feature of the context for the task when children were asked to draw themselves doing mathematics, which took place in a classroom, but 12/14 girls drew themselves working at a desk. One even went to the length of imagining herself working at a desk out in the woods, as shown in the extract below and Figure 4.17:

> *And tell me about this drawing that you did*.
>
> So, erm, so in like a wood, because I was like 'where can I do it, I want to do it somewhere different'. So I did it in a wood, with some trees, and then I've got a little table, like one of those pop up tables, and my squared piece of paper, and I'm doing 213 divided by 10, and its… just shown there, because it would be like that, and then divided by… like that…

Figure 4.17 Aimee's drawing of herself doing mathematics

Of the two remaining children, one drew herself at the whiteboard in the classroom. The only non-classroom-based context came from Lauren, who drew herself lying in bed rehearsing her times tables to help herself get to sleep. Location was also a theme emerging from the concept maps, with several children choosing to include where they did their mathematics. This generally focused on school, although at home, at the park, in the car, at Nana's and even at Brownies featured. Interestingly whereas every drawing of a child doing mathematics at a desk showed them in isolation, almost every instance of mathematics away from a desk was accompanied by an explanation of doing mathematics with others. These findings resonate with those of Rock and Shaw (2000b) who found that no children in their sample of 215 provided an example of mathematics drawn from outside the classroom.

The use of tools featured strongly within the girls' portrayals of mathematics, in particular within their drawings. An analysis of the content of the drawings revealed the spread shown in Table 5:

Pencil	Calculator	Exercise book	Ruler	Eraser	Interactive whiteboard	Pencil pot/case	None
6/14	1/14	12/14	4/14	1/14	1/14	3/14	1/14

Table 5 Breakdown of the tools present in drawings of 'doing mathematics'

Images of exercise books dominated, with only one child not including any tools within her drawing. This gives an impression of mathematics as a book-based, technical subject, reinforced by the concept maps where children also included other equipment such as protractors and tape measures and echoing the tendency of girls within Kelly's study to emphasise the mechanical aspects of mathematics (2004). Whereas primary mathematics teachers are encouraged to incorporate a wide range of manipulatives into their lessons designed to support children's conceptual and procedural understanding, such as number lines, bead strings or Numicon intervention materials, none of these materials featured in children's drawings, despite these being present in the girls' classroom. The scrapbooks contained a much wider range of tools and artefacts, in particular money and measuring equipment such as weighing scales, thermometers and jugs. This may have led to some of the distinctions children made between their home and school mathematics, whereby home mathematics was linked to the real world:

> *Do you think there's a difference between the kind of maths you use at home, and the kind of maths that you do in your lessons?*
>
> Yes. Because the kind of maths that we do in our lessons, it's not like everyday maths. It's just … because when we do like problem solving, you can do problems in real life, but they're not like real life things. You can still use them, because at home you just use the money and all that sort of… basic stuff. But you don't need all that hard problem solving and stuff.
>
> *So, you said a moment ago, that the maths you do in school isn't like everyday maths.*
>
> No.
>
> *Can you say a bit more about that?*
>
> Well, because… everyday maths is just money, and percentages, and all that basic stuff. But in school maths, sometimes like you do investigations, and they're not the sort of thing you'd do in everyday life. Yes.
>
> Excerpt from pupil conference transcript with Taylor.

Taylor’s summary of the differences between home and school mathematics echoes the findings of Bonotto and Basso (2001) that the role of connecting mathematics with reality is generally delegated to word problems, but actually these do not really model or mathematicise children’s real-world knowledge. The case-study school has recently installed an outdoor classroom, and prides itself in the quality of its outdoor-based curriculum enriching classroom-based lessons. Yet the children exclusively drew mathematics as a desk- and exercise book-based subject; real mathematics took place at home.

4.5 Hard or easy, right or wrong: dichotomies in views of mathematics

When characterising mathematics across the range of data collection strategies, two key dichotomies came into play: mathematics as a subject which is either hard or easy, and mathematics as a subject which is either right or wrong, seen as one of the threats to mathematical resilience by Johnston-Wilder and Lee (2010b).

Children spoke frequently about their satisfaction when they got their mathematics ‘right’, such as getting 20 out of 20 on a times-tables test or test of mental recall. As will be explored further in the following chapter, judging themselves as getting mathematics right or wrong was often a key factor in forming their self-concept as a mathematician:

> *And what do you think they would say about how you are as a mathematician. Do you think you are a mathematician?*
>
> mmm… sometimes. But if I feel like I get too many questions wrong, and only a few questions right, I feel like I’ve sort of disappointed myself.
>
> Extract from Millie’s pupil conference.

Getting all, or a high proportion of, their answers ‘right’ was sometimes associated with making progress in their mathematics lessons or moving onto working at a higher level, for example when Alice discussed how it was judged that she was ready to move on: ‘And I got ticks, I got them all right, and a smiley face, so I thought that was good.’ Millie used her scrapbook to rehearse areas of mathematics then ask an adult to help her mark whether or not each question was correct, and Taylor self-marked her written calculations (Figure 4.18).

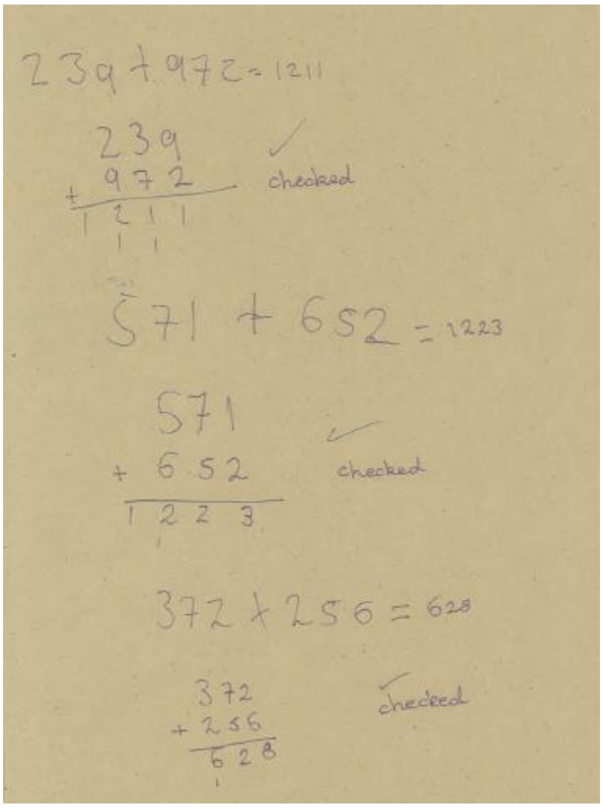


Figure 4.18 Marked written calculations in Taylor's scrapbook

Getting things right was contrasted with making silly mistakes, and having mathematics marked as right was integrally linked with being successful even when this had taken place some time ago (the pupil conference extract is linked to the image shown in Figure 4.19):

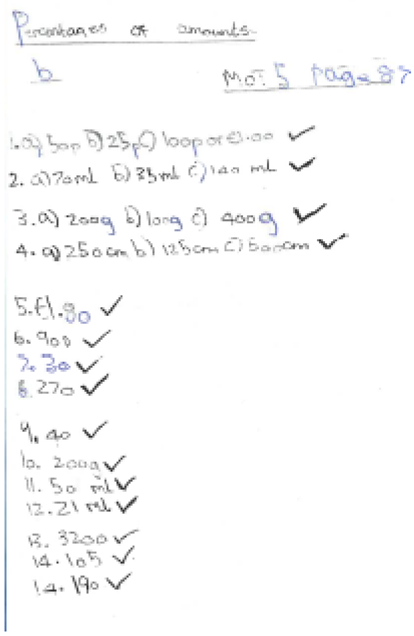


Figure 4.19 Successful work on percentages in Emily's scrapbook

Is there anything in your scrapbook that you want to tell me about? Some of it's a long time ago.

> Erm, the percentages of amounts. I did that in year 4 and I was really good at it, so I thought I would photocopy what I did. So I photocopied the work, and … my mum marked it, and I got everything right, so I was really happy with myself. So I thought I would put it into my scrapbook.

However, some of the children had more subtle ideas around the tendency of mathematics to be deemed right or wrong. Millie discussed the positive features of tasks based on estimating, because these did not involve being right or accurate, valuing improvement instead, echoing the kind of more subtle understanding of success in mathematics recommended by Middleton and Spanias (1999). On the other hand, as one of the higher attaining girls in mathematics, Sally relished the challenge and satisfaction of getting mathematics 'right': 'I like it when you get to the end of a question and you're marking it, and you get it right, I really like it when I get it right.'

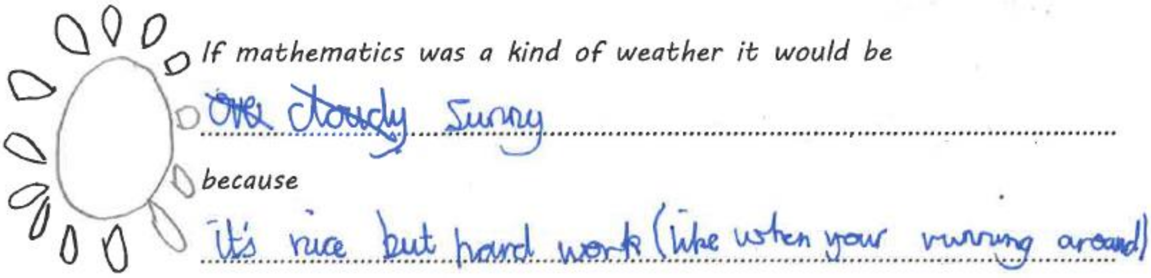
Similarly to the role of artefacts in distinguishing between home and school mathematics, Hetty saw a clear difference between mathematics at home and at school in terms of whether it was seen as right or wrong:

> *And erm... do you think there's differences in the kind of maths you do out of school and in school?*
>
> Yes. Because in school, it's like… question and answer, and you either get it wrong or right. But out of school, you can do what you like, you don't have to do a certain thing like percentages or thermometers, you can do anything you like to do with maths… because you could find something hard, and you could work on it at home.

In Hetty's world at least, the kind of integration between mathematics in the child's own culture and the formal mathematics encountered at home recommended by Adam et al. (2003) was not yet a reality.

How children respond to getting mathematics right and/or wrong is linked to the other dichotomy observed within the girls' data, that of seeing mathematics as a subject that is hard as opposed to easy, or in some cases hard for some and easy for others. It is well-established within the literature that mathematics as a subject is seen as difficult, and therefore seen as a key indicator of intelligence (Epstein et al., 2010). As will be explored further in Chapters 5 and 6, children had different attitudes towards whether finding mathematics hard or easy was a good or bad thing in terms of their own mathematical development. An unexpected result from the children's relationship wheels was the prevalence of girls referring to seeking or receiving help when they were 'stuck' on their mathematics, which featured in 8/13 of the relationship wheels constructed.

Two contrasting attitudes towards the hardness of mathematics were demonstrated by Hetty and Poppy. Whereas Hetty is comfortable with having to work hard in her mathematics (Figure 4.20):


If mathematics was a kind of weather it would be

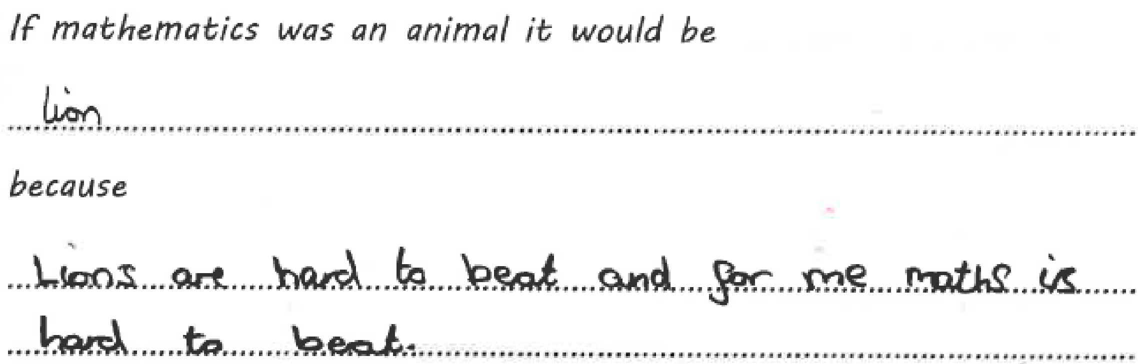
One cloudy sunny

because

It's nice but hard work (like when your running around)

Figure 4.20 Metaphor elicitation task, Hetty

a constant theme across the sources of data for Poppy is her battle with mathematics as a subject which she finds challenging (Figure 4.21):


If mathematics was an animal it would be

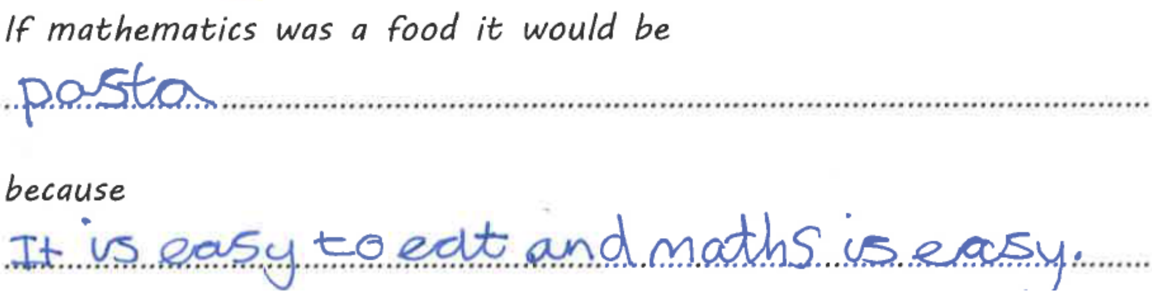
Lion

because

Lions are hard to beat and for me maths is hard to beat.

Figure 4.21 Metaphor elicitation task, Poppy

This tendency to see mathematics as hard rather than easy could be tied in with the characterisation of mathematics amongst this group of girls as being about knowing and using facts or carrying out calculations, with little emphasis placed upon open-ended tasks, communication or the aesthetic qualities of mathematics as recognised by Ernest (2014) or du Sautoy (Gold, 2006). A contrasting voice is provided by Alice, a relatively high attainer in mathematics, who declared that mathematics was easy (Figure 4.22):


If mathematics was a food it would be

pasta

because

It is easy to eat and maths is easy.

Figure 4.22 Metaphor elicitation task, Alice

Every girl in the study had a view on whether mathematics was hard, easy or a mixture of the two, with the concept of the difficulty of mathematics arising unprompted within every pupil conference and the word 'hard' appearing 132 times over the course of the 14 interviews. When characterising mathematics as hard, children tended to refer either to complex calculations, knowing and using number facts which they found difficult to remember, or understanding tricky concepts such as fractions.

> … I'm not really good at fractions, but I still try to practice them, and I am getting better at fractions. But I find it hard when you do percentages and fractions and decimals connected together. And percentages, some people did in year 4, but I'm not very good at it because I can't really work it out sometimes, how you sort it out.
>
> Extract from Millie's pupil conference.

'Easier' aspects of mathematics varied from child to child, and often corresponded with liking that area of the curriculum. On the concept map shown as Figure 4.23, notice how multiplication and times tables are hard and 'make my head hurt', whereas the more straightforward operations of addition and subtraction are characterised as being easy and even given a smiley face.

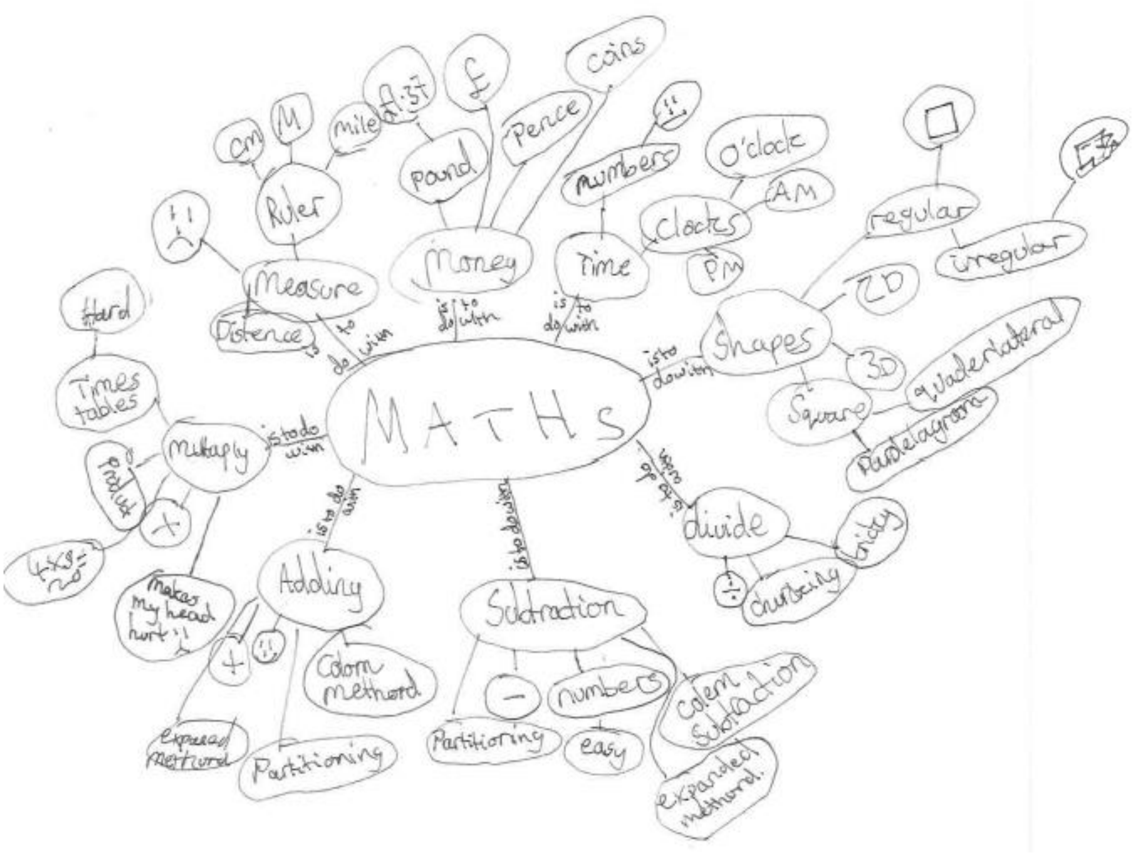


Figure 4.23 Taylor's concept map of mathematics

It should be noted that seeing mathematics as hard was not necessarily a negative reaction; for some of the girls the difficulty of mathematics was part of its challenge and therefore its reward. The complexities of relationships between finding mathematics difficult or easy and consequences for seeing themselves as being mathematicians will be explored in Chapter 6, along with how these ideas link with resilience.

4.6 Chapter discussion and summary

Whatever else the research showed, it is incontrovertible that the case-study girls held strong, vibrant views about the nature of mathematics, in contrast with some of the children studied by Young-Loveridge et al. (2006). Akin to the children in Grootenboer et al.'s study (2002) they were more than able, and in fact keen, to express their ideas. Characterising it as anything from Brussel sprouts or sushi to sausages or a carrot, a soaring blue tit or jumping dog, a labouring mobility scooter or speedy car, they were not short of opinions on what mathematics is, is like, and how it features within and influences their lives. Whether or not children found relevance in mathematics as they encounter it in their home and school lives, how they characterise it, where it is seen as taking place and their beliefs about mathematics as a subject may all impact upon their longer-term willingness to persevere and to see themselves as a mathematician.

In addressing the first research question concerning how girls perceive mathematics by looking at how they characterise mathematics as a subject and what mathematics they recognise as part of their daily lives, some key themes have emerged. The first of these is the tendency for this group of girls to associate mathematics with contrived, nonsensical questions, perhaps echoing the tendency of teachers to introduce word problems as a way of linking mathematics with the real-world (Bonotto & Basso, 2001). The children striving but failing to find a genuine purpose for the mathematics which was such a big feature of their school lives were often but not exclusively those at the lower attending end of the group, with the girl most able to give authentic examples of application of mathematics to real-life problems (Taylor) being amongst the highest attaining as measured by teacher assessment. The 'disconnect' between children, mathematics and the real-world reported across the literature was present within the girls' lives, along with the idea of the 'othering' of mathematics as a subject.

Whilst the associations between mathematics and speed described within this chapter are predicted by the literature, teasing out the subtleties of perspectives relating to speed is more challenging. It takes time and confidence as a teacher to provide space to value children's attempts to grapple with and make sense of mathematics, despite the importance of this sense-making for children's learning and future commitment to mathematics through a developing identity as a mathematician (Burton, 2002; Kaplan & Flum, 2012). Providing a safe space and time for children to rehearse, explore and explain their developing mathematical understanding was an unexpected side-effect of the scrapbook methodology used within this study, and may prove a useful tool for further exploration.

It was interesting to read and see the children's expressions of the size of mathematics. Is this associated with the sheer amount of time dedicated to mathematics within the primary curriculum, its importance as deemed by society or indicated by its presence within end of Key Stage assessment tests and reporting arrangements (DfE, 2013b), or related to the shadow mathematics casts over the lives of children such as Lauren and Poppy, with struggle and labour key aspects of their stories? Without further investigation it is impossible to tell from the data, but with Bell and Kolitch (2000) suggesting that seeing struggling with mathematics as being valuable is a key element of developing mathematical resilience, a raised awareness of children's beliefs about the nature of mathematics struggle can only be valuable for educators.

Whilst an emphasis on number and calculation within children's recognition of elements of the mathematics curriculum was predicted, I was particularly interested by the justifications children gave for including artefacts such as rulers and dice within their scrapbooks because they had numbers on them and were therefore mathematical, rather than as legitimate aspects of mathematical activity in their own right. Whilst Bishop incorporates 'playing' as one of his six fundamental activities of culturally-located mathematics (1988, p. 182), a simple search reveals that the words 'play' and 'game' do not appear once within either the statutory or non-statutory elements of the National Curriculum for mathematics (DfE, 2013a). The words calculate and calculation occur 49 times in the same curriculum. The playing that was evident within some of the children's scrapbooks was not replicated within their portrayals of doing mathematics when data collection was based within school. In contrast their drawings, concept maps and an analysis of the scrapbook contents showed that mathematics was overwhelmingly associated with carrying out calculations. In contrast to the world of the mathematician Marcus du Sautoy being an 'extraordinary' place to be (Gold, 2006), the impression given by the range of data collection methods is that in the eyes of this group of girls mathematics is desk-based, involves arithmetic and commonly times tables, and is about getting the correct answer. The rich vein of authentic mathematics incorporated within some of the girls' scrapbooks as instances of mathematics in real-life provides the kind of powerful potential to 'help children identify with mathematics in new ways' suggested by Jay and Xolocotzin (2014, p. 11). However, this was wholly absent from their drawings of themselves doing mathematics or concept maps setting out what they believed mathematics to comprise. It isn't so much that children didn't recognise wider elements of mathematics within their daily lives, as that they did not seem to legitimise these elements as being part of what it meant to do mathematics. This gap could perhaps by bridged by the bringing of the kind of 'cultural artefacts' (Bonotto & Basso, 2001, p. 387) present within some of the children's scrapbooks into the school-based mathematics experiences.

The girls' portrayal of mathematics as a subject which is either right or wrong revealed intricate differences within their attitudes towards and understandings of mathematics. Sally's stance in being satisfied by getting mathematics 'right' is subtly difference to the confidence gained by Hetty when working at home when it didn't have to be right or wrong. Higher attaining children seemed to be able to differentiate between those areas of mathematics they found hard or easy, whereas children who characterised mathematics as difficult or a struggle were more likely to see mathematics in general as an unremitting mass of content to be beaten into submission.

This chapter has explored how children characterise mathematics. The next will consider the social aspects of the relationships this group of girls built with and around mathematics, and the roles of other people in forming their mathematical identity.

5 Collaboration, comparison, isolation: the role of significant others in forming a mathematical identity

The second overarching research question for this study concerned how the girls made sense of their mathematical identity in relation to the role of other people. This chapter explores the role of people in forming children's perceptions of themselves as mathematicians.

To varying degrees, teachers, parents, siblings, grandparents, cousins, friends and peers all featured within the girls' mathematical worlds. At different times these influences were positive, negative, benign, malignant, reassuring and undermining. Unpicking the role of other people in forming children's mathematical identity was complicated further by contradictory messages within different data sources. For example, within the individual pupil interviews almost all of the girls discussed the benefits of working with their friends, particularly when grappling with aspects of mathematics they found difficult. Yet within their drawings, 100% were working alone. The scrapbooks were particularly helpful, along with the relationship wheels, in gaining a more balanced picture of the role of other people, coupled with children's verbal explanations of the scrapbooks and photographs.

This chapter is organised around the key themes arising from the data. Firstly, the explicit and implicit feedback the girls received from those around them, and how this shaped their views of themselves as mathematicians. Linked to this feedback, the data showed they were constantly not only judging themselves and feeling judged by others, but ranking themselves in terms of ability. Next, the social aspects of doing mathematics are considered. Who did the girls talk about or include within their portrayals of day-to-day mathematics, and what role did they play? The chapter ends by considering the role of mathematical role models, and their influence upon children's developing mathematical identity.

5.1 Feedback: teacher, family, friend

Sometimes the feedback children received on their mathematics was explicit and part of formal classroom processes, for example through the marking of work. Lauren really valued the positive feedback she received from her teacher for a piece of mathematics she had been struggling with, selecting it to photograph and place into her scrapbook (Figure 5.1).

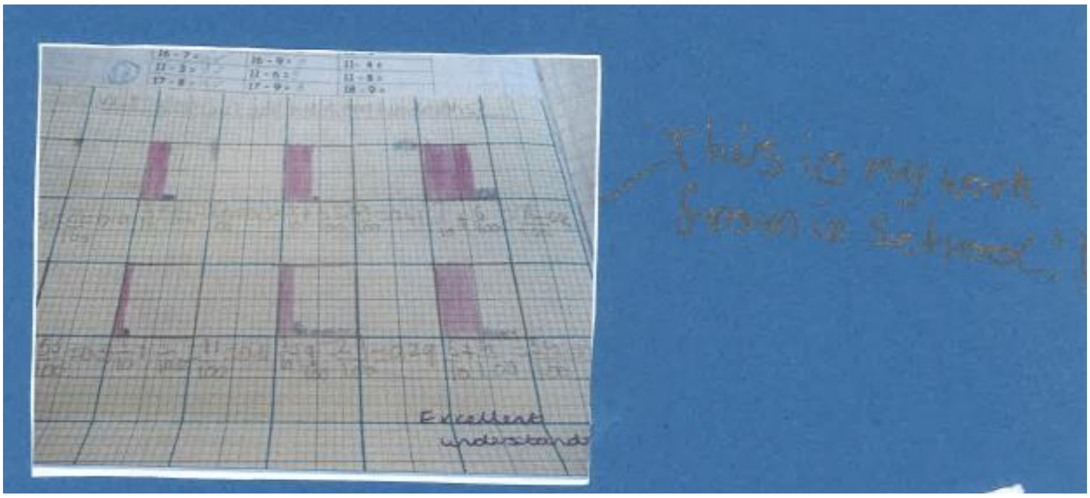


Figure 5.1 Photograph of marked work within Lauren's scrapbook

Beyond feedback from the teacher, Lauren (a lower attaining child) was heavily influenced by the views of others about her as a mathematician. She valued the feedback from her friend:

> …and whenever I got a question right, she was like 'well done Lauren', and she was … making me feel proud of myself, because she knows that I find it hard, and she knows that I want to get better, so she kind of helps me.

On the other hand, despite the feedback received, her mum appears to have reinforced rather than challenged her negative view of herself as a mathematician (throughout, italics denote the words of the interviewer):

> *Do you think your family influences how you feel about maths at all?*
>
> Well my mum knows that it's not my subject. Yes, and she is quite glad that you've come to try and make me feel more confident. But she's… she's never been able to make me feel confident about maths. She always knew, that I… that it's not my subject, and I just find it hard. Because I don't get maths, I find it hard and I get really annoyed. So yes…

Given the finding of Sheldon and Epstein (2005) that parental beliefs do predict children's achievement, this is a cycle which it may be challenging for Lauren to break. Unfortunately this is reinforced by the feedback Lauren receives from her younger brother. Her relationship wheel revealed that her brother 'worries her'; telling her that she should be able to do better or that he is already as advanced as her despite his age. Sally (one of the highest attaining girls) received a very different kind of feedback from her mother, which reinforced her sense of self as a mathematician:

> *Do you think you're a mathematician?*

> Yes.
>
> *Yes? What makes you say that?*
>
> It's just that I… my mum always says that I'm really good at maths, because she was like, she was trying to work out in the shop there was a sale, and she was trying to work out how much there was off this school skirt, and I got it right and she got it wrong.

Receiving feedback from other people was also a strong feature of Millie's relationship wheel: the head teacher 'supports me by saying well done', and her grandparents 'say well done and that helps me'. Perhaps receiving positive feedback reassured her that she was making progress with her mathematics and that her effort was paying off. Dweck (2007) warns of the dangers of ill-targeted praise, which can reinforce the idea that children have the 'gift' of mathematics and undermines their confidence when things go wrong. Instead, feedback which emphasises the importance of effort, progress and learning from mistakes is more likely to empower girls in taking responsibility for their own learning. This kind of feedback can be seen in the marking of Emily's work by her class teacher, as she reveals when asked how she thinks her teacher would describe her as a mathematician:

> I keep getting notes in my books saying you're getting there, just keep going. So I think that's what the teachers would say.

Although the examples of feedback from teachers to date have been positive, the kind of feedback provided by marking was a more negative experience for Poppy, possibly because it reinforced her sense of mathematics being either right or wrong. Poppy explained that she felt she could tell the time on both analogue and digital clocks at home perfectly well, but could not understand why she needed to work out the kind of questions encountered at school.

> When it's just telling the time, then you just know it and no one's… no one's like marking it… when you're doing it in your book, someone's marking it and telling you if you've got it wrong. But if you're like telling the time, then there's no one to tell you if you've got it wrong or not.

The explicit and implicit feedback children receive from teachers, family and friends or peers all informed the judgements the girls made about their own ability and ranking in the mathematics class, reinforcing the socially-constructed nature of mathematical identity (Wenger, 1998).

5.2 Judgements: ranking and the ability discourse

What makes you say you're not very good at maths?

Because… because I'm on the lowest group for things… and… people that are on the same group as me can do things that I can't do.

Extract from Poppy's conference transcript

One of the most striking features of the data was the extent to which children not only judged themselves as mathematicians, but compared themselves with the abilities, or perceived abilities, of others. This was a strong feature of 10 out of the 14 pupil interviews, and came across as a constant theme of their mathematical lives. This is perhaps unsurprising, as Marks indicates: 'Ability is a pervasive discourse within England, particularly in mathematics where ability-grouping practices are commonplace' (Marks, 2014). Whilst this school is one-form entry and children are taught in mixed-ability classes, within the classroom children are grouped by ability, something of which the data shows they are well aware, as seen in the examples below.

The girls made judgements based upon their physical positioning in the classroom and the message this gave them about their ability. Mackenzie (attaining towards the lower end of the girls in the class, but slightly above national expectations) was very clear that the location of children in their mathematics lessons related to both their attitude towards and their aptitude for mathematics:

> *So tell me, do you think there are groups of children who enjoy doing maths?*
>
> Yes, I find that the boys in our class like doing maths, and a couple of the girls. Because, there's like tables, there are two tables that are on the same level, and I'm on one of them… and on this side, there's the people who really enjoy maths, and are really good at maths. But this side is people who don't really like maths, and go… and you know, don't get that much stuff, and … we're on a lower level, but I'm proud of that because I know what I know. So… er… so their side of the room, that side of the room is the people who like maths a lot. I'm not saying we don't like maths, it's just we aren't as good as them. Yeah, so… yeah… so… they're like enjoying maths over there. Because we get… they get more work, and trickier work. We get… we get loads of work, but not trickier work. So… that's it.

This awareness of the location of ability within the classroom is echoed by Millie whilst explaining the progress she had made recently. Having this progress recognised involved physically moving across the classroom to the 'top table':

…Well, I used to be in the second to highest in maths, but now I'm at the top. Mrs Jones kept on saying that she knew that I could do it, and that she knew I could keep on doing it even if I got stuck, and I remember the day that I got to go to the top table, but I thought I wouldn't be staying there but I was, but that day Mrs Feirn was in the classroom as well…

How did that make you feel?

Over the moon!

Adding to the theme of speed being perceived as a key element of mathematics, even as a high-attaining mathematician Taylor used speed as a key factor in making comparisons about mathematical ability.

Do you think there's a particular kind of person who likes doing maths, or is good at maths?

Yes, there's… the two girls that sit on my table, they're always like ahead of everyone. And they're always getting, understanding it and everything. And me and my other friend on the table, we're sort of just like a few questions behind, but we're going at our own pace, and they go really quickly.

A further indicator of the different ability levels in the classroom was perceived by the girls to be membership of the high-attainers' intervention group 'HAG'. Three members of the class (Taylor, Polly and Sally) attend HAG, and the other class members were keenly aware of who attended this group and why. For some, it was a source of inspiration:

Do you think there are groups of children who like maths in the school?

Well, I think it's the HAG people, because they're in HAG so I think they enjoy maths, that's why they're in the top group, but… they all sit on the high table, or like the furthest table that's good at maths, and so do I but I'm not in HAG though.

Is that something you would like to be?

Yes.

Is it?

Yes, by the end of the year I really want to be in HAG.

Why do you say that?

> Well, I just want to really be in it because I just want to do more harder maths… and I just really want to go there, because I've got a happy dance, I want to do my happy dance [laughs]
>
> Transcript of individual pupil conference, Millie

Although Lauren also aspired to be in HAG, for her it was a source of resentment, believing attendees were receiving an additional entitlement:

> Because they go to HAG, they come back and say 'it was really fun' and that just makes me feel a bit annoyed, because I'm not there, and I don't know what they're doing, so I want to go up and be like them, and get a good education, and not a terrible one because I'm not good at maths. So… yes…

This may be a manifestation of one of the 'unintended consequences' of ability grouping as reported by Marks (2014), with lower-attaining pupils sometimes receiving reduced educational experience and opportunity. Whilst there is no further evidence to support that this was actually true in the case-study school, it was certainly Lauren's perception. It is also interesting that she seems to imply the kind of view that mathematics is a gatekeeper subject, associated with higher status and unlocking future potential seen within the literature review (Jorgensen et al., 2013).

Whilst the girls were aware of their status in the mathematics classroom and how their attainment compared with that of their peers, they displayed varying levels of comfort with their own perceived level. Alice was comfortable with knowing there are those seen as being above and below her:

> *And what do you think, do you think you're a mathematician?*
>
> Erm… I think I'm fairly good at maths, but there are some people… obviously I'm not going 'oh yeah, I'm the best', but there are always people that are better than you, and no one's ever perfect, so I think she would describe me as good. But I need to work on some things.

Mackenzie, on the other hand, almost seemed bewildered by those around her who appeared to find mathematics so much easier:

> *Describe a person that you think is good at maths.*
>
> Ok, this is the … boy-wise, there's a boy in my class, he's on holiday at the moment. He's really good at maths, and he goes to like these… he does maths at home all of the time. The first day he gets homework he does it. So he just… he knows everything straight

> away, I don't understand it. He's so quick at maths, and I'm so slow at maths, sometimes, so…

The impact of comparisons with others was most apparent when reading the heart-breaking account of Poppy. Poppy saw herself as being bad at mathematics, basing her view largely upon the comparisons she made between herself, her peers and the members of her family.

> In maths, I get a bit upset when people go up, like when they're on the same level as me one time, then they go up and I stay on the same or go down, I get a bit angry with myself because I'm not getting better at it.

Seeing others making progress she perceived as being better than her own reinforced her sense of her own inadequacy. Such ability grouping in primary mathematics has become increasingly prevalent within the last 10-15 years, in large part due to the increasing focus on standards as measured by statutory assessment tests (Hodgen & Marks, 2009).

Throughout this section we have seen evidence not only of the unintended consequences of classroom practice, but of the socially-enculturated nature of mathematical identity formation. The girls picked up on the cues of physical positioning in the classroom, membership of or exclusion from the high-attainers' group, and their perceived progress relative to other members of the group. This in turn informed or reinforced their belief in their own self-efficacy as a mathematician, raising questions for classroom practitioners as to how we balance the desire to encourage children to be aspirational and persevere in aiming to improve, whilst avoiding the intrinsic messages about mathematical ability so powerful in shaping children's self-perceptions.

5.3 Mathematics as a social activity: the world of 'doing' mathematics

Throughout the data, the role of others in the girls' mathematical lives was a constant presence, with children operating within the kind of socially complex, dynamic environments found by Walls (2003b). Mention of other people in verbal, written, diagrammatic or pictorial form fell roughly into the following categories: collaboration and independence, seeking and receiving help, motivation and challenge and sources of anxiety. Key sources of evidence were provided by the relationship wheels, scrapbooks, children's drawings and accompanying discussions, although evidence could also be found in unexpected places such as the concept maps, for example within references to doing mathematics at Nan's house (Aimee) or statement that 'I like working together' made by Mackenzie.

Analysing the relationship wheels to discover who occurred most frequently revealed the following pattern, in decreasing order of prevalence (Figure 5.2):

Teacher → Mum → friends → Dad → other teachers → CF → brother → sister → grandpa → teaching assistant → cousins/grandma/head teacher

Figure 5.2 Prevalence of 'significant others' mentioned within relationship wheels

The class teacher was included in all 13 relationship wheels completed, and cousins and the head teacher were only referred to by one of the girls (see Appendix 20). Perhaps naïvely, I was surprised to see myself (CF) occurring within six of the relationship wheels as 'someone they thought of when they thought of mathematics'. Typical comments were 'she helps me see maths in real life' (Hetty) and 'she helps me in wanting to do maths and teaches me in a different way' (Tilly), raising interesting questions as to the role of myself as researcher and impact of being involved in the study on the children.

5.3.1 Collaboration, independence and isolation

A complex picture of collaboration, independence and isolation was revealed by piecing together evidence across the data sources. The first of these was a frequently occurring theme of the pupil interviews, arising unprompted within most discussions. For example, Millie gave the following detailed exposition of the dynamics within her group in mathematics lessons:

> Well sometimes in maths, because on my table is Polly, me, Taylor and Sally, and we have to pull the table out, and if... but always, if we are doing a piece of work there's one person who is good at it, then we explain it to the other person, then we tell the other people. But mainly Sally gets stuck, and Polly is good at things, but I'm good at things, so then I explain it to the rest of the table, but then I explain it to Taylor because sometimes she doesn't understand. And… but Sally, she doesn't really get it sometimes because she doesn't understand the questions, especially word problems. I find word problems quite easy depending upon, like how they're worded, because if they are worded like I can't understand them, then I pronounce the word. Because I remember we did word problems yesterday, and I did the wrong thing, because I looked in Polly's book to see how she'd done it… and then I understood how to do it.

In contrast, examples of collaboration rather than receiving help when stuck were rare within the relationship wheels. A notable exception is Mackenzie's, when she illustrated how she and her friends work together and discuss their mathematics (Figure 5.3):

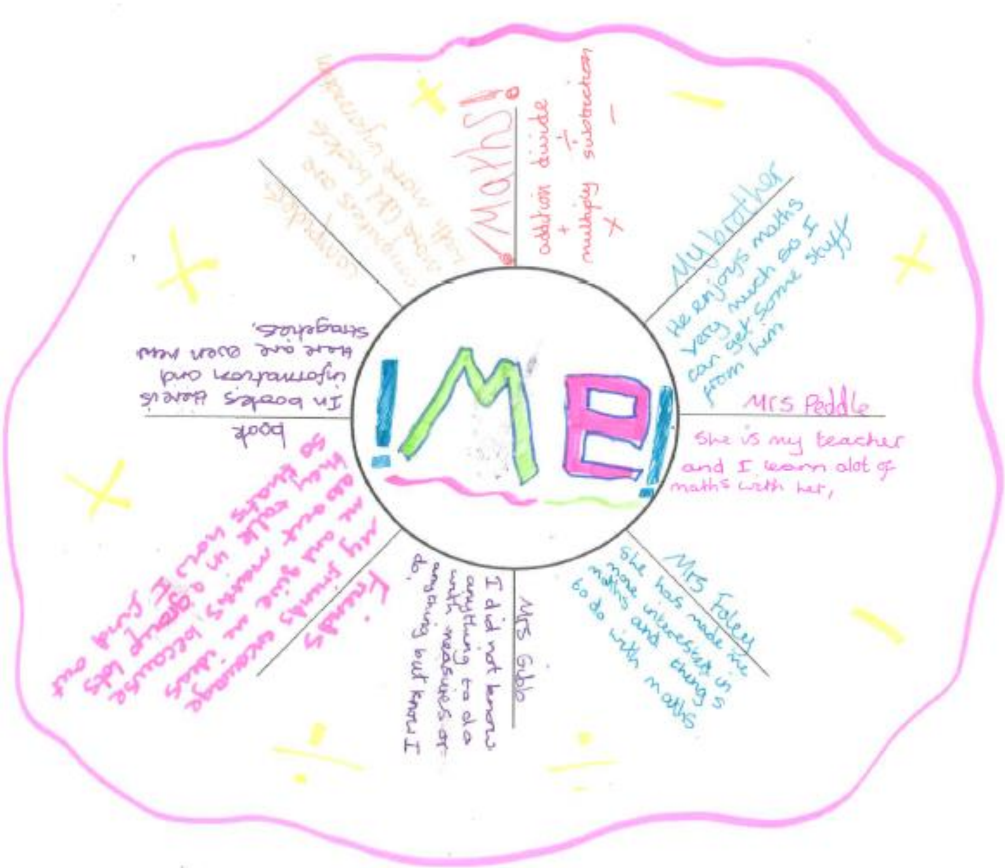


Figure 5.3 Mackenzie's relationship wheel

Mackenzie's explanation of her preferred ways of working shows that the social relationships around her mathematics group are far from straightforward. Earlier on in the interview she had provided extensive examples of the positive impact of working together, but here she seems to question the benefits, particularly when she is feeling confident in her mathematics.

> And I like working in partners and a group, that's what I love working in. I don't like working by myself. Well sometimes I like working with myself, by myself, sometimes, because… like…. People might copy you, and you know it really well, but the other person doesn't. So you're like 'don't copy me', and they are still copying you. So I like working on my own sometimes when that happens, and I don't want to work with anyone else, because I know that I'm going to get lots of work done because I know it.

It would be interesting to explore with Mackenzie and her classmates different types of cooperation and collaboration, perhaps towards a shared goal rather than supporting each other towards individual goals, whilst maintaining the support structures which they clearly find key to negotiating their way through the mathematics they find more challenging. Building on this theme, Poppy explains the importance of who she works with:

> *So is it helpful working with other people?*
>
> Yes. And also… I like… I find it better to work with my friends, not someone else that I don't really talk to that much. I find it better, because I can say what I honestly think. But with someone that I don't really talk to that much, then… I …. If they get it wrong, then I don't really know, I just wouldn't be so… honest.

Within this group she has the confidence to challenge other people and compare their ideas, whereas outside this friendship group her confidence melts away. Aimee picks up her theme, but through her eyes attitudes towards collaboration in mathematics are related to gender rather than to friends and peers:

> *So tell me then, what groups of children do you think enjoy doing maths?*
>
> Erm… so mainly girls. Because boys are just like 'I don't care about what you do, I just care about what I do', and girls are like 'hey you're stuck on that, I'll help you when I've just finished this question', then they know people will help them, and they'll help us back.
>
> *Say a bit more about what you just said about boys and their approach to their maths.*
>
> They just like… they don't really help anyone, they just… they don't help them, they just tell them the answer, but then it's not them learning, and they just care about what they get.

Rather than being outcome driven, Aimee values the importance of process; being able to simply obtain a correct answer by being told misses the point as far as she is concerned, as it does not provide opportunities for learning, echoing the finding that girls tend to prefer collaborative rather than competitive approaches (Boaler & Irving, 2007; Frost & Wiest, 2007).

One of the unforeseen disadvantages of collaboration in the classroom is that its breakdown in the classroom can leave a child feeling isolated rather than supported. The following transcript explains the image represented in Figure 5.4, drawn by Skye (the caption reads 'I don't really understand this investigation'):

Figure 5.4 Skye's drawing of herself working alone on an investigation

Tell me about your drawing.

Erm.. I normally find investigations hard. And … normally I have Alice and Jasmine… and they go and sit on the carpet. But then I'm left by myself. So I have to do it by myself.

Oh, ok – so why do they go and sit on the carpet?

Because… maybe they don't understand something, so Mrs Jones brings them down to the carpet and I stay on the tables.

Interestingly the teacher found it difficult to see this picture, as she believed that Skye had been making good progress and was feeling more confident within mathematics. This revealed the power of the drawn image as predicted by Merrimam and Guerin (2006), allowing Skye to show a situation which was a significant feature of her mathematics lessons but not apparent to the teacher.

Feeling isolated when working on mathematics is revealed within the following transcript extract, based upon Figure 5.5. It is also interesting to note the value Tilly places upon being asked to draw and talk about her feelings towards mathematics:

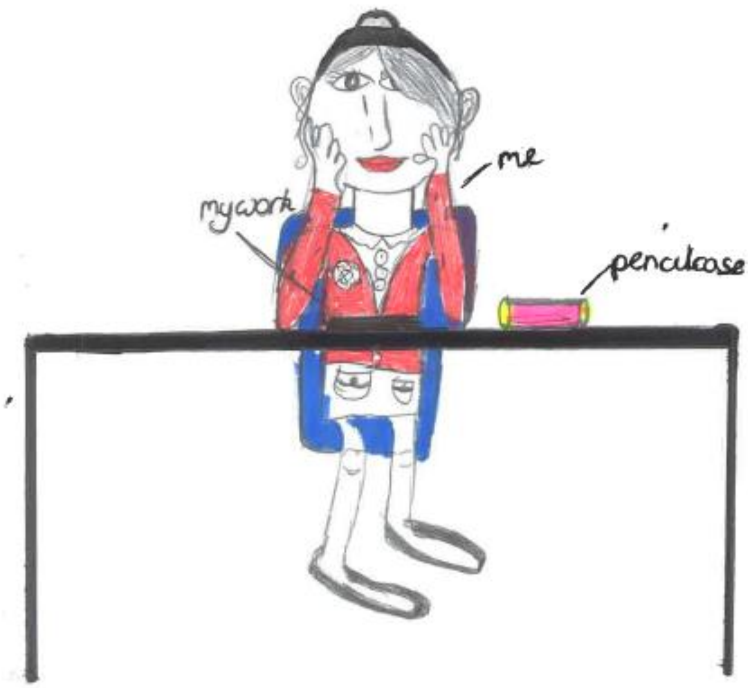


Figure 5.5 Tilly's drawing of herself doing mathematics

Ok, so tell me about your drawing.

Well, … I like… I do a lot of maths at school. I'm not very good at it, I'm in the lowest group. I wanted to… be able to express my feelings about maths, so I decided to draw me with my papers, my pencil case, yeah, and I just thought it would be interesting to share… my emotions about maths, and my feelings and what I feel about it. So I just decided to draw a picture of me like that.

So, where are you…?

Probably at home. Or like somewhere in a school, in a room alone, trying to do my work at my own desk and everything.

Polly felt isolated due to her gender when she became a member of the HAG intervention group whilst in Year 3, and discovered that not only was she the only girl attending from her class, but that there was only one other girl in the entire group.

And how do you feel about going to HAG?

I feel really happy, because I enjoy it, I find it fun, even though when I started I was the only girl.

Were you?

Yes, when I started, I was the only girl from my class.

So what was that like?

It felt annoying that I was the only girl in my class there, but I still really enjoyed it, because… well, because I enjoyed maths.

So you managed it anyway. Was it hard being the only girl?

[laughs]. It was, very hard, being the only girl.

Why was that?

Well because… all the boys were clubbing together, and leaving me out. So when I started there were only two girls, me and one of the current year 6s, so we worked together, and she helped me.

Ok. And is it still like that now, in HAG.

No, because Taylor and Sally joined, Taylor joined when she joined the school, and Sally joined in year 5. So I feel a lot more comfortable about it.

Alongside their overall preference for working cooperatively, most notably with their friends, many of the girls also displayed the willingness to work independently, particularly if they were finding their mathematics straightforward. Because independent work was often self-directed, this is discussed within Chapter 6 when the girls' resilience and ownership of their own mathematical development is explored.

The examples of collaboration and isolation above are drawn from experiencing mathematics within school time. Many of the examples based at home of social contexts are discussed elsewhere in relation to receiving feedback, role models, motivation and challenge and seeking and receiving help. The small number of examples of mathematically-focused collaboration revealed by children's entries into their scrapbooks tended to centre upon practical activities such as baking, playing games or working out pocket money and change, reflecting the findings of Sheldon and Epstein (2005) that the most effective home-based activities were those that encouraged interaction and talk. Two examples are provided by Jasmine (Figures 5.6 and 5.7):

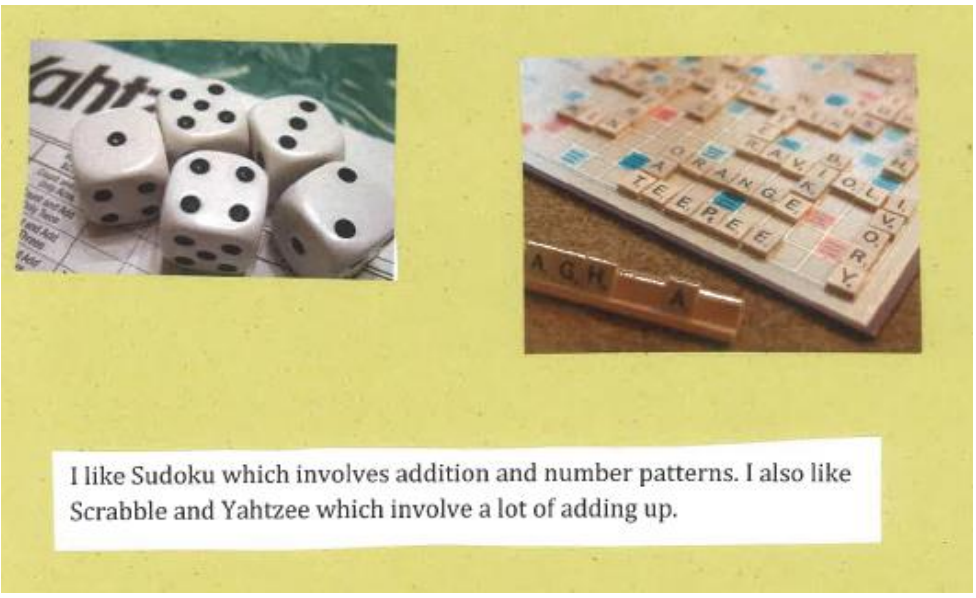


Figure 5.6 Playing games – extract from Jasmine's scrapbook

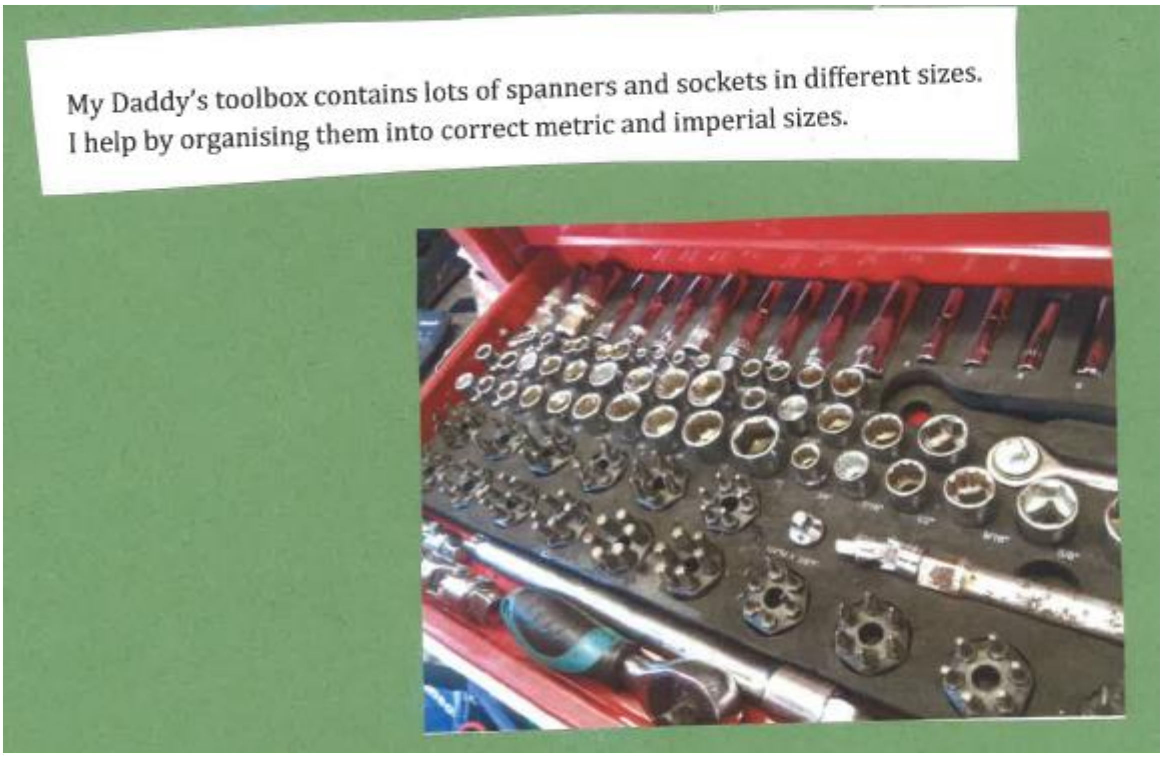


Figure 5.7 Working in the garage – extract from Jasmine's scrapbook

These examples, which contain genuine applications for mathematics illustrate two of Bishop's 'fundamental activities', playing and measuring (Bishop, 1988, p. 183), and provide fertile opportunity to implement his guiding principle that ideas from the child's home culture should be used within or as a basis for their educational mathematics experience.

5.3.2 Seeking and receiving help

Many of the references to doing mathematics with others were related to seeking and receiving help rather than being about active cooperation towards a shared goal. A prime example can be seen in Figure 5.8, where almost all of the references within Emily's relationship wheel are to receiving help:

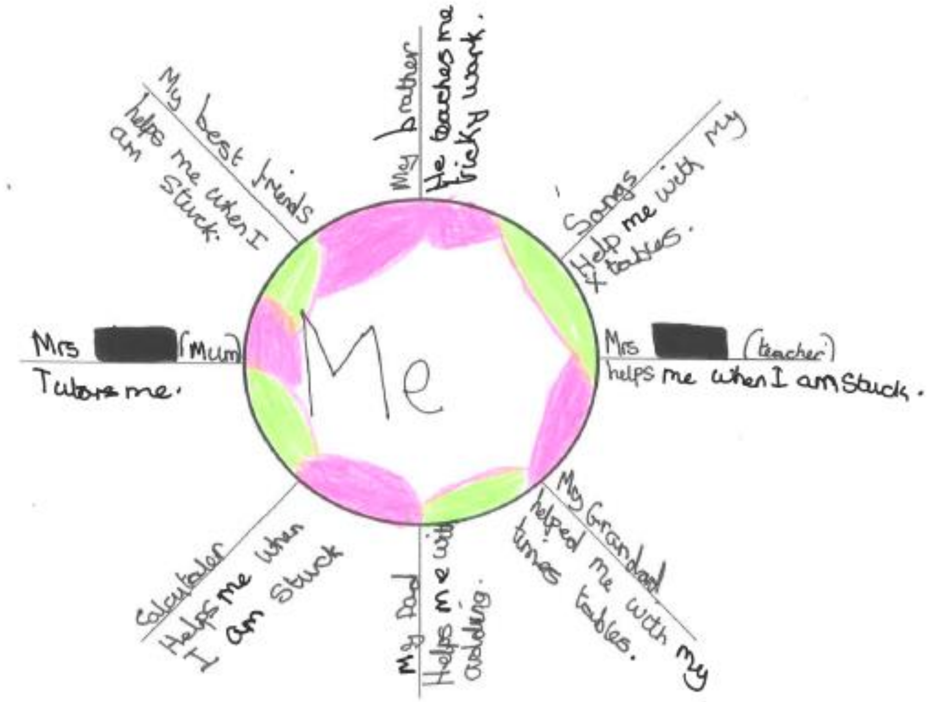


Figure 5.8 Emily's relationship wheel

Out of 70 verbs across the 13 relationship wheels, 'helps' appeared 30 times (43%), far more frequently than any other verb, for example 'teaches' only occurred 6 times (see Appendix 20): only Mackenzie and Millie did not include someone helping them. This idea of being stuck and needing help could link to the perception of mathematics as a hard subject discussed in Chapter 4. In terms of who helps most, this was parents (in particular linked with homework), followed by teachers, friends and a teaching assistant. One of the key times in which parents interact mathematically with their children has been found to be regarding homework (Landers, 2013), and in fact within the relationship wheels all references to parents related to being helped by them when stuck and/or on homework, excepting Emily who receives tutoring from her mother and Millie who mentions her parents having faith in her. Whilst there was no sense of the 'mathematical trauma' referred to by Lange and Meaney (2011) in their analysis of the dynamics around mathematics homework, it is striking that within the relationship wheels none of the children referred to doing mathematics *with*, rather than being helped *by*, their parents.

A key source of help was talk partners, specifically set up within this classroom as a policy to allow children to support each other. Talk partners have become increasingly prevalent in mathematics lessons over the last two decades, since the introduction of the National Numeracy Strategy framework (DfEE, 1999), with an accompanying emphasis on children being table to talk about and explain their mathematical reasoning, reinforced by lead writers on mathematics pedagogy such as Askew (2012).

Millie summarises: 'Me and my partner work together, so if we get stuck we just help each other'. Hetty provides more detail about how she uses the talk partner system:

> *When you work on your maths do you tend to work on your own?*
>
> Erm… I sometimes… it depends what task we're doing. If it's like… if it's things I find easy, I just put my head down and get it all done. But if it's something I find hard, I would use my partner to help me.

Whilst for most girls having talk partners provided a source of support, in Hetty's case it was less clear cut:

> My partner sometimes says 'oh I'm better at maths because I'm on the higher step than you', but it doesn't necessarily mean that they're better, because in their maths, they're not very… they're not very quick sometimes and they don't really get it that well.

In this extract Hetty has sufficient confidence in her own mathematical ability to cope with the message she receives from her partner. Despite being one of the higher attaining mathematicians, a drawing included within Taylor's metaphor elicitation revealed the isolation she felt when struggling with mathematics in the lesson (Figure 5.9):

Figure 5.9 Taylor's depiction of isolation in the mathematics classroom

Taylor finds it frustrating when she feels like those around her understand their mathematics but she does not. As she explained, 'That's just me when I'm just not understanding anything, and no one's helping me, it's like I'm in the rain. It's like, no. I need some help!'

5.3.3 Motivation and challenge

The kind of encouragement and challenge received by teachers, family and friends, coupled with whether this was a motivating or demotivating influence, varied considerably from child to child. For Hetty the gentle challenge she received from her family encouraged her to improve (Figure 5.10):

Figure 5.10 Hetty's photograph of a dartboard in her family room at home

And is this something that you use, is this at home?

Yes.

Who do you use it with?

My mum and my dad.

And when you are using it, who does the maths, who does the working out the scores?

My mum wants me to do it because she thinks it will help me to develop my maths.

And what do you like?

I like it when… my brother knows the answer… I know the answer before my brother [laughs].

This theme of challenge from family members continues with Aimee. It is interesting that the emphasis is on helping Aimee to improve her speed of mental calculation and recall of facts:

> My mum… helps me with my maths so much. She's like you've got 30 seconds to answer this and I'll get Jack to see if I've got it right, and most of the time I get it right. And… brothers help me with my times tables, and teaches me like their way of doing it. So I know lots of different ways.

A contrasting type of challenge is provided by Emily's mum, who also teaches at the school and tutors Emily at home.

So, what I'm hearing from you, is that you like … you like it to be a little bit hard.

Yes.

Do you think everybody's like that?

No, because some people get stuck on the hard stuff and they don't like being stuck? I like being stuck, so then I can figure stuff out eventually and then be proud of myself.

So where does that come from, then. Why do you think you're like that?

Because my mum's a lot like that. She works here actually, and she's taught me to say… only like the hard stuff. Then I've got into only liking the hard stuff.

In this case the challenge is to accept and rise to more demanding tasks, rather than emphasising speed. In this, Emily displays some of the 'protective factors' leading to mathematical resilience such as adopting a growth mindset and seeing mistakes and struggle as part of the learning process (Bell & Kolitch, 2000; Johnston-Wilder & Lee, 2010b). In some cases motivation was provided by role models as discussed below, for example within Lauren's desire to be sufficiently good at mathematics to be a teacher like her mother.

Whereas Hetty mentioned that her class teacher challenges her, a different take on the idea of challenge came from Taylor, who rather than being challenged by others seeks out challenge for herself:

> Because if one day we're doing something really hard, I'm normally like… I find this quite confusing. But then if we're doing something easy, I'll normally write in my book 'I'd like something more challenging'.
>
> *Ok. So did you just say you'd like something more challenging?*
>
> Yes. If it's easy, I'd write in my book 'I'd like something more challenging'.

Lauren too was motivated to challenge herself, but in her case it appears to be out of determination not to be outdone by her younger and more confident brother.

> Well my brother, Callum, because… he kind of … because he is going on, because he's on the same level as me, and like he can do harder stuff than me, he's the one… that kind of makes me want to… he's good at maths, so that makes me… it makes me feel annoyed, so I want to get better, to try to be higher than him, and prove that he can't be better than me, he may be younger but I'm still going to be better.

There is a fine line between positive motivation and anxiety, examples of which are discussed within the next section, along with their link to personal mathematical identity.

5.3.4 Sources of anxiety

Overt references to other people causing anxiety were rare but noteworthy within the data. The most striking is that evident within Hetty's relationship wheel (Figure 5.11):

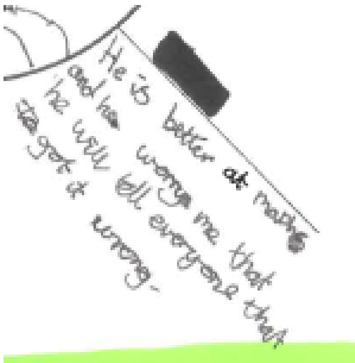


Figure 5.11 Extract from Hetty's relationship wheel

Although it would be easy to read something into the fact that this was a male peer causing her anxiety, it was balanced in the same relationship wheel by reference to a male friend who smiles at her when she succeeds, making her happy. As was seen in Poppy's relationship wheel, being teased by her sisters about her mathematics was significant enough for her to include, and Lauren also refers within her relationship wheel to her brother 'worrying her' about her mathematics. Taylor also hinted at her anxieties around aspects of mathematics within her animal metaphor (Figure 5.12)

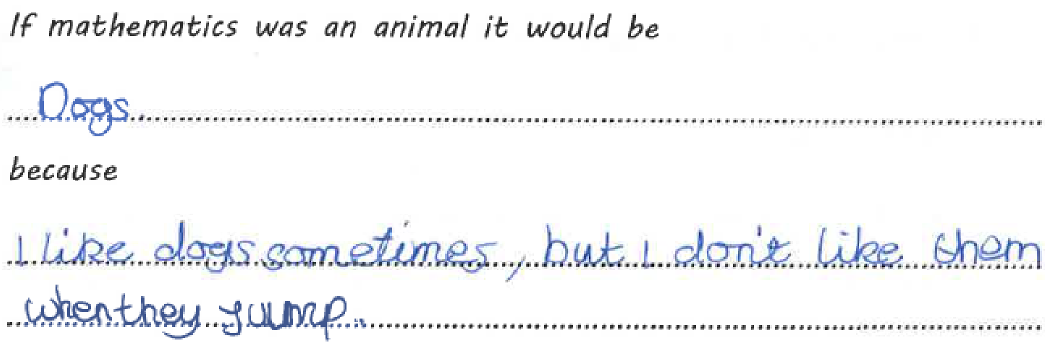


Figure 5.12 Extract from Taylor's metaphor elicitation task

Analysis of Taylor's data seems to suggest that rather than specific people causing her anxiety in relation to mathematics, she has a very fine sense of when she is and is not comfortable with the level of demand provided by the tasks she is set. On the one hand, she requests more challenging work when she does not feel stretched, but on the other she does not like being left alone with a mathematical task that she doesn't understand, perhaps showing unconscious awareness of Vygotsky's 'zone of proximal development' (Vygotsky, 1978, p. 86) within which both the pitch of the task and the support of more expert others are key features in success or failure. This echoes the findings detailed earlier that speed and 'getting it' were associated with being identified as mathematically successful. Whilst female teachers displaying mathematics anxiety is identified within the literature as a source of anxiety and having a detrimental effect upon girls' mathematics achievement (Beilock et al., 2010), there was no evidence within this data of anxiety amongst female teachers as a contributory factor towards girls views of themselves as mathematicians.

5.4 Mathematical role models

The role of mathematical role models within the girls' mathematical worlds was an important theme in terms of not only who featured, but who did not. Statements across the pupil interviews, for example, added up to a strong theme that key people had a significant impact upon girls' views of mathematics and themselves as mathematicians. Notice how the social learning theory idea of 'alignment' (Wenger, 2009, p. 5) is present within this simple statement about the mathematical skill of estimation, as Millie coordinates her perspectives with those of her family:

> I think my mum and my sister like estimating. I definitely like estimating.

Aimee looks up to her significantly older brother, who challenges her to improve her mathematics:

> *Tell me about what it says here, next to your brother.*
>
> Erm… he is really good at maths, like if you give him a really hard question he will do it in a couple of seconds, and he is really good.
>
> *So …*
>
> He always helps me.
>
> *You've written 'he is a mathematician', haven't you, just there.*
>
> Yes. Because he always helps me. Every day before I go in a room, he gives me 5 questions. I'm like 'just let me in!' but I have to do them.
>
> *And how does that make you feel?*
>
> It makes me annoyed at the time, but once I've done them, I'm like 'actually I've learned something' so I'm quite pleased.

Although this approach might intimidate some children, Aimee rises to the challenge provided by her older brother, and is resilient enough to overcome negative attitudes towards mathematics held by other family members who try to convince her that mathematics is boring. Whereas close family members have a big impact upon Aimee, her friend Alice has been heavily influenced by the positive role model provided by a member of her extended family.

Where do you think you've got your love of maths from?

My auntie, definitely I think.

Ok, tell me a bit more about that.

She, studies… well she used to study maths, and she still loves maths, she just loves it, so always when I'm at her house I'm like 'yess, I've got my maths' and she'll be like 'ooh, have you got maths', and like…. And she'll be like 'ooh, I love maths', so that's where I think I get it from. Because… I might get it from my mum, but I think I definitely get it from my auntie.

Another contrast is provided by Mackenzie, who identifies as someone for whom mathematics is hard. In this she believes she takes after her mum:

So, how do you see yourself using maths in the future?

…. I see myself like my mum. I see it like… work's very tricky for her, but she's getting there. She's good at doing it, but in some things, she's kind of… like, stuck on it, and she's like… always on the phone sometimes, talking about work and everything, so… I think she's getting good at it, so I might get better and better at it, and have a job like her, or something… so yeah.

The importance of female role models for children is noted within the literature on resilience and gender, for example Boaler (2014), Martinot and Désert (2007), and Moreau et al. (2010). However, one of the striking features across the modes of data collection was the almost total absence of any influential person outside the sphere of immediate contact. The sole reference to anyone other than a friend, adult at school or family member was to Albert Einstein, remotely connected to Emily via her great-grandfather. Even with this connection, she did not know anything about Einstein as a mathematician, and did not make any links between him and the mathematics she encountered. Ironically, greater knowledge of the correspondence between Einstein and children at the time might be supportive given the tendency of this group to make comparisons: 'Do not worry about your difficulties in Mathematics. I can assure you mine are still greater' (Einstein, 1949, cited in Küpper (2000)).

Everyone else who appeared was directly known to the girls. The only recognition that 'mathematicians' exist outside the educational environment was provided by Hetty, but unfortunately this was not in an entirely positive context:

So… how do you see yourself using maths in the future?

> I think I… I think I would use it, like when I go to the shops or to tell the time, but I don't think I'm going to become like a famous mathematician or anything.

There were no characters from films, books or the television, and no further references to mathematicians past or present; the idea of mathematics as carried out by mathematicians in the same way as writing is carried out by recognisable authors was almost entirely absent from these girls' lives.

5.5 Chapter discussion and summary

One of the key developments in understanding of mathematics education over the twentieth and beginning of the twenty-first centuries has been the acknowledgement that mathematics does not take in place in a vacuum. Rather than simply emphasising the individual constructing their own mathematical understanding, Vygotsky established mathematics as building connections through social interactions and talk (Montague-Smith & Price, 2012). Extending these ideas, sociocultural theorists Lave and Wenger emphasised the importance of belonging to a community of practice, a process which involves engagement, imagination and alignment, with learning situated and taking place through participation (Jaworski, 2009; Lave & Wenger, 1991). The picture painted by the pupil conference transcripts, within which the majority of girls expressed a preference for working with others, the relationship wheels in which there were only rare examples of genuine collaboration rather than seeking and receiving help, and the girls' drawings in which all appeared isolated from their peers, suggests that the dynamics around the social world of these girls' mathematical interactions are complex and fluid. This reflects the 'dynamic, recursive' world of pupil experience predicted by Pollard and Filer (1999, p. 283), within which pupil learning and identity should be recognised as less static than is implied by school achievement as measured by academic outcomes.

A positive feature of the way social relationships appear to be managed within this mathematics class is the degree of control many of the girls felt, for example being able to choose when to ask for help, when to work with others or alone, and when to continue trying out ideas in their own time. It was when they felt out of control, for example when their support structure was removed or others working at a similar level were moved on, that their feelings of anxiety appeared to increase. In fact, evidence suggests that interventions focusing upon understanding and controlling negative emotional responses might be productive in allowing children who are anxious but actually mathematically competent to be identified (Maloney et al., 2015).

One striking feature was how the children appeared to associate membership of the community of mathematicians with their geographical location within the classroom, reinforced by whether or not they went to the HAG and the constant comparisons they made between themselves and others around them, all of which were tied up with their understandings of themselves in terms of their mathematical ability. To a certain extent this resonates with the notion of 'elitism' as expressed within Nardi and Steward' T.I.R.E.D model (2003, p. 357), within which only particularly intelligent people are seen as being able to succeed in mathematics. The negative effects of the increasing focus on ability within primary mathematics are well documented (Hodgen & Marks, 2009) and this focus was certainly present throughout the discourse of the children. What is more nuanced is the girls' reactions to this ability discourse, with it appearing to be a source of inspiration, satisfaction, resentment and/or confirmation of inadequacy depending upon the child's own self-concept. How these aspects built into forming their mathematical identity will be further explored in Chapter 6.

The lack of external role models introduced by the girls into their various portrayals of their mathematical worlds contrasted strongly with the prevalence of inanimate tools – rulers, pencils, calculators, exercise books. When considering the role of other people, there were only isolated examples of an awareness that mathematics exists outside the world of education. Would this be the same in a similar analysis regarding literacy? Would discussion of the nature of reading or writing be devoid of reference to known authors or literary figures? Given the desire of the participants to carry out mathematics as a social activity, constructing understanding, providing support and celebrating successes, surely it is worth at least exploring how mathematics as a wider human endeavour rather than isolated set of knowledge, understanding and processes might be brought to bear on our classrooms. In 1995 Leone Burton set out a plea for the social aspects of mathematics together with the value of intuition and insight to be placed at the heart of mathematics, so that 'Mathematics could then be re-perceived as humane, responsive, negotiable and creative' (Burton, 1995, p. 289). For these girls it appeared that part of this plea from twenty years ago had been recognised; they were in a classroom situation allowing collaboration and peer support, and were often well supported by their extended family. However when it came to portraying themselves doing mathematics, the picture that emerged was still one of isolation, both from each other and from the wider world.

Across the data there was a strong sense of support from parents and extended family. This ranged from support when stuck with homework, being set additional questions or bought practice workbooks, to baking together and discussing mathematics at the dinner table. Sometimes, this support bolstered girls' self-esteem and determination to succeed, but from time to time it appeared to undermine confidence, increase pressure to perform quickly or do as well as a younger sibling. Whilst being hesitant to suggest the kind of 'school knows best' model of home-school communication implicit within the Williams review (2008) as discussed in Chapter 2, the data suggests there is scope for some kind of structure allowing children, teachers and parents to get together and explore the kind of family support for mathematics which emphasises growth, risk-taking and ownership rather than speed and always being right. Such a discussion could be enriched by raising awareness of the role of struggle in the identity formation and success of recognised mathematicians. One such example is that of Andrew Wiles, credited with solving the infamous ‘Fermat’s last theorem’ after 350 years of individual and collective endeavour. Not only did he spend 7 years grappling with the problem, but when he finally revealed his solution to the Isaac Newton Institute conference in Cambridge it was found to contain an error, requiring several more months of work to rectify (Boaler, 2009). This kind of story, together with an understanding of the work of researchers such as Carol Dweck (Dweck, 2000; Yeager & Dweck, 2012) in recognising the importance of valuing effort rather than believing in innate ability, could be powerful in reframing family dynamics around mathematics.

In terms of methodology, one of the original research aims of the study had been to investigate whether being involved in a research project of this kind had an impact upon the girls’ attitudes towards the subject, but was rejected as it suggested a more experimental design which was inappropriate for the rest of the study aims. My unexpected presence within the girls’ relationship wheels as an influential person in their mathematical world together with the interest girls displayed in drawing, writing and discussing their perspectives on mathematics suggests that this is a line of enquiry worth pursuing in the future.

Chapter 6, the final results chapter, builds upon the findings discussed so far of children’s characterisations of mathematics and mathematicians and the social world within which they operate, and draws out key factors in becoming and being a mathematician.

6 It's all down to me: becoming and being 'a mathematician'

The second key area of research for this study centred on girls' mathematical identities, how they positioned themselves as mathematicians, and the factors affecting the sense they made of these identities. As well as the characterisations of mathematics set out in Chapter 4 and the social influences upon children explored within Chapter 5, analysis of the data confirmed that understanding the girls' beliefs about the nature of mathematicians and their own role in being and becoming a mathematician was key to understanding their mathematical identities.

The subheadings within this chapter arose from initial and focused coding of the data. Asking children whether they thought they were a mathematician arose naturally within the first conference, and provoked such an interesting discussion the same prompt was used across the subsequent interviews. Data from this specific prompt is supplemented by data across the pupil interviews, when girls volunteered their views about the characteristics of effective mathematicians and whether they themselves measured up to those perceived characteristics.

6.1 Being a mathematician

Data in this area fell into two distinct but interrelated categories. The first related to what it meant, through the girls' eyes, to be a mathematician. The second related to the children's own opinions about whether or not they met these perceived criteria and therefore were 'a mathematician' themselves.

6.1.1 What does it mean to be a mathematician?

Exploring this question proved fascinating, with contradictions between different viewpoints throughout the data. In some cases, children's beliefs about being a mathematician echoed the topics explored previously about the nature of mathematics as a subject, for example within references to speed and mathematics as a hard and challenging subject. Aimee described her brother as being really good at mathematics and 'a mathematician' within her concept map, justifying this by saying 'if you give him a really hard question he will do it in a couple of seconds'. She went on:

> *So what does it mean to be a mathematician?*
>
> Like… you've got to be like really, <u>really</u> good at maths. Like you can do really hard questions like that, well not all of them, but a lot of them.

An interesting tension emerged around the girls' attitudes to difficulty in mathematics. Skye stated that being good at mathematics and liking it were associated with being able to do it easily, Alice referred to finding mathematics easy leading to enjoyment, with people not enjoying it who find it hard or tricky, and Mackenzie hints at the self-fulfilling cycle of liking mathematics leading to understanding and enjoyment, hinting at Ernest's success cycle (Ernest, 2011) whereby success, pleasure and persistence become mutually reinforcing.

> *Ok. So what kind of characteristics do you think you have to have to be a mathematician?*
>
> Er… you react to maths like you like it a lot. Because, if you like it a lot, then you… you'll be showing that you like it a lot, then you'll be learning it, then you'll be better and better. So, that's a good way of being like a mathematics-person. And… er, characteristics… they… they show in their learning that they know what's going on a lot, but if they don't know what's going on a lot they sometimes just ask a partner.

On the other hand, some of the same girls along with others recognised that it was how they responded to 'hard' mathematics that marked out the mathematicians, reflecting the kind of key indicator of resilience mentioned by Hernandez-Martinez and Williams (2013) whereby mistakes and struggle are seen as part of the learning process. Although Alice had previously referred to a mathematician being someone who found mathematics easy, she also recognised the need to rise to a challenge:

> *And what kind of person do you think makes the best mathematician?*
>
> A person who enjoys maths and finds maths easy maybe, or who just loves maths like me, I love maths and I love a challenge in maths. For warm up in maths, I'm like it's easy, slow and steady, then when I do my proper work I want it to be hard and challenging. That's what I like.

Whereas Tilly mentioned that a mathematician is someone who automatically knows their times tables, Skye believed that in order to be a mathematician you 'have to give up time to practise', implying that in her eyes being a mathematician is about competence and mastery of skills. Taylor also recognised the need for resilience as well as hard work:

> *What kind of person do you think makes the best mathematician?*
>
> Someone who's like really focused, and listens a lot, and … er … doesn't let anyone else who is like going faster than them bother them.

The theme of listening and having to concentrate recurred within Sally's transcript, another of the high-attaining mathematicians:

> *What kind of person would you say is good at maths?*

> Erm… one that concentrates, and really likes to sit there working stuff out… I think that sometimes when it's hard, it makes it more fun, because you just have to keep on working on it, and you don't like get bored trying to work out any questions or anything.

Whereas the children who are lower attaining tended to believe those who are good at mathematics find it easy, it was more common for the higher-attaining children to refer to liking a challenge, being focused and concentrating. This ties in with Kilpatrick et al. (2001)'s notion of a 'productive disposition' (p. 131) towards mathematics, where diligence was an essential element of success alongside children's belief in their own efficacy.

The issue of mathematical collaboration also arose; rather than mathematical success being an individual enterprise, for Aimee being a mathematician necessitated a willingness to work alongside and support others:

> *Ok. So what kind of person do you think is good at maths?*
>
> So like a person who is always willing to help other people when they're stuck, not just tell them the answer. Not copying anyone, and if you're stuck, then use your brain, then use a book, then use a buddy, then if you're really stuck just leave it then move on then come back.

Another theme arising from the data was the contradiction between those who saw clear links between being a successful mathematician and having skills in other subjects, and those for whom being mathematical meant people were less likely to enjoy or be good at other subjects, suggesting the kind of 'othering' of mathematics reported by Piatek-Jimenez (2008):

> *What kind of person do you think makes the best mathematician?*
>
> Erm… someone whose … who has lots of things in their brain about maths, and not good at other subjects. And they work out things and they… they do it really quickly. So some… some things like in a shop, like if they had like a percentage offer, so if they pick up the item they'd already know how much the actual item was.
>
> *You said something a minute ago about not very good at other subjects. Could you say a little bit more about that?*
>
> Because… most mathematicians, they're not very good at subjects like literacy, because they like maths. And they… they think maths is really easy. Then they would find literacy quite hard…
>
> Hetty's transcript

On the other hand, Sally and Jasmine both linked mathematics with music, stating that someone who is good at mathematics is likely to be good at music and vice versa. Jasmine's views of mathematicians were unusual, with her describing the best mathematicians as being smart, imaginative, creative, and 'handy'.

> Most of the people who like maths in our class also like music. They… they normally …. They're normally only good at maths, but, they're good at another thing as well, like music or art.

As a counterpoint, Polly associated achieving success in mathematics with having a spirit of adventure:

> *So what kind of person do you think is good at maths?*
>
> Well, someone who likes adventure, because maths investigations can be very adventurous, because they can go on for a long time, each investigation goes to a new investigation.

The last word in this section goes to Lauren, who drew together ideas including family influence, the nature of mathematics and links to aspirations in expressing her views about being a mathematician.

> *So, what about when people are grown up, what do you think it means to be a mathematician?*
>
> Hmm… just… you'll be… I'm not really sure. Well… you'll be able to do quite a lot of things, because maths isn't just to do with one thing, it's to do with loads and loads of things…and … because my uncle's, I think he's something to do with maths and that. And… it makes you get a better job… it makes you do more things, because if you want to be a teacher if you know maths then you can be a teacher, you can be like engineer, and all sorts, if you know maths. But if you're not the best at maths, then you'll have to find something else. Or you could … well, you don't always have to be good at maths to get a good job. Because you could be not the best at maths, then get the job to do with maths, then that will make you better.

Within this explanation, Lauren acknowledges that there is more than one way to become good at mathematics, and although she is currently clear that she is not a mathematician as will be seen below, she leaves the door open to this possibility in the future.

6.1.2 Being a mathematician

The question of 'do you think you are a mathematician?' was inserted at an unobtrusive point in the interview when it fitted with the flow of the other questions. A summary of responses is provided below as Table 6 (girls are listed in order of attainment as judged by teacher assessment, from lowest to highest).

Child	Response
Jasmine	Not really
Aimee	Not quite, but I want to be…
Alice	I'm fairly good at maths…partly yes and partly no
Emily	In the middle and getting there
Lauren	No
Mackenzie	More of an artist
Poppy	No
Tilly	No, not really
Hetty	Not really, no
Skye	No, not really
Millie	Sometimes
Polly	Yes
Sally	Yes
Taylor	Sort of

Table 6 Responses to the question 'Are you a mathematician?'

The only children to give an unequivocal yes were Sally and Polly, both of whom attend HAG. The other attendee, Taylor, was the most ambivalent towards mathematics throughout the data collection, as summarised within her food metaphor (Figure 6.1):

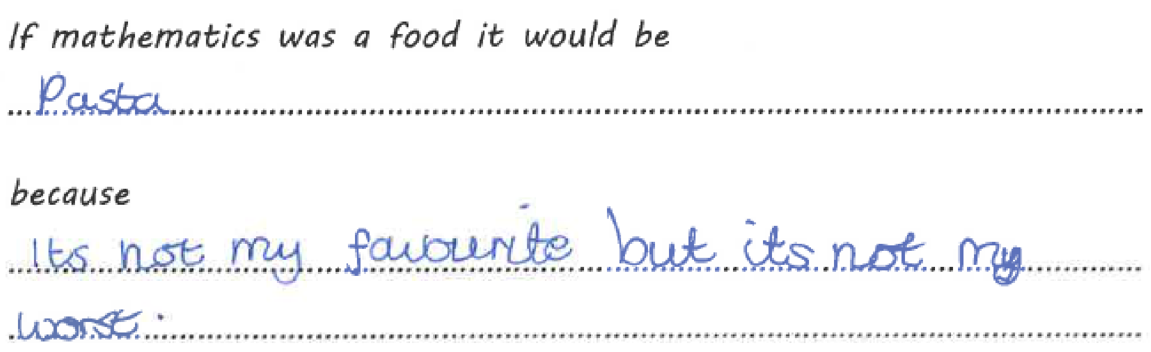

If mathematics was a food it would be
Pasta
because
Its not my favourite but its not my worst.

Figure 6.1 Taylor's 'food' metaphor

The idea of becoming a mathematician being a journey rather than a binary state was expressed by Aimee, Alice and Jasmine, Aimee stating that she was 'not quite' a mathematician but always tried to do her best, and Alice that she needed to work on some things before she could be seen as a mathematician. Jasmine reported getting better at mathematics, which was leading to her becoming more confident, but 'not really' being a mathematician. By replying that she is not really a mathematician because there are areas of mathematics which she finds tricky, Tilly assumed that in order to be a mathematician you have to be good at all areas of mathematics, echoing the sentiments of Skye explored above:

> *Would you say you're a mathematician?*
>
> No, not really. It depends on what it is. Because I'm good at like… like converting time, and stuff, but I'm not really good at division, and other stuff like that, like my times tables. I'm ok at decimals but I'm not that good at fractions either.

Hetty and Polly provide interesting contradictory responses (it is worth noting that Hetty entered the research period at a level well above the national average for her age):

> *So… do you think you're a mathematician?*
>
> Not really, no.
>
> *What makes you say that?*
>
> Because… I'm not that good at maths. Because some things I find really tricky, like percentages, because I don't really get it. And then the people on the top table, they get it as soon as she says it.

In contrast Polly associated finding mathematics hard but rising to the challenge with being a mathematician, using her drawing of herself doing mathematics (Figure 6.2) to illustrate:

> This subtraction here… some people might find it hard, but I also find it very fun, so I enjoy doing it, even though it's hard.

Figure 6.2 Polly's picture of herself doing mathematics

Across the range of data collected, the three children in the group who repeatedly appear to have the lowest levels of confidence in themselves as mathematicians are Poppy, Mackenzie and Lauren, alongside Tilly who also referred to herself as not being very good at mathematics and not really a mathematician. Whilst towards the lower end of the attainment spread amongst the girls in the class, these girls all entered the year slightly above the expected attainment for their year group. This could be evidence of the effects of being a less confident member of a relatively high attaining group.

Poppy referred to being disappointed in and angry with herself for her perceived mathematical failings throughout the pupil conference. She was willing to work hard, and could identify areas that she did like, but her overwhelming belief was that she was not a mathematician.

> *What about at maths, or what would your friends and family say?*
>
> That I need to work on it, a lot more than all the other subjects. I find it harder, because maths is the most tricky subject for me.
>
> *Would you say you're a mathematician?*
>
> No.

No? Why not?

Because I'm not very good at it. And I don't enjoy doing it. I enjoy doing it, but… I enjoy some things more than others. So if it was fractions and decimals, I'd find that lesson so boring and really hard.

A little later in the interview, the following sequence occurred:

Ok, that's very interesting. If you had to sum up your confidence in maths, what would you say?

10 being the highest?

Yes, we could do it like that.

My confidence… …I don't know really, 4 or 5?

Ok. And if you could change one thing, about your relationship with maths, what would it be?

Being good at it, because then I'd enjoy it more.

Poppy associated being good at mathematics with lifting her out of her current negative relationship with the subject, but at no point within her interview does any hope on her part emerge that she might be able to get better. This would perhaps suggest what Ernest (2011, p. 109) refers to as the 'Failure cycle', within which perceived failure at mathematical tasks lead to poor confidence and mathematical self-concept which in turn leads to mathematics avoidance and reduced opportunity to learn, feeding back into failure in a never-ending cycle. Somehow Lauren and Mackenzie both maintained a more positive learning stance (Pollard & Filer, 2014) despite being utterly convinced that they are not mathematicians. First Mackenzie (who echoes the theme of mathematics as a desk-bound activity discussed previously):

Do you think you're a mathematician?

I'm more… I like writing. I like art and everything. Because in art, I'm proud of most of the work I do. But in maths, sometimes I'm proud, sometimes not. I like out and about, and like all that drawing stuff, but maths… it's just… hard, for me. Hard. So most of the time I don't really understand it. So… yeah.

And finally for this section, Lauren displays evidence of the fixed mindset reported to be so negative for children's mathematical identity (Dweck, 2000, 2007):

So do you think you're a mathematician?

No.

What makes you say that?

I… I'm just… I find it better doing literacy, and I'm not a person who's really good at maths, and who loves it, so I just think I'd better not be a mathematician…

In terms of identity formation relating to how a person knows and names themselves (Grootenboer et al., 2006), Lauren's phrasing of 'I'm not a person who…' is conspicuous and echoes Nardi and Steward's ideas of depersonalisation and elitism (2003). The fact that only two of these girls identified as being a mathematician echoes the suggestion of Mendick (2005) that the socio-cultural construction of gender and mathematics in the UK as opposing ideas make it difficult for girls and women to identify as 'good at maths' (p. 204), although the data suggest that the judgement they made about their own mathematical ability formed a stronger influence than issues around gender. It would be interesting in further research to investigate and compare the characterisations similarly-attaining boys make of themselves as mathematicians to explore further the gendered nature of mathematical identity formation.

6.2 Born or made?

Having reviewed the literature around mathematics and the affective domain, and found the debate around fixed and growth mindsets (Dweck, 2000, 2007) to be key in investigating reasons why females come to the viewpoint 'I can't do mathematics', an emergent line of enquiry was whether girls believed mathematical aptitude was inherited or acquired.

Two of the girls came out with a clear 'no' regarding mathematics aptitude as inherited: Mackenzie and Tilly. Mackenzie's transcript reveals:

> I don't think you're born good at maths. I think… when you get used to it, you like it or you don't like it. So… when I got used to it, I wasn't really a big fan. And like maths wasn't… I wasn't understanding it that much. But some people, they're like… they understand maths so well, and I can't see how it is… well I don't think they're born with it, they have to know… maybe it's like their hobby or something, like maybe they go to a maths club or something, yeah.

Although Mackenzie did not believe that people are born good at mathematics, she struggled to understand how others find it easy when she finds it so difficult, suggesting that there might be some kind of external factor like involvement in a club or hobby. Tilly on the other hand justified her statement with reference to the effort that goes into being a mathematician:

Do you think some people are born to be good at maths?

No, I think they just practice, I think they practice and they just get better.

In contrast, three girls directly asked whether mathematicians are 'born or made' believed that mathematical ability was inherited, at least in part. The first of these was Poppy, who began by asserting that children would follow in the footsteps of their parents, although subsequently she allowed for parents wanting their children to be mathematical even when they weren't themselves:

So do you think that some people are born as mathematicians, and some people aren't?

Yes. Because if their parents are really good at maths, then they are going to be really, really good at maths as well. Because like… and also, if their parents aren't so good at maths, and then their parents want them to be good at maths, then they could start… then they have to start learning quicker.

This implies that in her eyes children whose parents are not mathematical will have some kind of deficit to make up. Taylor also made the case for an inherited inclination towards mathematics:

So do you think they were… some people are born liking maths, and some people…

Yes, I think some people just like it when they're born, it's just a natural thing. Some people just don't naturally like it.

Finally, Polly attributed her mathematical ability to her parents, stating that her mum and dad were both very good at maths. Although most children were not directly asked whether they believed children were born or made, the evidence summarised below relating to resilience, ownership and internalisation suggests that the majority of them took a high degree of responsibility for their own mathematical progress, suggesting that rather than believing mathematical prowess as being inherited and therefore determined, they instead saw themselves as having a key role to play.

6.3 Gendered beliefs around mathematical aptitude

There were few overt references to gender differences within the data, in particular as regards mathematical ability. One of the few girls to refer to gender differences was Hetty, who believed that rather than being better at mathematics, boys simply believe they are better:

Do you think people find it easy to admit that they find something difficult in maths?

I think… I think the boys wouldn't admit it. Because they think boys are better at maths than girls. And I think the girls would admit it, because they would be honest and then people would help them with it.

So, what made you say that you think that boys think boys are better at maths than girls?

Because, boys just think they're better than girls at everything, but they're not necessarily are (sic), because in HAG there's only 4 boys, and there's 5 or 6 girls.

In this case having direct evidence to contradict the notion that boys are better at mathematics was helpful to Hetty, vindicating the school's decision to move towards ensuring the HAG had a more equal gender balance. Polly, however, did appear to rate the boys above the girls as mathematicians:

I don't think it should make a difference, but I think some of the boys are like a tiny bit better than the girls.

What makes you say that?

Well, erm…I think they have a bit more experience? They are a bit further ahead.

When asked, she was unable to elaborate on why the boys might have more experience in mathematics than the girls. Poppy also believed that there is a gender difference in terms of who is stronger at mathematics, but unfortunately was unwilling to elaborate:

Ok. So, do you think there are different groups of children, or types of children that enjoy doing maths?

Yes. I think… that… in our class, I think the boys are better at their maths than the girls.

And what makes you say that?

I don't really want to say.

Also considering groups of children who enjoy doing mathematics, Mackenzie stated 'I find that the boys in our class like doing maths, and a couple of the girls'. She went on to provide more detail when prompted to describe a person who is good at mathematics. After describing a boy who does mathematics at home all the time and is quick at mathematics she went on to explain:

…and then girl-wise… there's, some of the girls, in our class, really like maths. And … react to maths like that's a big part of life, but I don't react to maths like that's a big part of life, because sometimes it’s not. So… yeah… I can’t, the girl I’m describing is more like the boy. She doesn’t… well, she loves maths, she does, so they’re probably the same.

This perhaps echoes the prevailing deficit model present in the 70s, 80s and into the 90s that females needed to become more like males in terms of their mathematics, attaining male norms (Leder, 2007).

It is difficult to discern whether the skew towards females being represented across the different data sources reveals anything about children’s beliefs regarding gender, or simply that life in the primary school is dominated by female teachers and support staff. Taking the relationship wheels, the majority of references were to the female class teacher, followed by Mums and friends, both of whom were predominantly cast in the role of ‘helping’ with mathematics. Dads featured but less frequently than mothers; however brothers and grandfathers were more frequently mentioned as positive providers of support and encouragement than sisters and grandmothers. Two of the girls, Aimee and Lauren, specifically mentioned more able older and younger brothers respectively, but this was specific to their families and there is no sense overall that they believe male family members to be generally more able mathematicians than females.

6.4 I would be better if I worked harder: resilience, ownership and internalisation

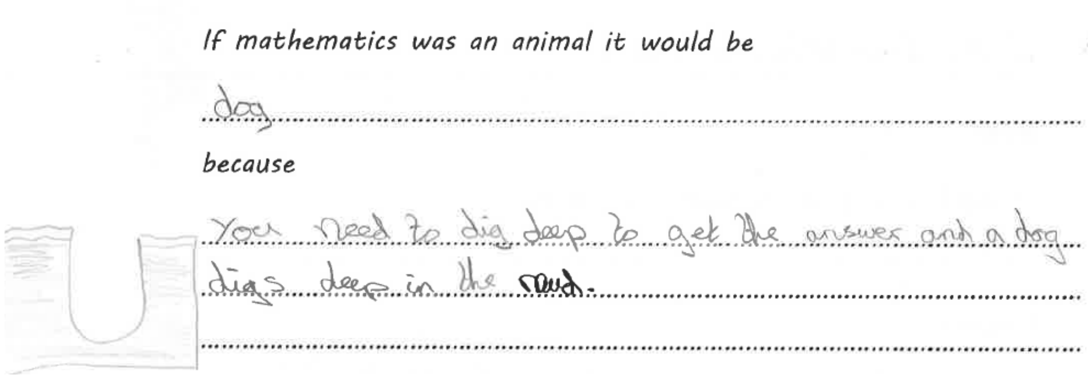


Figure 6.3 Digging deep: extract from Skye’s metaphor elicitation task

Across all forms of data collection I was struck by the responsibility the girls’ took for their own mathematical development, one of the factors seen as key to being mathematically resilient (Bell & Kolitch, 2000; Johnston-Wilder & Lee, 2010b). They could articulate what they perceived as their strengths and targets, where they felt they needed to improve, and what they were currently working on. As a group they constantly referred to work they carried out in their own time or within the school day beyond the mathematics lesson, and strategies they used to avoid resorting to asking the teacher. Skye’s animal metaphor reproduced in Figure 6.3 illustrates a typical willingness to ‘dig deep’ in order to achieve success.

Nine of the scrapbooks contained instances of girls doing what I coded as ‘rehearsing school mathematics’. This involved writing out times tables, rehearsing fractions calculations, or practising methods of calculation they had been learning about in school. Figure 6.4 shows an example from Taylor, followed by the accompanying explanation from her transcript:

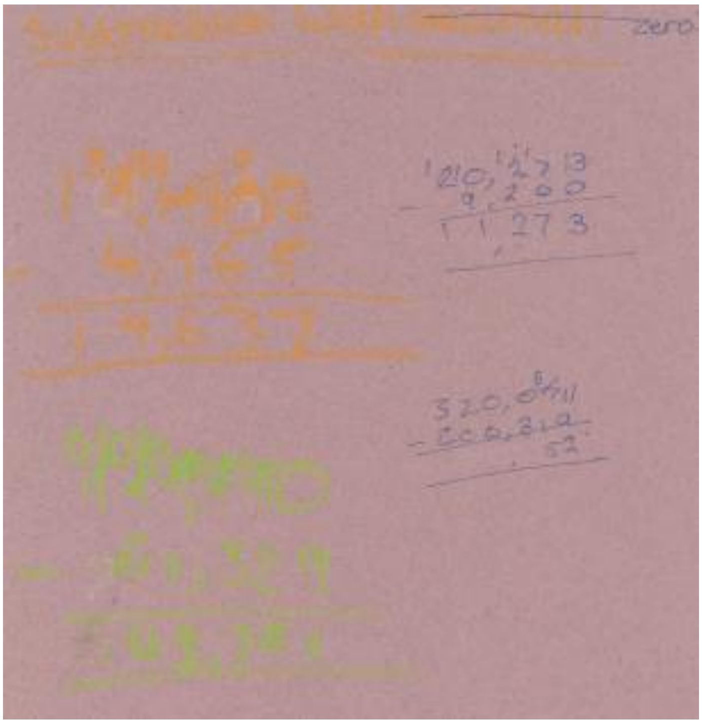


Figure 6.4 Rehearsing subtraction methods – extract from Taylor's scrapbook

> *So what made you choose to put this into your scrapbook?*
>
> Because we’d been working on it at school, and I just tried to keep practising it.
>
> *Ok.*
>
> I knew what we had to do, but I forgot for a little bit, and once I’d been getting a few questions wrong at school, I just wanted to keep on practising it so it got stuck in my head.

This belief that both effort and experience will lead to success over time illustrates perfectly the ‘productive disposition’ seen as so important to mathematical learning by Kilpatrick et al. (2001, p. 131). Similarly, Lauren’s scrapbook contained frequent examples of her trying out the mathematics she had been learning at school, particularly methods of calculation (Figure 6.5).

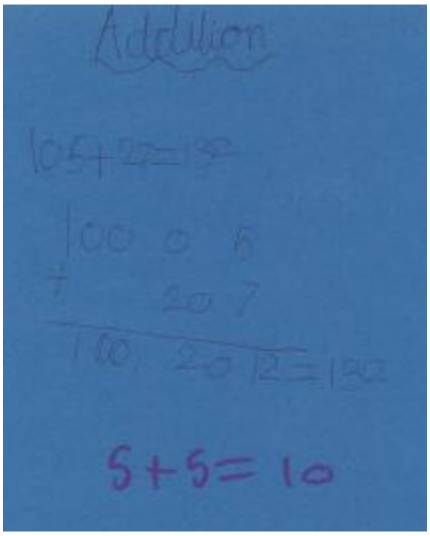


Figure 6.5 Expanded written addition – extract from Lauren's scrapbook

This theme of using the scrapbook as a safe space to practise mathematics learnt at school was also present within Hetty's scrapbook, as shown within Figure 6.6 and explained within the extract from her pupil conference transcript reproduced below.

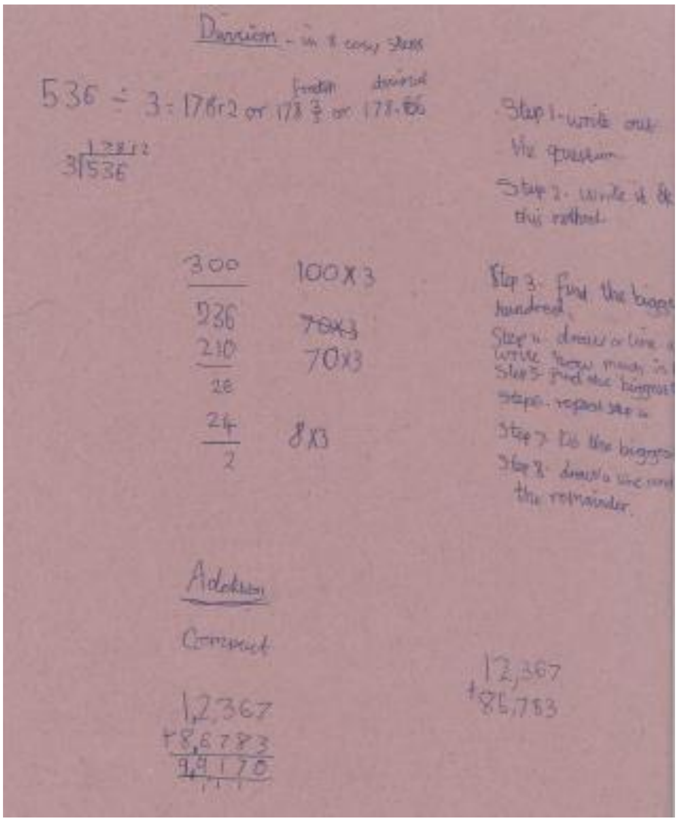


Figure 6.6 Consolidating division strategies: extract from Hetty's scrapbook

> Because I find division quite hard, I wrote the steps out for myself, so I could keep going over them again.
>
> *So what made you choose to put that into your scrapbook?*

Because… that day we were doing strategies, and I didn't get individual ones that well, so I thought I should write it down somewhere to help me, and I just thought I should do it in my scrapbook. And I did some decimal calculations and some word problems.

Mackenzie also chose to rehearse school mathematics in her scrapbook. Notice the errors when she attempted to provide accompanying division facts to go alongside the 5 times-tables (Figure 6.7):

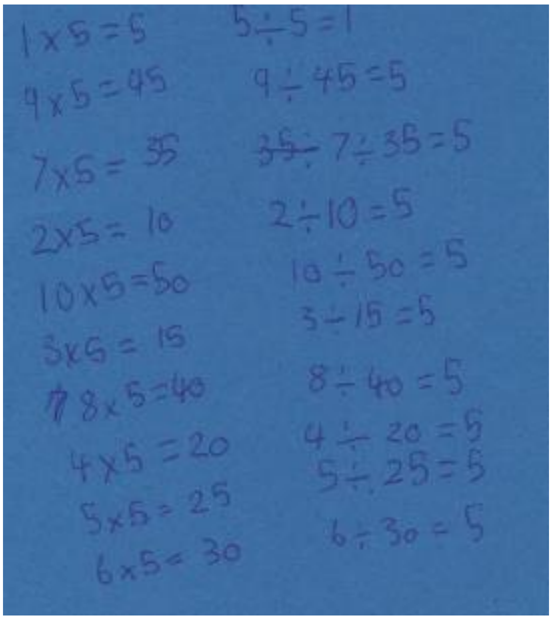


Figure 6.7 Attempting to practise multiplication tables – extract from Mackenzie's scrapbook

The errors within the scrapbook raise an interesting question about ownership. For the purposes of this research, the children were asked to put anything into their scrapbook which would show mathematics in their lives; the decision to include rehearsal of mathematics they were carrying out at school was theirs, and the scrapbooks were not marked in any way. Discussion with the children suggested that some simply chose to put these examples in to reflect the mathematics they did at school, whereas others actively adopted the space as somewhere where they could practise, secure and improve their calculation skills, echoing the findings of Stuart (2000) that mathematics journals can provide a useful vehicle for reducing anxiety. An unforeseen strength of the scrapbooks in this context lay in the children's ownership of them as secure spaces to try out and rehearse mathematics; however a potential weakness was their errors went uncorrected and could become embedded. The confidence children felt to try out and record mathematics within their scrapbooks contrasted sharply with Skye's explanation of her recording within the school environment when stuck on a piece of mathematics:

What do you do when you get stuck?

I try doing some workings out on the … on pieces of paper. And then…really lightly, and then rub them out…

Why do you rub it out?

… I don’t know.

One of the key words within the title of this subsection is resilience, which is currently receiving focus as a key element in children and young adults gaining success in mathematical qualifications and going on to post compulsory study (Goodall & Johnston-Wilder, 2015). An insight into the resilience needed to cope with the mathematical world she inhabits was provided by Taylor’s illustration of herself doing mathematics, represented in Figure 6.8.

Figure 6.8 Taylor’s drawing of herself doing mathematics

Within one image we have pragmatic concerns, content-based questions, emotional reactions and metacognition; a significant demand upon a still-young child. Girls also demonstrated great resilience in resisting the sometimes less than encouraging feedback they received from friends and family members, from Aimee’s family members telling her that mathematics is boring to Millie’s rejection at the hands of her sister. Tilly’s resilience was sorely tested by a critical incident which occurred at the beginning of Year 5 as she moved into her new class.

> I want to be good at maths, but I feel … because at the beginning of the year, I just didn’t think I’d be able to do anything in maths, but that’s because I accidentally got put into the highest group, and I struggled, and so I asked to be moved down to the lowest group, and Mrs Jones didn’t realise, so … so I got moved down to the lower group, and I feel much

more confident now than then. And I can do most of the stuff, but I'm still learning, like this isn't all easy, I'm still learning, but yeah…

This incident had clearly knocked Tilly's confidence, and she referred to it several times throughout the conference. Despite this, with her teacher's support Tilly had worked hard to overcome her negative feelings about mathematics and at the time of the conference believed herself to be making good progress:

Where do you think people get their ideas about maths from?

I think they get it from their past. Because that's where I got mine from, because I was put in the higher group accidentally, and she… she told me to move down, she didn't know why I was up there, and … then, I just got loads of ideas, like pop in about maths now, but before it was like my worst subject, because I knew I would get everything wrong, so when she said it was maths I was like 'oh no, I'm going to get everything wrong again', but now I'm much more confident, and I'm even helping other people now, not people helping me as much, so I think people get their ideas from the past.

The ownership Tilly took of her own mathematical development is clear, reflecting a 'learning stance' (Pollard & Filer, 2014, p. 9) that reflects a belief that practice and determination will pay dividends:

And is there anything else that you think I should know about you and maths, or your relationship with maths?

Well, I do practice a book every day, and I ask Mrs Jones for sheets of maths that I can practice, and sometimes I do… I work through the easier columns through to the harder ones. And I just do maths anywhere, I do it in my garden, I do it in my room …

How do you feel about that?

I feel like… I'm actually trying to make myself better, and I'm trying to get better at maths. But then again, I kind of wish I was really good at maths, so I'd feel proud, but anyway… I just have hopes, that I'm better at it.

Whilst there were many positive examples of children carrying out additional practice to improve their mathematics 'level', for some girls this appeared to turn into frustration and even anger, for example Millie's reference to her disappointment in herself when she got too many questions wrong. Nowhere is this internalisation more marked than within Poppy's frequent references to her feelings of inadequacy as a mathematician. The extract is preceded by her drawing of herself doing mathematics, reproduced as Figure 6.9.

Figure 6.9 'It's normally what I look like when I'm doing maths'

Throughout Poppy's data can be found examples of her personal struggle with mathematics, even associated with this innocuous looking photograph from the school playground (Figure 6.10):

Figure 6.10 Poppy's photograph of mathematics in the school grounds

> *So what made you take a photograph of that?*
>
> Because I knew that I struggled with that, and I wanted to take a picture of it so I could … so I could get better at it and work on it.

Her transcript continues upon this theme, showing her frustration at herself for her perceived lack of progress through discussing her weather metaphor:

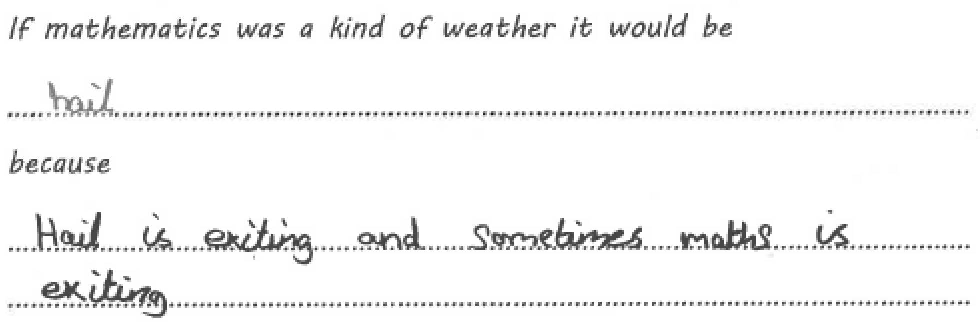
Tell me a bit about what you've said here, about hail.

The kind of weather would be hail, because hail kind of comes down really hard and it hurts you, and in maths, I get a bit upset when people go up, like when they're on the same level as me one time, then they go up and I stay on the same or go down, I get a bit angry with myself because I'm not getting better at it.

What do you mean by going down a level?

Like, if I'm getting… if I'm not getting it right or something, if I'm not getting better at it, and I'm getting worse at it, then I go down. It kind of makes me really angry with myself, because I'm not… I'm not… working hard enough.

Poppy's explanation of her image within the metaphor elicitation task, reproduced as Figure 6.11, came as a surprise, given the more positive explanation she had provided of mathematics being 'sometimes exciting':



If mathematics was a kind of weather it would be

hail

because

Hail is exiting and Sometimes maths is exiting

Figure 6.11 Mathematics as hail: extract from Poppy's metaphor elicitation task

Without the discussion about her metaphor, Poppy's feelings about herself as a mathematician may have gone unnoticed, raising the question of how many more children live with these kinds of undetected feelings about mathematics.

Being willing to persevere is a theme running throughout the available evidence, counteracting some of the less confident mathematicians' characterisations of able mathematicians being able to work out answers quickly or without effort. Once again, a final word in this section goes to Lauren's summary of her personal feelings towards mathematics:

Is there anything else you think I should know about you and maths?

Hmm... not really, just that I find it hard and I'm quite worried about maths. I find it one of my worries. I have lots. So… that's one of them, yes, that's it.

She accepts that mathematics for her requires effort, persistence and sheer hard work, but does believe that this effort will pay off, a least in part:

> Because I did understand it, because as I got used to it, I understand things more, so I do it more and more often, then I get used to it.

As explored within the literature review, such perseverance is unlikely to be sustained if children do not see a purpose for their endeavour (Ainley et al., 2006; Ashby, 2009). The extent to which the girls saw themselves as continuing with post-compulsory study and using mathematics within their future careers is explored within the final section of this chapter.

6.5 Looking forwards: continuing with mathematics and the role of aspirations

Aged nine or ten at the time of the pupil interviews, the girls were young to be asked about their future career plans and aspirations. Despite this, almost all had well-reasoned views about future study of mathematics and career choices. Inevitably friendships had an influence, for example the three prospective veterinary surgeons were all good friends.

Those who did want to continue with mathematics beyond compulsory study reported a variety of reasons. Examples include Alice who wanted to continue simply because she enjoys the subject, similar to Polly who did not know what she wanted to do as a career choice, but wanted to continue to study mathematics due to her enjoyment of the challenge it provides. In some cases wanting to continue was explicitly linked with career aspirations, as it was for Emily who reported wanting to be a vet and associated mathematics with future earning potential:

> *So when you're older, you'll have to carry on studying your maths until you've done your GCSEs, but after that you'll have a choice. So do you think you'll carry on studying it when you don't have to?*
>
> I think I will. Because if I stop doing it then I won't get a good job. And then I won't earn the money that I want.

Aimee also associated mathematics with good career options, and wanted to be a vet, but did not link this with post-compulsory study of mathematics or have a particularly clear vision for how mathematics might be used:

> *So, how do you think you would use maths if you were being a vet?*
>
> Because you have to like… pay, and you have to get the right equipment for the right animal. You would have to do like…so I'll use this one, and then use a certain amount

> more, and how many millimetres or metres you'd need to use of it, so that would help you.

One of the other girls who considered it likely that they would continue with post-compulsory study was Sally, who identified mathematics within being a teacher or working in a bank, both career choices she was considering. Mathematics was also associated with Tilly's chosen career; she had a clear vision for how she would use mathematics as a hairdresser and believed she would continue to study the subject, despite expressing nervousness about studying mathematics getting more difficult in the future.

Rather than believing she would need to continue with mathematics in order to fulfil her career aspirations, Millie saw her love for mathematics and science as driving what she would choose to do as her career:

> *Do you think you'll carry on doing maths after that when you don't have to?*
>
> Well, I would either like to be a vet or a maths teacher at school because I love maths. And sometimes… because I'm quite good at science too. So science and maths equal vet, being a vet, so I would like to study maths even if I don't have to, so I would always choose maths and science.

Lauren's view of her future was also affected by her feelings towards mathematics, but unfortunately for her the influence was negative rather than positive.

> *I know this is a long time ahead... do you think you might choose to carry on studying maths when you don't have to?*
>
> Well my mum will probably say it's up to me, it's my decision… and I... I don't know… I think, thinking about it now, I think I will, just to try and get me better. But maybe then I might not, because I don't know what it's like there, because I've always been dreading going to secondary school, and I don't know what it's like, what the teachers are like teaching maths, and if they give you hard stuff and everything. So I'll probably see what it's like when I get to the point.

She also appeared to restrict her future career choices based on her perceived mathematical ability, discounting the possibility of becoming a primary teacher because of the need to teach more difficult mathematics. Expressing her desire to teach young children in pre-school like her mum, she stated:

Well, I think I would use it, yes, but not like… as much as… as much, because younger kids don't know that much, so you teach them simple things, which is good for me, because I know all that simple stuff. So, yes.

Belief, or rather lack of belief, in her mathematical ability also informed Poppy's response:

Do you think you are likely to want to do maths, or do you think you might not carry on with it when you get to that point?

I'm not sure, because like in the future, I might get better at maths and I might be really, really good at it. And then… if I'm not very good at it, like I am now, then I probably won't … I won't want to do it. Because I don't want to do something that I'm not very good at.

Whilst it is easy to see decisions about future mathematics study and career options as being negatively impacted by lack of faith in their mathematical ability, particularly in the light of the importance of mathematics for future wellbeing and earning potential (OECD, 2013; Parsons & Bynner, 2005), for some of the girls this was a positive decision. Skye, for example, simply preferred art as a subject, and valued being good at art and drawing above wanting to continue with mathematics. Having set out her desire to be an actress, Mackenzie was happy for her options to unfold as her career plan became clear:

Well… I'm thinking of a job when I'm older as an actress. So I may carry on with maths, but I may not. It has to depend what I think when I'm older. At the moment, I'm half thinking carry on, but half thinking not.

Finally, Taylor gave the following, considered response when asked about the role mathematics might play in her future life:

How do you see yourself using maths in the future?

Erm... probably just for like basic things, like for change, money and… basic stuff, because I don't want to like go onto maths for a job or anything.

Don't you?

No.

Why not?

Because, I just… I don't really, really enjoy it. I'll do it, it's ok, but I wouldn't want to do it for life.

Although as one of the highest attaining mathematicians in the group this is perhaps surprising, it aligns with her ambivalence towards the subject discussed earlier. Her further explanation of why she does not want to work in the future conveys perhaps the lowest level of aspiration amongst all of the girls interviewed:

> Because… I just don’t. I don’t know why, I don’t want to…. I want to do something that isn’t really hard, because it can be really hard type of maths, and I just don’t want that to be me.

6.6 Chapter discussion and summary

One of the themes discussed within Chapter 4 was that of mathematics being seen as difficult or easy, right or wrong, and the implications of these dichotomies followed through into many of the girls’ attitudes towards being and becoming a mathematician or someone who would use mathematics within their career. There were mixed attitudes towards difficulty in mathematics, with some girls thinking that mathematicians find mathematics easy, whilst others (or in some cases the same children) reporting a belief that what marked out mathematicians was them being comfortable with finding mathematics difficult, the latter view being a particular feature of the higher attainers and echoing the viewpoint of Lee (2009) that part of a growth mindset is being prepared to struggle, rather than interpreting difficulty as an indicator of low mathematical ability. In discussing the implications of entity (fixed) versus incremental (growth) mindsets, Yeager and Dweck (2012) suggest that students can be taught the science underlying the potential to change and develop. Whilst their article focuses upon older pupils perhaps a positive step could be providing time for children to discuss each other’s’ perspectives on mathematics and identify some of the misconceptions they hold about ability and effort.

Despite their many positive attitudes towards mathematics, overwhelmingly this group did not see themselves as being mathematicians. For some this was simply a question of seeing themselves as being on the route to becoming a mathematician, but for others there was an unequivocal ‘no’. Using the notion of ‘self-story’ (Bruner, 2004, p. 709), it was not part of some of the girls’ own narratives that they were a mathematician. This is concerning given the importance of seeing themselves as mathematicians, or at least as someone good at mathematics, for engaging in a future involving further study or a mathematics-related career (Kaplan & Flum, 2012). Going back to their attitudes towards the role of effort and the nature of mathematicians, for evidence they seemed to look towards how difficult or easy they found mathematics – so it was not a belief that effort was futile, rather that effort could lead to improvement and even success, but not necessarily being a mathematician. The two girls that did see themselves as mathematicians were high attaining, in the able pupils withdrawal group and received positive reinforcement from their families.

Whilst there were few instances of beliefs amongst this group of girls that there were differences in mathematical aptitude linked to gender, those that did exist were skewed towards boys being better than girls, with the exception reported in Chapter 5 when mathematical ability was associated with collaboration, therefore girls were seen as stronger. There was no evidence amongst this group that they believed teachers viewed boys as being better than girls, and the research design did not provide opportunities to explore whether parents held these views.

Perhaps the most notable theme arising from analysis of the data concerning the girls' attitudes towards themselves as mathematicians and their progress was the ownership they took of their mathematical progress. There were frequent examples of children actively seeking out opportunities to rehearse and improve their mathematics, in particular relating to calculation strategies, fractions and times tables. An unexpected feature of the scrapbook methodology was the opportunity several of the girls took to use their scrapbook as a safe space to practise areas of mathematics where they believed they needed to improve, reflecting the findings of Coles and Banfield (2012) regarding the power of mathematical journals and suggesting that practitioners could consider providing similar opportunities for children even when not involved in research.

This group of girls could not be accused of a lack of the element of 'productive disposition' (Kilpatrick et al., 2001; Pollard & Filer, 2014) that involves a belief in diligence. Far from disowning responsibility for their development, if anything it was entirely absent from this group of girls' discourse to believe that the responsibility for getting better at mathematics lay anywhere other than with themselves. Whilst this might suggest a positive, growth attitude, in one of the girls this appeared to be extreme, leading to self-blame and a sense of failure. Whilst it was outside the remit of the study or expertise of the author to explore issues around mental health, after seeking advice from the chair of the ethics committee these concerns about a specific child were shared with the head teacher.

A productive disposition, however, is seen by Kilpatrick et al. (2001) as wider than being prepared to be diligent: it also incorporates beliefs that mathematics is useful and in the child's own efficacy. As was reported in Chapter 4, several of the children struggled to articulate a vision for how mathematics could be used beyond the world of education and the purpose of specific topics such as fractions and times tables which took up such a large proportion of their time. Coupled with the lack of clarity about how mathematics might be used within a future career beyond a limited range of careers based on handling money, baking, hairdressing and being a veterinary surgeon, alongside the tendency of this group of girls to see themselves as not being a mathematician, this paints a worrying view of the future. On paper, given their attainment levels on entry to year 4, this group could be destined to attain highly at the end of Key Stage 2 and

GCSE level. Will they become the girls reported by Sheldrake et al. (2015) as not choosing to continue with mathematics despite their obvious capabilities?

Building on findings of the study in terms of children's characterisations of mathematics and the social context in which they carry out mathematical activities, this chapter has explored what the data reveals about becoming and being 'a mathematician'. Some of the images and quotations contained revealing a troubling insight into the world within which these girls operate. Whilst for many the picture is a positive one, with a love of mathematics and confidence in themselves as mathematicians shining through, for others their view of themselves as not being a person who can succeed in mathematics is already well established. The next chapter draws together and discusses the trends emerging across all three results chapters in aiming to shed light upon the sense girls make of their mathematical identity.

7 Discussion

This study was born out of a desire to better understand factors leading to women and girls identifying with the phrase ‘I can’t do mathematics’. Why do so many females, often perfectly capable mathematicians, come to believe so strongly that mathematics is not for them? Whilst gender gaps in mathematical attainment have generally been eliminated at all but the higher levels, there remains a tendency for girls to under-estimate their mathematical ability, lack confidence, and shy away from the kind of positive mathematical identity that might allow them to continue with mathematics into and beyond post-compulsory study.

In conceptualising and constructing this study I hoped it would make a meaningful contribution to knowledge of this phenomenon through allowing a specific group of girls to shed light upon their emerging mathematical identities, framing findings in terms that might be useful for educators seeking to better understand girls’ perceptions of mathematics. The design following an all-girl sample supported looking into these aspects of their mathematical worlds in depth. Specifically, the research questions were:

1. How do girls perceive mathematics?
    a. How do they characterise mathematics?
    b. What mathematics do they recognise as part of their daily lives?
2. How do girls make sense of their mathematical identity in relation to:
    a. How they characterise mathematicians?
    b. The role of other people?
    c. How they position themselves as mathematicians?

There has already been substantial discussion of the study findings embedded within the preceding three chapters. This chapter summarises findings and contributions to knowledge against each of the research questions in turn before discussing implications for practice, both of the findings themselves and of the methodological processes which have allowed deep insight into girls’ perceptions of mathematics.

7.1 Girls’ perceptions of mathematics

The first research question, aiming to ascertain how this particular group of girls perceive mathematics as a backdrop to understanding how they make sense of their mathematical identity, was split into two parts. The first of these concerned their perceptions of mathematics as a subject, and the second what mathematics they recognised as part of their daily lives, both now and as a potential element of their futures.

7.1.1 Characterisations of mathematics as a subject

As predicted by the literature (Ashby, 2009; Borthwick, 2011; Walls, 2003b) number and calculation were prominent in the girls’ visions for what constitutes mathematics as a subject, and speed and size were important factors. Alongside number and calculation, aspects of mathematics such as fractions were emphasised, with all of these appearing both within children's portrayals of mathematics within the classroom and within their determined attempts to get better at mathematics through repetition and self-regulated practice. Coupled with this emphasis on certain areas of mathematics there emerged, predominantly in the discourse of less-confident mathematicians within the group, a lack of understanding of why these areas were actually so important. For the most part the girls accepted this curriculum without question and their emphasis upon number and calculation reflected the balance of the taught curriculum they received, however the lack of emphasis upon some of the more dynamic topics of the curriculum such as geometry, key life skills such as handling data, and algebraic reasoning provides food for thought and leads back to the question explored within the literature review of the overall purpose of the mathematics curriculum.

The girls' propensity to see mathematics as contrived, inventing the kinds of word problems that could only be features of a mathematics lesson rather than genuinely found in the world around them was a striking theme, as was the geographical location of where mathematics is carried out, revealed particularly through their drawings. Few of the girls were able to articulate examples of applying mathematics as a tool to realistic problems in real-life; instead, many of them took the kind of questions only found within mathematics textbooks and tests with them into their home lives via their scrapbooks.

The theme of dichotomies in views of mathematics, the tendency of this group of girls to see it as a subject which is either hard or easy, right or wrong, emerged across the data sources and particularly within the interviews, drawings and scrapbooks, echoing results reported by Mendick et al. (2008). The data suggests, however, that the picture underpinning these dichotomies is subtle and complex. Some children preferred working on mathematical skills such as estimation because these skills released them from the pressure of having to gain a right answer, whilst others felt one of the contrasts between home and school mathematics was the need to be 'right' at school or have their mathematics judged. For some mathematics as a subject that could be judged 'correct' was a source of satisfaction and enjoyment, for others a source of stress and discouragement. All of this points to the importance of the class teacher understanding the viewpoint of the individual, their perceptions of the nature of the subject, and providing a variety of ways into meaningful tasks that allow children to understand not only how areas of mathematics connect together but why mastering them is important.

7.1.2 Mathematics as a feature of daily life

Integrally linked to, informing and informed by how this group of girls characterised mathematics as a subject was the second question concerning what mathematics they would recognise as part of their daily lives. Reviewing the writings of authors such as Pais (2011), Bishop (1988), Masingila et al. (2011) and Rowlands and Carson (2002), this study aimed to ascertain whether children would recognise activities in the home as mathematical unless they were validated by formal, academic activity, and whether commonalities or differences would predominate when portraying home and school mathematics. Analysing and contrasting the more home-based elements of the study, the scrapbooks and photographs, against the more school-based data collection methods such as concept maps and children's drawings, revealed a mixed picture.

There were many heartening examples of home-based mathematical activity being recognised as such, particularly amongst the games and hobbies of Jasmine, the many and varied family-based activities of Hetty and the recognition of mathematics as a problem-solving tool within the pictures and annotations included by Taylor. In supporting the findings of Winter et al. (2004) that puzzles, games and practical activities were a feature of home-based mathematics, but contradicting those of Masingila et al. (2011) in finding that at least some of the children did recognise them as such, the data suggests that there is scope for more frequent and consistent links being made between the two predominant locations for learning in a child's life, home and school. One possible bridge supported by the data is the use of cultural artefacts as recommended by Bonotto and Basso (2001); receipts, recipes or travel guides are examples of the kind of artefacts that might be used as a starting point for classroom-based mathematical enquiry, and the presence of these within the higher- but not the lower-attaining children's scrapbooks suggest the potential benefits of making these links explicit for all children.

Taken as a whole, the data suggests that this group of girls did recognise a variety of mathematics within their daily lives, but there were individual differences in this regard, and this authentic home-based mathematics tended to be overwhelmed by rehearsal of the more formal, arithmetically-based activity deemed necessary for success at school. As for the future, the limited view of the usefulness of mathematics in terms of money and measures (both stronger features of home- rather than school-based data collection methods) and absence of a vision for how some of the fundamental ideas and processes in mathematics (proportional relationships, logic and deduction, patterns and algebraic reasoning) might prove useful suggest that as educators we are currently missing an opportunity to hook children into believing that mathematics is a subject to which they should commit.

7.2 Constructing a mathematical identity

Particularly striking within the data was the role that significant others – family, friends, teachers (but not figures in media or wider society) and not least the child themselves and their own judgements – played in their developing relationship with mathematics. Children were constantly receiving both overt and unintentional feedback about themselves as developing mathematicians, which alongside the judgements they made about themselves and others had a strong impact on how they made sense of their evolving mathematical identity. Sitting alongside the complexity of their social world in doing mathematics was the feeling of isolation, particularly when things went wrong for them and they felt they did not understand what they were doing or why.

This study has explored identity from a socio-cultural rather than psychological perspective. Rather than aiming to analyse all of the factors involved in identity formation, it set out to explore the idea of mathematical identity as a construction that girls can express, and how this communicated identity is made sense of in relation to characterisations of mathematics and mathematicians, self-beliefs and the role of others. A striking feature was the individual nature of the developing identities of the girls within the study. Whereas two of the higher attaining girls saw themselves as a mathematician, one was more equivocal; whereas one child saw themselves as ‘more of an artist’, another was ‘partly’ a mathematician due to being fairly good at it. This diversity reinforces the notion of identity as complex, situated and in flux. Building upon the findings set out and discussed within Chapter 5, each of these questions is now addressed in turn.

7.2.1 Characterisations of mathematicians

Although there were some fairly predictable responses in terms of what the girls recognised as being characteristic of being a mathematician, for example being fast at arithmetic and able to ‘get it quickly’ in grasping new mathematical ideas, perhaps the most striking finding was actually the lack of characterisation of mathematicians in the first place – the absence of awareness that mathematicians exist beyond the immediate world of family members and teachers. This may be in part linked with the reviewed literature suggesting that girls are more likely to favour, and possibly therefore recognise, mathematics rooted in practical application (Boaler, 1997; Ceci & Williams, 2010; Mendick et al., 2008), and therefore struggle to associate themselves with being a mathematician rather than simply someone who could do mathematics. There was little evidence of cultural gender stereotypes regarding mathematics amongst this group of girls, and similarly their views of mathematical ability were more nuanced than the binary view of individuals as either brilliant or bad at mathematics within popular culture reported by Moreau et al. (2010).

Perhaps unsurprisingly, positioning mathematicians as ‘other’, in terms of personal attributes and physical location, tended to be a feature of the less confident mathematicians – Lauren, Mackenzie and Poppy. Their self-story (Bruner, 2004) was that mathematics was for other people, not for them. Beliefs about mathematicians echoed conceptions of mathematics as a subject – the logical conclusion of mathematics being a subject involving rapid computation, knowledge of times tables and relatively meaningless word problems is that an effective mathematician will do things quickly, know their number facts and not necessarily be good at or interested in other subjects. The data suggests it is unlikely that educators can improve the likelihood of future engagement with mathematics without tackling both the messages received via classroom activity, curriculum and home interactions about the nature of mathematics, and the dearth of access to images of mathematicians as aspirational role models.

7.2.2 The role of other people in making sense of a mathematical identity

Questions emerging from the literature review included whether relationships and aspirations were themes within children's characterisations of themselves as mathematicians – whether influential others would shape their self-belief, and the role of social comparison within developing a domain-specific academic self-concept (Chmielewski et al., 2013). The methodology was designed to be sensitive to these factors alongside messages in the home about gender roles (Kelly, 1986), anxieties about mathematics and emphasis on computational ability amongst parents (Mann, 2008), and the possible impact of what Marks (2014, p. 39) terms the 'pervasive ability discourse'.

In seeking to shed light on the research question 'how do girls make sense of their mathematical identity in relation to the role of other people', the only conclusion possible from this research is that interactions with other people do shape children's self-belief, perceptions of mathematics and mathematical identity through constant overt and intrinsic feedback. Whilst data did not reveal significant messages from home or school regarding gender roles, it did support an emphasis upon computational ability, the impact of social and familial comparison on academic self-concept and the tendency of this girls to see the role of others as supporting them when stuck, giving them feedback on the correctness or otherwise of their mathematics or reinforcing their view of their status as a mathematician, rather than as partners in mathematical enquiry. This in turn manifested itself in children's reporting of themselves as 'not a person who is good at mathematics', belief that they needed to get quicker at carrying out calculations or recalling tables facts, and conceptions of the role that mathematics might or might not play in their future lives – in short, in their evolving mathematical identity.

In terms of who played a role in girls' expressions of their mathematical identity, teachers, parents and friends were all prominent, followed by siblings and grandparents. As discussed earlier, significant only in their absence were recognised mathematicians, either historical or contemporary, along with mathematical role models gained through the media.

7.2.3 Factors affecting girls' own positioning as a mathematician

The data showed that children's characterisations of mathematics and their relationships with others and feedback they received on their mathematical development both fed into their developing mathematical identity, alongside deeply held albeit contradictory beliefs about what it means to be a mathematician and whether mathematicians are born or ability can develop over time. Some gendered views of mathematics and mathematicians emerged as reported in Chapter 6, along with themes around their views of the role mathematics might play in the future. However, the strongest theme emerging from the data shedding light on the girls' mathematical identity was the degree to which they took ownership of their own mathematical development. Rather than feeling helpless in the face of the mathematics they were expected to conquer, the girls took full responsibility and believed that everything depended upon them working harder and harder in the pursuit of progress. Accompanying this sense was the feeling, for some, of self-blame when they could not make the progress they were looking for. This seemed to lead for some to a positioning of themselves as struggling with mathematics, and away from self-identification as 'a mathematician', reflecting the findings of Isaacson (1990), Mendick (2005) and Piatek-Jimenez (2008) that some females have difficulty in identifying themselves as pure mathematicians. It may also echo findings that females often opt for careers where mathematics is embedded rather than explicit, such as veterinary science (Ceci & Williams, 2010), therefore not self-identifying as a mathematician.

Rather than the kind of can do / cannot do division suggested by Jorgensen et al. (2013), girls were more likely to position themselves as being on a journey towards mathematical improvement – in fact, the key limiting factor in their own eyes seemed to be their time and energy. At the time of writing, significant influence is being placed on the importance of children holding a 'growth mindset' (Dweck, 2000; Yeager & Dweck, 2012), a belief that rather than being born with a finite amount of mathematical ability, effort is purposeful and perseverance can lead to improvement and success. The girls in the study appeared to hold some of the elements of this growth mindset – often their self-image appeared to be that they could grow and improve, but not necessarily to the point of being considered a mathematician themselves. These ideas link closely to those of purpose and utility (Ainley et al., 2006), with some girls apparently limited by their understanding of the point of mathematics, both now within mathematical tasks and in the future.

Analysis of the data emerging from this study suggests that this growth mindset or productive disposition (Kilpatrick et al., 2001) might usefully be set in the context of a collaborative environment in which rather than progress depending upon the efforts of an individual, there is shared responsibility towards a mutual goal. Mathematical resilience and productive dispositions are subtly different ideas; the latter is an important element of the former, but does not necessarily lead to a resilient learner without other factors coming into play. Consistent with evidence reported by various authors (Boaler et al., 2011; Boaler & Irving, 2007; Frost & Wiest, 2007), this study confirms a preference for collaborative working rather than being left in a vacuum with their mathematical difficulties. Furthermore, it adds to our knowledge by suggesting the need for a more subtle approach to collaboration in mathematical learning, taking into account the possibility of collaborating towards a shared goal rather than to meet individual goals (through help when becoming stuck), the flexibility of pupil control over when to work together or individually, and communication to harness motivation and challenge without inducing anxiety and negative comparison. The implications of such findings for practice are discussed below.

7.3 Possible implications for educators

The purpose for undertaking this study was the hope that it would extend our understanding of this area as well as inform practice and empower educators to foster a positive, long-term mathematical identity amongst the girls in their care. Alongside findings against the first two research questions as set out above, the case-based approach and data collection tools were selected in part to allow for the presentation of accessible examples and development of strategies for securing pupil perspectives that might be used by practitioners wanting to investigate the mathematical identity of their own pupils. This section addresses this aim by drawing out some of the more striking implications of not only the findings themselves but of the methodology of the thesis.

7.3.1 Safe spaces for mathematical exploration

The title of this sub-section refers to three particular types of ‘safe spaces’. The first of these is what might be termed a safe social space around the child. From their relationship wheels, scrapbooks and individual pupil interviews, it became apparent that a range of people featured highly in girls’ mathematical worlds. From encouragement in the home, reinforcement through marking or verbal feedback, or support structures through friends when stuck, the girls benefitted from having ‘safe’ people they could go to when needing to discuss their mathematics. Where they were frightened that a classmate would laugh at them for making a mistake, or felt they were in the ‘wrong’ ability group and therefore out of their ‘growth’ zone (Lee & Johnston-Wilder, 2016, p. 18), this threatened their confidence to explore and had a knock-on effect on their fragile self-efficacy. This in turn raises the importance of the class teacher finding out what is perceived as safe for an individual child, as discussed further within the section reviewing the value of gaining girls' perspectives.

The second refers to the unexpected outcome that many of the girls in the group seized the opportunity of having a place of their own, in addition to the typical school exercise books and homework sheets, to rehearse their school mathematics. Although there have been a small number of studies exploring the use of journals within mathematics development (Coles & Banfield, 2012; Kostos & Shin, 2010; Stuart, 2000), I had seen the use of scrapbooks as a data collection tool for the purposes of the study, and was surprised that it seemed to fill a gap in terms of a safe space for children to consolidate the learning that had taken place at school. Whether this would be a useful tool for boys as well as girls, and the role of adults in mediating the contents to avoid the embedding of errors and misconceptions, remains to be seen and provides a clear opportunity for further study. Furthermore, there were many lovely examples of recognising and applying mathematics in the home embedded within the scrapbooks, and these might usefully be shared between children to broaden the perspectives of girls for whom mathematics is purely arithmetic and number. With mindsets often presenting as context-specific, for example a child being willing to practice and persevere in a sporting context but convinced that mathematics is a subject they just cannot do (Lee, 2009), opportunities to discuss and share mathematics as a construct existing in a wide range of contexts might help individuals move beyond their own limiting self-image.

Finally as discussed within Chapter 4, the teacher could strive to provide safety in terms of time. The pressure of speed resonated with several of the girls failing to self-identify as a mathematician, with various of them intimidated by the speed with which children they saw as being more able completed calculations or grasped new ideas. The cessation of timed mental arithmetic tests within the statutory assessment process in England at the end of Key Stage 2 coupled with the emphasis within the NC aims upon conceptual fluency, reasoning and problem solving (DfE, 2013a, 2013b) provides an opportunity for teachers to protect those children taking time to grapple with mathematics from feelings of inadequacy due to a perceived need to do everything quickly.

7.3.2 What is the point? Articulating the purpose of mathematics

The subtitle of this section is in itself controversial. One of the key findings in this study in relation to girls' mathematical identity was a tendency amongst some to see mathematics as without purpose or application to current and future lives. However the consequent implications of this finding are not straightforward. Both mathematical and scientific progress have often been marked by chance outcomes of exploration and innovation; from the serendipitous discovery of penicillin to the use of complex numbers as the foundation of economics and engineering, application and purpose came after, rather than before, the original discovery. However, for this group of girls at least, the lack of a bigger picture of where they were going with their mathematics and why was a barrier towards engagement and ownership. Lauren struggled to articulate why times tables were so vital to success, Mackenzie was sure that fractions were important if she could only figure out why, and many of them searched for realistic scenarios onto which they could project their skills in solving word problems. The current National Curriculum for mathematics sets out as the purpose for studying the subject:

> 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 (DfE, 2013a, p. 3).

Embedded within this statement is the implication that not all mathematics will have an immediate application. This, together with the data from this study, points towards the need for a two-pronged approach towards improving the likelihood that children will develop a commitment towards mathematical success. Firstly, where topics within the mathematics curriculum have direct applications and connections, these should be shared and explored with children. If Skye and Mackenzie connected pattern, ratio and proportional reasoning with their love of art they might be keener to persevere; if Lauren understood how times tables underpinned fractions and scaling, division and wider calculation she might believe that her success in learning the times tables facts indicated that she really was a mathematician. In other words, utility as well as purpose of mathematical tasks should be clear (Ainley et al., 2006). Three of the girls aspired to become a veterinary surgeon, not uncommonly in my experience of working with primary-aged children: what an opportunity to ask a vet into the school to talk about concrete examples of how they use mathematics within their day-to-day jobs, beyond the obvious applications of dealing with money and measures.

Less tangible but arguably equally important is how to engage children in developing mathematical curiosity, or the kind of creative, discovery-oriented abstract mathematics described by Schoenfeld (1989) and discussed within the literature review. Rather than striving to create contrived situations in which to apply mathematical problem solving, middle and lower attaining children in particular in this study could be supported to find success and satisfaction in spotting patterns, asking ‘what if’ questions and describing situations. The predominance of arithmetic and desk-bound mathematics within drawings, scrapbooks and discussions suggest that these are the benchmarks by which the girls predominantly formed their own mathematical identity, tying back into the need for them to be aware of 'real' mathematicians across the range of identifiable careers but also carrying out pure and applied mathematical study. Despite the recommendations of OfSTED (2011) to invite women in science, technology, engineering and mathematical fields into schools to provide positive female role-models, it appears for this group at least this as an area still in need of development.

7.3.3 'I can't do maths' → 'we can do maths': reframing mathematics as a social endeavour

This recommendation arises from discussion of the findings relating to the role of other people in forming a mathematical identity which might be sustainable into the children's future education and careers. Whilst there were frequent references across the data to working with other people, these predominantly related to receiving help when stuck; collaboration was framed as working collaboratively towards individual goals, rather than working together on a shared goal, for example solving a particular mathematical problem, despite findings that collaborative work might support the move towards mathematical resilience (Johnston-Wilder & Lee, 2010a). The collaboration sought after by authors such as Boaler (2002) and Mendick (2005) as a key strategy for engaging girls in mathematics was present, but somehow in a way that reinforced a negative mathematical identity of feeling inadequate rather than, for most girls, contributing positively to their self-image. Whilst establishing mathematics as a social endeavour, collaborative rather than isolated in nature, might be interpreted as general good practice rather than relating specifically to girls and mathematics, the literature suggests that this would have a more significant positive impact on female learners (Boaler, 1997; Ceci & Williams, 2010; Mendick et al., 2008). This analysis leads to the recommendation that collaboration should be valued as an important mathematical skill in its own right, potentially adding to girls' identity as a member of a mathematically-successful group. This kind of inclusive knowledge of how to 'recruit support in pursuing mathematical learning' is seen by Lee and Johnston-Wilder (2016) as one of the four aspects of mathematical resilience, alongside a growth mindset, valuing mathematical learning and an acceptance that carrying out mathematics involves struggle.

Building on the previous section, one of the most striking findings of this study was not only the importance of people close to the child in influencing their mathematical identity, but the lack of awareness that mathematics as a human endeavour is part of our historical, contemporary and international culture. Perhaps little has moved on since Burton's (1995) request to emphasise the humane, socio-cultural nature of mathematics. Knowing about mathematicians is currently absent from the National Curriculum, but as its introductory pages point out teachers should see the statutory content as just one element of a child's schooling; schools should decide what else should fill the remaining space and time within the available school day (DfE, 2013c). As I walked around the school forming the location for this study I noticed frequent posters promotion contemporary authors to inspire children to read, or linking reading with popular films and culture; there was no equivalent for mathematics. Seeking to thank the school for the significant time and energy invested in supporting the study, I approached several publishers to ask if they produced a poster pack on famous mathematicians appropriate for primary-aged children that I could purchase as a gift; none of them did. A reasonable recommendation arising from this study is that publishers urgently seek to close this gap.

7.3.4 Managing mindsets: building awareness of complex identities

This study did not set out to be an investigation of either mindsets or resilience – instead it aimed simply to paint a picture of the girls' mathematical worlds and through this to shed light upon how they made sense of their own mathematical identity in relation to their perceptions of mathematics as a subject, 'mathematicians', and those around them. However, what became apparent from analysing the data and reviewing the discussions within all three findings chapters was the recurrent theme of resilience – against grouping structures in the classroom, a lack of self-belief and mathematics which was seen to value speed, size and arithmetic competence. As discussed above and within Chapter 6 there was no lack of a growth mindset (Dweck, 2000; Yeager & Dweck, 2012) amongst the group of girls in the study; they all had a clear sense of what they needed to do to improve and took full ownership of their own progress, believing that they could get better through hard work rather than that they had a finite amount of mathematics ability. I was left wondering whether the class teacher and school leaders were fully aware of the responsibility girls took for their own development, and whether the current emphasis on a growth mindset might actually increase pressure on children to believe they must work ever harder. Understandings of mindsets are subtle and developing, for example with Lee (2009) suggesting that focusing upon a growth mindset implies a belief in success in terms of improvement in learning of mathematical ideas rather than necessarily reaching the same outcome. For some of the girls, this responsibility for growth weighed extremely heavily. This is in no way meant to imply that teachers should limit children's aspirations or promote an entity theory of intelligence (Dweck, 2000), rather that they might usefully be aware of the pressure that a growth mindset places on individuals to improve and succeed, and share the responsibility for development with them.

For some children, a focus on Kilpatrick et al.'s notion of productive disposition (2001), incorporating a belief in one's own efficacy and the rewards of effort with a belief that mathematics in itself is worthwhile, might be a more useful concept than the slightly more individualised construct of a growth mindset. This links closely to the idea of the 'amber' or 'growth' zone developed by Lee and Johnston-Wilder (2016, p. 18), within which collaborative working and giving and receiving support are key to continued learning. Either way, a key recommendation of this study is that teachers make themselves aware of children's mathematical identity, the impact of these identities within and beyond the mathematics classroom, and the consequent impact upon their health, happiness and daily lives. Adding to the idea of 'protective factors' in building mathematical resilience (Hernandez-Martinez & Williams, 2013), the following image may prove useful to practitioners in considering the pressures upon children as they form their mathematical identity (Figure 7.1).

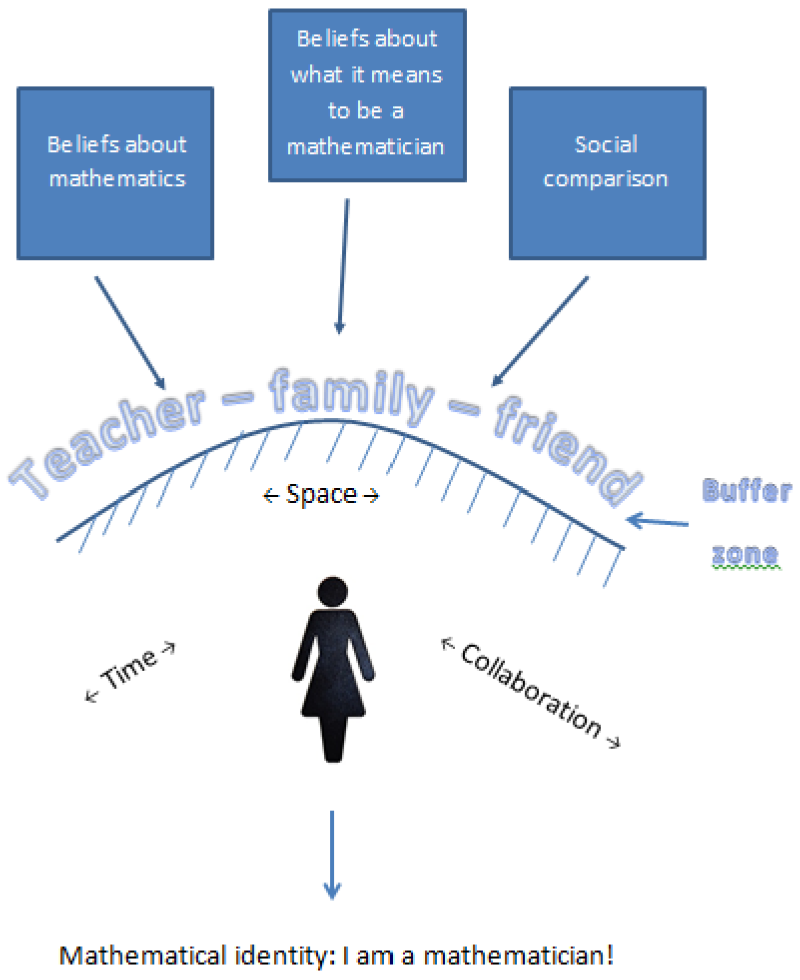


Figure 7.1 The buffer zone

A particular feature of the girls studied was the fact that as a group they were operating above national expectations, but within the context of a particularly high attaining class. This brought its own pressures, most notably upon the children in the middle range of this high attaining group, and an implication arising from this study is that teachers should be aware of the pressures upon children with these characteristics and sensitive to their self-beliefs. Use of a growth mindset, without a buffer zone such as that described above, might in some cases lead to anxiety and mathematical harm. This echoes the findings in Smith's (2014) review of research regarding the importance of advice and encouragement in mediating potential effects of lower self-concept upon participation. Whilst acknowledging that teachers, family and friends can add to pressures on children, Figure 7.1 positions teachers, family-members and friends as part of a protective 'buffer' between the pressures on children arising from conceptions of mathematics, mathematicians and through social comparison, acting through the provision of time, space and collaboration to help individuals form a positive mathematical identity. This could combine naturally with the notion that mathematical resilience might be named with pupils as a strategy for supporting open discussion of anxieties towards and support for mathematical learning and learners (Johnston-Wilder & Lee, 2010a).

7.3.5 Gaining girls' perspectives: the value of taking a girls'-eye view

This study set out to use a mosaic of data collection approaches in order to build a rich, situated view of how girls make sense of their mathematical identity. The principle underpinning this approach was simple as set out by the UNCRC; not only do children have the right to express their views and have those views listened to carefully, but they have the right to share their beliefs in an age-appropriate manner (United Nations, 1989). As suggested by Lee and Johnston-Wilder (2011), pupil voice can be powerful in bringing greater understanding by practitioners of the factors involved in perceptions of mathematics learning and mathematical resilience.

One of the most interesting and poignant moments in the study arose when I revisited the school to share a summary of the findings with the head teacher and mathematics subject leader. There were many positive moments, such as the finding that all girls had not only a desire to succeed but a clear image of what they needed to do to improve. They welcomed the rich examples of mathematics recognised in some of the girls' own lives, and the positive attitudes displayed by many. However there were poignant moments too, in realising that there was a huge mismatch between the images of mathematics across the curriculum and as an outdoors subject they sought to convey and the girls' perceptions of mathematics as number- and calculation-based, book-bound and sedentary. Most striking of all was the anonymised sharing of the following image, reproduced here and in Chapter 5 (Figure 7.2):

Figure 7.2 Taylor's depiction of isolation in the mathematics classroom

Taylor presents as a capable mathematician, confident in her friendships and able to see applications for mathematics in her daily life, yet without this study the fact that there were moments when a child in the class felt like this might have gone unnoticed. In Lee and Johnston-Wilder's terms she had moved from the amber or growth zone, in which she is challenged and learning, into the anxiety or red zone, triggering the fight or flight mechanism and precluding effective learning. (2016, pp. 17-18). Following the model through, the ability of the teacher to recognise when the child is moving between zones and needs support to regain a position of growth becomes a key element of the teacher's role. To the extent that this research study adds to our knowledge of how to allow children to share their perspectives on their mathematical identities, the value of taking a girls'-eye view cannot be denied.

7.4 Summary

This chapter has sought to draw out some of the wider themes of the findings, building upon the discussion relating results to literature located within the preceding three chapters. Girls' sense-making of their mathematical identity has been found to be complex and nuanced, heavily influenced by their conceptions of mathematics as a subject and by their interactions with other people. The range and depth of both their conceptions of mathematics and the sense they make of identity in relation to their positioning as a mathematician have been both revealing and surprising, leading to the conclusion that in order to fulfil Kaplan and Flum's curricular aim of building a sustainable identity (2012), teachers need to understand and acknowledge these identities and their impact on girls' mathematical lives.

The final section of this thesis draws together the study, returning to the original aims as set out in the introduction, discussing limitations of the methodology and identifying implications and opportunities for further research.

8 Conclusion

Driven by personal interest, professional experience and reading around the phenomenon of female mathematical identities and disengagement with mathematics, this study set out to investigate girls' perceptions of mathematics and how they make sense of their mathematical identity. Given the complex, situated and evolving nature of identity, the study took a grounded, interpretive case-based approach, employing a mosaic of qualitative data-collection methods to shed light on girls' perceptions of mathematics. Whilst there has been substantial research into gendered difference in mathematics outcomes and contributory factors over the last few decades, this thesis has added to the body of knowledge relating to gender and mathematics identity through providing opportunity to listen to a specific group of girls and analyse what they tell us about the sense they make of their mathematical world and their place within it. The image presented of a buffer zone has the potential to move forward our understanding of how teachers, family and friends might protect girls from some of the influencing pressures of social comparison, beliefs about mathematics and what it means to be a mathematician, sharing the responsibility of a growth mindset and providing them with time, space and opportunity to form an enabling identity as a mathematician.

The methodology of this thesis has provided the opportunity for children to be heard deeply through the mosaic of approaches deployed, with analysis of strategies such as scrapbooking providing new insight into ways of bringing together home and school activity. This in turn allowed an insight into their own individual 'self-story' (Bruner, 2004), allowing the study of diversity within and between individuals as well as the emergence of patterns in girls' perceptions of mathematics and their related mathematical identities. Gender has provided the backdrop to the study, with the aim of allowing this group of girls to be heard and my interpretations as a researcher to draw out implications and recommendations for practice.

8.1 Summary of findings

The study aimed to set out findings against the research questions of how girls perceived mathematicians including their characterisations of mathematics and recognition of mathematics within their daily lives, and secondly how they made sense of their mathematical identity in relation to their characterisations of mathematics and mathematicians, the role of other people and their own positioning.

The findings confirmed mathematics as being seen as number and calculation-based, textbook and deskbound and incorporating speed and correct answers, echoing the findings of previous studies. However these beliefs were by no means universal and the ability of some members of the group, often the higher-attaining, to recognise authentic mathematical activity within problems and situations presented within daily life suggest the importance of allowing girls opportunity to discuss their perceptions of mathematics. Too often girls (for example Aimee and Lauren) were unable to articulate the purpose of areas of mathematics such as times tables and fractions which had a huge role to play in the sense they made of their own mathematical ability. Individual teachers may not be able to change the statutory curriculum they are charged with delivering, but they could ensure that links are made between areas of mathematics and how this knowledge, skills and understanding can be utilised both within the world of work and future mathematical study: in other words, that both the purpose and utility of tasks are clear (Ainley et al., 2006).

Whilst we already knew that girls tend to prefer a more collaborative style of mathematics teaching and learning, eg Boaler (2014), the findings of this thesis suggest the need for a more subtle understanding of the nature of collaboration. Whereas others were frequently mentioned in terms of seeking and receiving help, the data suggested they would benefit from working collaboratively on shared outcomes rather than simply collaborative support for individual progress.

A key finding was the degree to which this group of girls not only took responsibility for their own mathematical development but felt that responsibility keenly. The sense they made of their mathematical identity was that whilst for most of them they could never become a mathematician, nor were they born with a limited amount of mathematical ability. Instead, they could grow and develop as mathematicians given sufficient effort and time. My findings suggest that teachers, family and friends could support them in this endeavour by providing safe spaces to allow them to succeed and value their own success, rather than positioning themselves as someone who struggles with mathematics, and could deploy the type of approaches developed within this thesis to ensure they are sensitive to when support and collaboration is needed.

The role of other people – notably teachers, family and friends – has been a constant theme throughout the range of data collected. Whilst these people can provide a buffer, allowing children the time, space and collaboration needed to develop a sustainable mathematical identity, they also have significant influence on the sense girls make of their mathematical identity through verbal and written feedback, daily interactions and decisions about how children are grouped, positioned within the classroom and the messages they are given within the home. Equally noticeable in the data was the absence of anyone not directly known to the child in relation to mathematics.

8.2 Possible suggestions for practice

The findings summarised above and explored in more detail within the discussion chapter lend themselves to setting out the following implications for educators. In this context the term 'educators' is taken in its broadest sense to include family, friends and policy-makers alongside those with a formal trained role: all those who potentially influence the sense children make of their mathematical identity.

Firstly, the findings suggest the value of providing safe spaces for mathematical exploration in terms of social interactions and collaboration alongside a physical location for children to try out and rehearse mathematics as well as value their own mathematical activities. These scrapbooks or similar could be developed and shared to broaden perspectives on the nature of mathematics, particularly of those unable to see beyond the immediacy of calculation, multiplication tables and knowing facts and procedures. Additionally the opportunity of the cessation of timed mental tests could be taken to shift the focus away from speed towards deeper conceptual understanding.

Secondly, teachers and all those working with children could be more clear about the purpose of individual skills, processes and understanding within mathematics. That is not to imply that every area of mathematics should have an immediate practical application, but to make educators aware that lacking a vision for the purpose of areas of mathematics signposted as so important through the emphasis they receive within the curriculum and in interactions with adults can be damaging for a productive disposition towards both themselves and the subject. The girls in this study tended to use a limited subset of mathematics as the yardstick by which they judged their own mathematical ability. Not only could we aim to broaden what they hold as important, but we could ensure that this subset is connected with purpose and aspirations.

Thirdly, the findings of this thesis suggest that attempts could be made to reframe mathematics as a social endeavour. Alongside the need for collaboration towards shared goals set out above, girls need to understand the role of people in mathematics as a discipline both historically and in the present day. Publishers could support this endeavour by making role models, including female mathematicians, more readily accessible to schools.

Additionally, the findings lend themselves to the recommendation that educators tread carefully whilst emphasising a growth mindset. Whilst this is undoubtedly a positive and powerful construct, there is sufficient evidence within this study to suggest that there are dangers, albeit for a small group of children, in placing emphasis upon the ownership of individuals for unlimited mathematical development. By reframing success away from 'I can't' towards 'we can', with the 'we' incorporating teachers, family and friends, we could help children to feel part of the community of those who believe themselves to be mathematicians, without burdening them with the sole responsibility for their own progress.

Building upon these four findings, the final recommendation is that educators take seriously the value of taking time to investigate girls' perspectives on themselves as mathematicians. One of the most striking moments in the whole process for me was sitting down with the school's leadership team to discuss the findings and sharing the anonymised image drawn by a high-attaining girl of how she felt when she was not understanding what was going on and nobody was helping. This was followed by the revelation of the extent to which children took ownership of their progress to the extent that some, not yet ten years old, were feeling angry and frustrated with themselves for not making even more progress. Even within a relatively small school placing high emphasis on pupil voice and knowing individual pupils, without the research study these feelings are likely to have gone unnoticed. The extent to which girls made sense of their mathematical identities in relation to the feedback they received from others was a key finding revealed by the mosaic approach taken to data collection, and this study has presented several strategies that would be readily applicable for a classroom teacher wanting to find out more about the identity and perspectives of the children in their care, identify their mindset, and provide support accordingly.

8.3 Methodology: review and limitations

The range of qualitatively-based tools deployed within this study was chosen to provide insight into the complex, situated and evolving phenomenon of mathematical identity. The different elements of the Mosaic served this purpose in complementary ways, all revealing different aspects of the girls' perspectives.

The metaphor elicitation task and drawings provided the strongest insight into subconsciously-held beliefs, and as such were perhaps the most powerful. In particular, the drawings revealed a diversity in beliefs about and emotions relating to mathematics, from anxiety about lack of understanding to enjoyment, positivity to feelings of isolation. Other tools such as the concept maps and scrapbooks addressed more closely the first research question regarding perceptions of mathematics as a subject, and particularly in the case of the concept maps provided readily accessible data easy to relate to curricular content. The scrapbooks also revealed the potential for safe spaces within which children can rehearse, experiment and record their own ideas about mathematics.

Taken as a whole, it was the combination of different elements of the Mosaic, drawn together by the individual pupil conferences, that proved so powerful in providing insight into this group of girls' mathematical identities. Rather than overlapping, different data sources added to the picture of individuals and their perceptions of mathematics and themselves as mathematicians. In terms of analysis, the least revealing elements of the Mosaic in their own right were the digital photographs, however the photographs embedded within scrapbooks situated discussions within girls' real-life contexts, and the involvement of attractive, child-friendly cameras supported the initial engagement of children with the research project.

Reviewing the methodology necessitates reflection on the process of data analysis. The decision to analyse the wealth of different data sets by hand rather than using computer software emerged from both the nature of the data itself and the methodology. Such diverse, often visual data lent itself to annotation, sorting and physical comparison, for example of drawings alongside relationship wheels or scrapbook pages against metaphors. The constructivist, grounded approach suggested conducting at least an initial analysis of data to identify subsequent lines of enquiry, best carried out immediately after data collection and with pencil and paper. However, analysing data by hand did present its own challenges, not least in terms of keeping track of themes and looking for patterns across all the different data sets. It required extensive time (and physical space) to set out, analyse, code and interpret that data, and it could be that a systematic coding and tagging of data using a qualitative data analysis package might have revealed further links between the different data sets.

There were many surprises in the data, revealed by the capacity of the Mosaic approach (Clark & Moss, 2011) to ensure that girls were heard deeply. I had not expected the extent to which girls would take responsibility for their own mathematical development, suggesting that holding a growth mindset might be a double-edged sword. Also surprising was the diversity in individual responses, both between different girls and contrasting responses within the same child. Perhaps most surprising of all was the sheer value of putting in place strategies to uncover the perspectives of girls on their own mathematical lives.

Any number of factors will have acted to limit the validity of individual methods of data collection within this study, many of which are related to the situated and real-world rather than experimental, laboratory-based nature of the design. Asking girls to draw themselves doing mathematics whilst they were in a classroom may have prompted them to locate themselves at a desk and using the most familiar mathematics-related object in the classroom, the textbook. Allowing them to be near each other when responding to metaphors may have led to influence between different participants upon what they were willing or unwilling to portray. Locating scrapbooks in the home will have led to varying levels of parental involvement and potential pressure, and the emphasis placed upon different elements of the mathematics curriculum by the class teacher and school curriculum is likely to have impacted upon the concept maps created at a particular moment in time. However, the combination of a mosaic of data collection methods based upon approaches inspired by research across many cultures and countries, spacing of data collection tools across both location and time to build trust and increase authenticity, and use of individual pupil interviews to allow pupils to confirm and illuminate their own mathematical 'truths' has led to a powerful portrayal of mathematical identity formation.

One of the key methodological decisions that has caused much angst throughout the study was the notion of studying girls and mathematics without including a comparative element – how could I say anything evidence-based about girls and mathematics without including comparison with boys? There were times when this became acute; having collected metaphor elicitation tasks from the boys in the class as well as the girls, the temptation to look at the work of the boys and compare it with that of the girls to analyse similarities and differences was strong. Whilst this kind of comparative study would provide a different angle and a starting point for further investigation, I stand by the decision to explore and describe this group of girls' evolving mathematical identities in their own right rather than in comparison with anyone else. The aim of the study was always to contribute to knowledge by deepening understanding of how a particular group of girls appear to make sense of their mathematical identity, and I remain comfortable with the decision not to diminish their voices by assuming they were only valid in comparison with those of boys. The girl-only sample allowed differences as well as similarities between girls to explored, for example their varying reactions to challenge, interpretations of what constitutes mathematics, and support received in the home. The findings and discussion have not been framed in terms of gender; they make no assertions that the factors relating to constructions of mathematical identity set out here are unique to girls, they simply add to understanding of the complex picture of how girls make sense of their mathematical identity.

A further possible criticism of the study is the lack of teacher or parental perspective; details of what was studied within the classroom at each of the data collection points were not gathered and the class teacher and close family of the girls were not interviewed to gain their perspectives. The reasons for this were part pragmatic due to limitations of time, and chiefly philosophical; the guiding principle was that data regarding their mathematical identities should come directly from the children themselves, addressing an under-studied source of information.

A chief limitation of any of the findings and recommendations of this study is that it is bounded in space and time, concerning the perceptions and factors relating to the construction of mathematical identity of a particular group of girls, in a particular school, at a particular period in time. Recommendations for practice are necessarily speculative: it remains to be seen whether the girls showing signs of possible future mathematical success or disengagement will go on to part company with mathematics or become its future champions. Based on the methodological approaches discussed by Silverman (2010) and Merrimam and Guerin (2006), the aim of this interpretive case-based study was always to shed light upon the phenomenon under review, adding to knowledge through rich, situated knowledge which might suggest concepts and relationships relevant beyond the bounds of the case itself.

Finally, the importance of a plethora of other factors in forming a mathematical identity should be acknowledged – this study has not explored either factors such as socio-economic status, position in family or parental education, or other directly mathematical factors such the other elements of mathematical proficiency within the model of Kilpatrick et al. (2001).

8.4 Possibilities for future research

Any piece of research tends to raise as many questions as it answers. A priority will be to follow up this group of girls, pending their permission, as they move into and through their secondary schooling. It would be fascinating to find out, for example, whether the girls become more or less able to identify roles for mathematics in their future, or make rich connections between mathematics and daily activities in their home lives, take mathematics on beyond post-compulsory study, or to find out how their characterisations of mathematics and themselves as mathematicians evolve over time. In summarising the findings I have expressed a concern about the pressure that a 'growth mindset' approach may place on individuals who already take a high degree of responsibility for their own mathematical development, and a collaboration with researchers with appropriate experience and expertise within the field of emotional and mental health would be welcome to shed light on these children's development over time.

Having carried out this research with one group of girls, the findings suggest it would be worthwhile applying similar research strategies with a comparative element, both in terms of including boys within a similar context to ascertain whether some of the factors involved in making sense of their mathematical identity are similar or different for boys, and in comparing findings for girls in different circumstances. A particular feature of this group of girls was the fact that they were relatively high-attaining, with data suggesting that being middle attaining within such a high attaining group has an impact on emerging mathematical identity. This suggests the value of looking at groups of girls in different organisational circumstances, such as where children are set for mathematics or are high-attaining within a lower-attaining cohort, and investigating whether similar findings such as the buffering role of teacher, family and friend alongside time, space and collaboration apply.

Having suggested that teachers, family and friends have a key role to play in developing girls' mathematical identities, it would be interesting to examine and extend the literature upon enabling adults reflecting upon and developing their own identities as mathematicians.

My findings suggest that a worthwhile avenue of future research would be to adopt a more action-research based design to consider the impact of involving girls in this kind of research upon their mathematical identity. Whilst they were involved throughout the data collection processes aimed to capture their perspectives, the girls in this study did not have opportunity to reflect directly on the difference being involved had made to their confidence or compare their views at the beginning and end of the study. Having established the value of safe spaces for mathematical exploration, a valuable line of enquiry would be to introduce techniques such as scrapbooking, drawing and metaphor elicitation as an integral part of mathematical education and work together with girls to evaluate the impact of these strategies. This might also allow for further investigation of the notion of a female mathematical identity, both in terms of individual diversity and group similarities.

Finally, the data has suggested that for these girls mathematics is generally only framed as a social endeavour to the extent that they are taught by people known to them, work on mathematics with their peers or family members and receive help when stuck. Given that one issue appears to be not so much the existence of mathematical role models, but rather access to them, a small-scale intervention study which provided access to these role models as an integral part of teaching and explored the impact would be welcome.

8.5 Impact on my professional practice

A guiding reason for choosing an educational doctorate rather than a PhD as my route to higher study was the opportunity to explore an area with a direct focus on my professional practice. In addition to the general professional development of working with leading professionals, refining my writing and research skills and building my knowledge through reading around the topic area, undertaking the doctorate has already had a marked impact on my professional practice and will continue to do so.

Firstly, I now have a far more secure evidence-based knowledge of issues surrounding engagement with mathematics, perceptions of mathematics and gender. Rather than a more general view, I can now include within my lectures specific, recent and relevant information to challenge trainee teachers' thinking about mathematics education. Secondly, undertaking a research project based on gaining children's perspectives has transformed my understanding not only of the importance of consulting pupils, but on manageable ways to do this in the context of a primary school. Finally, I now appreciate the pressures on young children as they form their mathematical identities, the complexity of their mathematical worlds, and the necessity of adults providing a buffering layer of time, space and collaboration to give girls a fighting chance of forming a resilient identity they can carry with them throughout and beyond secondary schooling. The methodology and data collection tools have provided concrete, poignant examples I can draw upon to bring to life the pressures girls feel under that threaten their developing mathematical identity and the kind of issues that can go unnoticed unless we as professionals make time to listen to what children are telling us.

8.6 Final summary

The research questions upon which this thesis was based are complex and cannot readily be answered through single words or phrases. Instead, this study has made an original contribution to knowledge through allowing a rich, situated perspective on girls' mathematical identities. It has found that girls make sense of their identities through a combination of factors including their perceptions of the nature of mathematics and what it means to be a mathematician, their interactions with other people and the responsibility they take for their own mathematical development. It has suggested that as educators we owe it to children to understand their emerging identity, connect mathematics with purpose and frame it as a social endeavour, and recognise their need for time, space and collaboration to build confidence in themselves as mathematicians. Finally, it has enabled me to better understand the complexities of developing a mathematical identity, to develop data collection methods that might be used by practitioners to gain similar insight into the sense their own children make of their mathematical worlds, and to develop an expertise I can draw upon within my daily interactions with teachers of the future. For this, if for no other reason, it will have been worthwhile.

9 References

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Appendices

Appendix 1 Ethical Approval Form

University of Reading

Institute of Education

Ethical Approval Form (version November 2012)

Tick one:

Staff project: ___

Postgraduate project: PGCE ____ GTP ___ MA ____ PhD ____Ed.D__√

Undergraduate project: ____

Name of applicant (s): …Catherine Foley…………………………………..

Title of project:…………Ed.D dissertation: Children's perceptions of mathematics……………

Name of supervisor (for student projects): …Dr Carol Fuller………………………….

Please complete the form below including relevant sections overleaf.

	YES	NO	N.A.
Have you prepared an Information Sheet for participants and/or their parents/carers that:			
a) explains the purpose(s) of the project	√		
b) explains how they have been selected as potential participants	√		
c) gives a full, fair and clear account of what will be asked of them and how the information that they provide will be used	√		
d) makes clear that participation in the project is voluntary	√		
e) explains the arrangements to allow participants to withdraw at any stage if they wish	√		
f) explains the arrangements to ensure the confidentiality of any material collected during the project, including secure arrangements for its storage, retention and disposal	√		
g) explains the arrangements for publishing the research results and, if confidentiality might be affected, for obtaining written consent for this	√		
h) explains the arrangements for providing participants with the research results if they wish to have them	√		
i) gives the name and designation of the member of staff with responsibility for the project together with contact details, including email . If any of the project investigators are students at the IoE, then this information must be included and their name provided	√		
k) explains, where applicable, the arrangements for expenses and other payments to be made to the participants	N/A		
j) includes a standard statement indicating the process of ethical review at the University undergone by the project, as follows: 'This project has been reviewed following the procedures of the University Research Ethics Committee and has been given a favourable ethical opinion for conduct'.	√		
k)includes a standard statement regarding insurance "The University has the appropriate insurances in place. Full details are available on request".	√		
Please answer the following questions			
1) Have you sought written or other formal consent from all participants, if they are able to provide it, in addition to (2)?	√		
2) Have you provided participants involved in your research with all the information necessary to ensure that they are fully informed and not in any way deceived or misled as to the purpose(s) and nature of the research?	√		
3) Is there any risk that participants may experience physical or psychological distress in taking part in your research?		√	
4) Have you taken the online training modules in data protection and information security?	√		
5) Does your research comply with the University's Code of Good Practice in Research?	√		
	YES	NO	N.A.
6) If your research is taking place in a school, have you obtained the permission in writing of the head teacher or other relevant supervisory professional?	√		
7) Has the data collector obtained satisfactory CRB clearance?	√		
8) If your research involves working with children under the age of 16 (or those whose special educational needs mean they are unable to give informed consent), have you sought parental consent or given	√		

parents/carers the opportunity to decline consent?			
9) If your research involves processing sensitive personal data[1], have you obtained the explicit consent of participants?			√
10) If you are using a data processor to subcontract any part of your research, have you got a written contract with that contractor which (a) specifies that the contractor is required to act only on your instructions, and (b) provides for appropriate technical and organisational security measures to protect the data?			N/A at this point
11a) Does your research involve data collection outside the UK?		√	
11b) If the answer to question 11a is "yes", does your research comply with the legal and ethical requirements for doing research in that country?			√
12a. Does the proposed research involve children under the age of 5?		√	
12b. If the answer to question 12a is "yes": My Head of School (or authorised Head of Department) has given details of the proposed research to the University's insurance officer, and the research will not proceed until I have confirmation that insurance cover is in place.			√
If you have answered YES to Questions 2 and/or 3, please complete Section B below			

PLEASE COMPLETE **EITHER SECTION A OR B** AND PROVIDE THE DETAILS REQUIRED IN

SUPPORT OF YOUR APPLICATION, THEN SIGN THE FORM (SECTION C)

A: My research goes beyond the 'accepted custom and practice of teaching' but I consider that this project has **no** significant ethical implications.	
Give a brief description of the aims and the methods (participants, instruments and procedures) of the project in up to 200 words. Attach any consent form, information sheet and research instruments to be used in the project (e.g. tests, questionnaires, interview schedules). Please state how many participants will be involved in the project: Approximately 30 *This form and any attachments should now be submitted to the Institute's Ethics Committee for consideration. Any missing information will result in the form being returned to you.*	
The aim of the research is to establish what mathematics means to primary-aged children, and to investigate whether the gap between 'real-life' and school mathematics can be closed through involving children in researching their own mathematical lives. This application represents the pilot phase of my Ed.D thesis. Data collection will involve: a) children keeping scrapbooks to document their mathematical lives. They will be encouraged to take ownership, choosing to incorporate evidence such as photographs of objects and activities at home, drawings of themselves or others engaged in mathematics, and/or journal writing. All children in the class will keep	

[1] Sensitive personal data consists of information relating to the racial or ethnic origin of a data subject, their political opinions, religious beliefs, trade union membership, sexual life, physical or mental health or condition, or criminal offences or record.

the journals, but only the journals of those giving consent will be used within the research;

b) children being given digital cameras to use at home as part of the process of documenting their mathematical lives; children will select and print images to incorporate as they choose;

c) some of the children being involved in focus group interviews, based on scrapbooks as a stimulus, to investigate further their perceptions. These will be transcribed and subsequently analysed (children randomly chosen from self-selecting sample)

Attachments: head teacher information sheet and consent form; parent/carer information sheet and consent form; children's information sheet and consent form, indicative focus-group topics.

B: I consider that this project **may** have ethical implications that should be brought before the Institute's Ethics Committee.	

Please provide all the further information listed below in a separate attachment.

1. title of project
2. purpose of project and its academic rationale
3. brief description of methods and measurements
4. participants: recruitment methods, number, age, gender, exclusion/inclusion criteria
5. consent and participant information arrangements, debriefing (attach forms where necessary)
6. a clear and concise statement of the ethical considerations raised by the project and how you intend to deal with then.
7. estimated start date and duration of project

This form and any attachments should now be submitted to the Institute's Ethics Committee for consideration. Any missing information will result in the form being returned to you.

C: SIGNATURE OF APPLICANT:

I have declared all relevant information regarding my proposed project and confirm that ethical good practice will be followed within the project.

Signed: …C·M·Foley………………… Print Name…C. Foley………… Date…………

STATEMENT OF ETHICAL APPROVAL FOR PROPOSALS SUBMITTED TO THE INSTITUTE ETHICS COMMITTEE

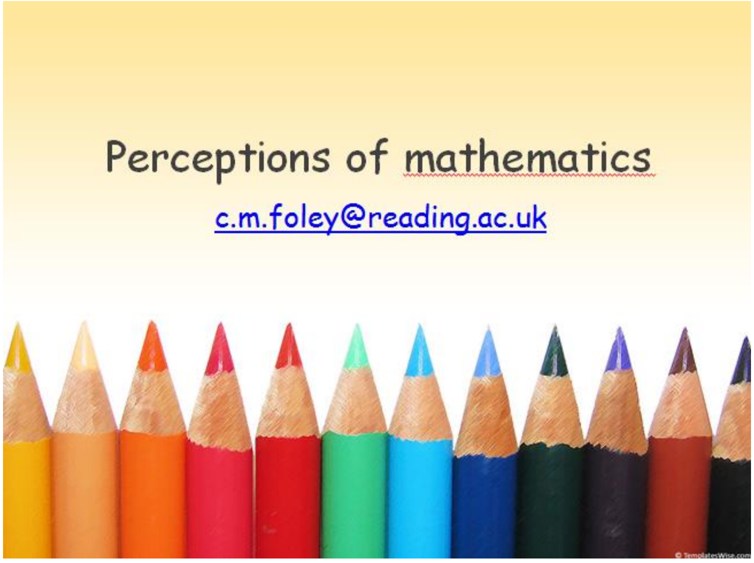
This project has been considered using agreed Institute procedures and is now approved.

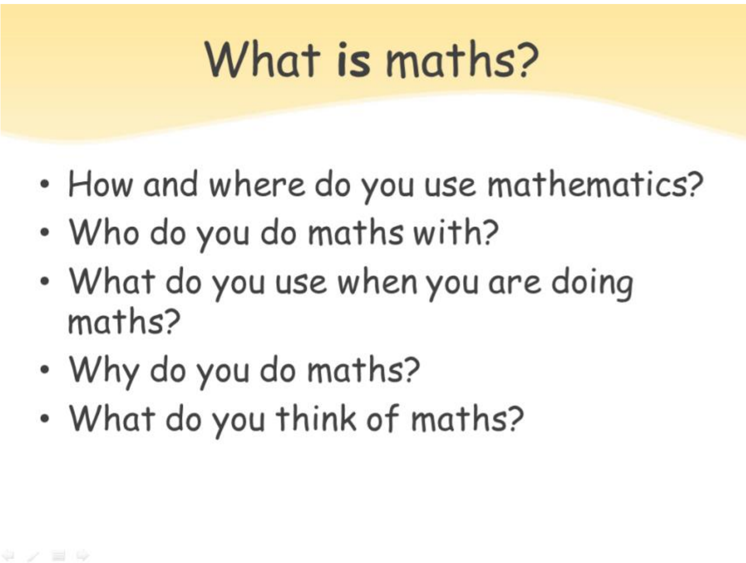
Signed: …………………………… Print Name……………………… Date……

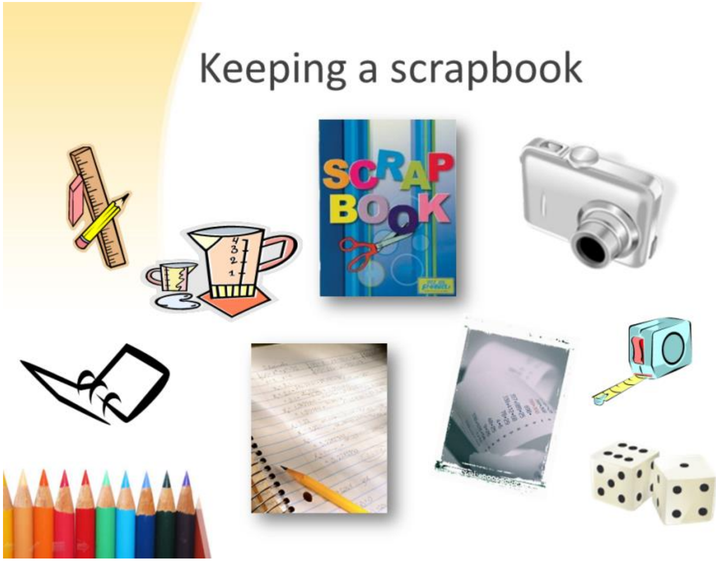
(IoE Research Ethics Committee representative)*

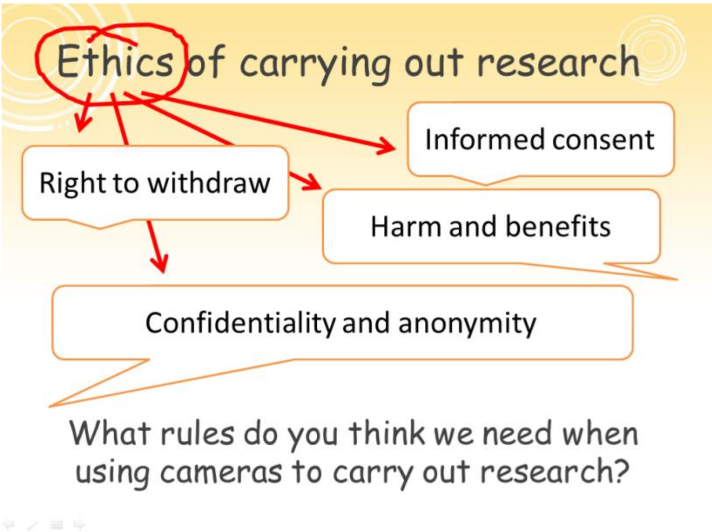
* A decision to allow a project to proceed is not an expert assessment of its content or of the possible risks involved in the investigation, nor does it detract in any way from the ultimate responsibility which students/investigators must themselves have for these matters. Approval is granted on the basis of the information declared by the applicant.

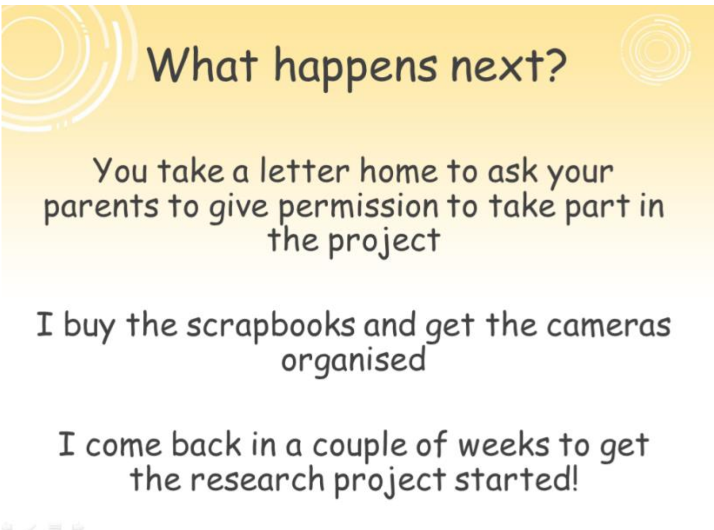
Appendix 2 Pilot study launch presentation






Keeping a scrapbook
SCRAP
BOOK


Ethics of carrying out research
Informed consent
Right to withdraw
Harm and benefits
Confidentiality and anonymity
What rules do you think we need when using cameras to carry out research?


What happens next?
You take a letter home to ask your parents to give permission to take part in the project
I buy the scrapbooks and get the cameras organised
I come back in a couple of weeks to get the research project started!

Appendix 3 Notes from interview with Head teacher

Discussion with Head teacher of case study school – 24th July 2014

Purpose of interview – gathering background data. Discussion took place at the beginning of the school vacation and lasted approximately 20 minutes.

- Girls' performance an issue at the top end of the ability range (particularly historically and for current Year 6 cohort)
- Reading seems to take over from maths in terms of support at home when children reach school age, and girls seen as better at maths
- Girls won't put themselves forwards in maths whereas boys dive in
- Considering and have spoken to parents about 'mummy maths' to promote awareness of the maths females do on a day-to-day basis
- Competition appeals to boys in the school but not girls
- Example of one able mathematician who has pushed himself to be good at maths due to peer pressure to be good – equivalent peer pressure does not appear to be there amongst girls
- High attainers group in maths changed to have top 3 boys and girls per year group, rather than the top overall as it had become very boy dominated
- Gender gap closing in KS1 and EYFS statistically
- School is historically boy-heavy
- Would love girls to say maths when asked what their favourite subject was, to think it's cool
- Girls in current Year 6 class in shadow of boys
- Key issues observed in girls is their retention of facts and figures
- Some parents of girls more likely to contact school regarding friendships or complaints about appearance, uniform etc than mathematics progress
- Always take equal number of boys and girls to mathematics challenge events
- Within science and technology event in schools, girls did just as well as boys due to better strategy and boys were surprised
- Believes attainment precedes confidence, based on own experience
- In EYFS, will be boys who come to mathematics resources, for example the 'flip' 100-square, rather than girls.

Appendix 4 Child guidance for data collection (September 2014)

Girls' perceptions of mathematics

Thank you again for taking part in this research. Remember you can talk to your class teacher or ask her to contact me if you have any worries or questions.

It would be great if you could have another go at keeping the scrapbooks about mathematics in your lives.

I will arrange to come in to collect the scrapbooks during the week beginning 20th October – just before half term.

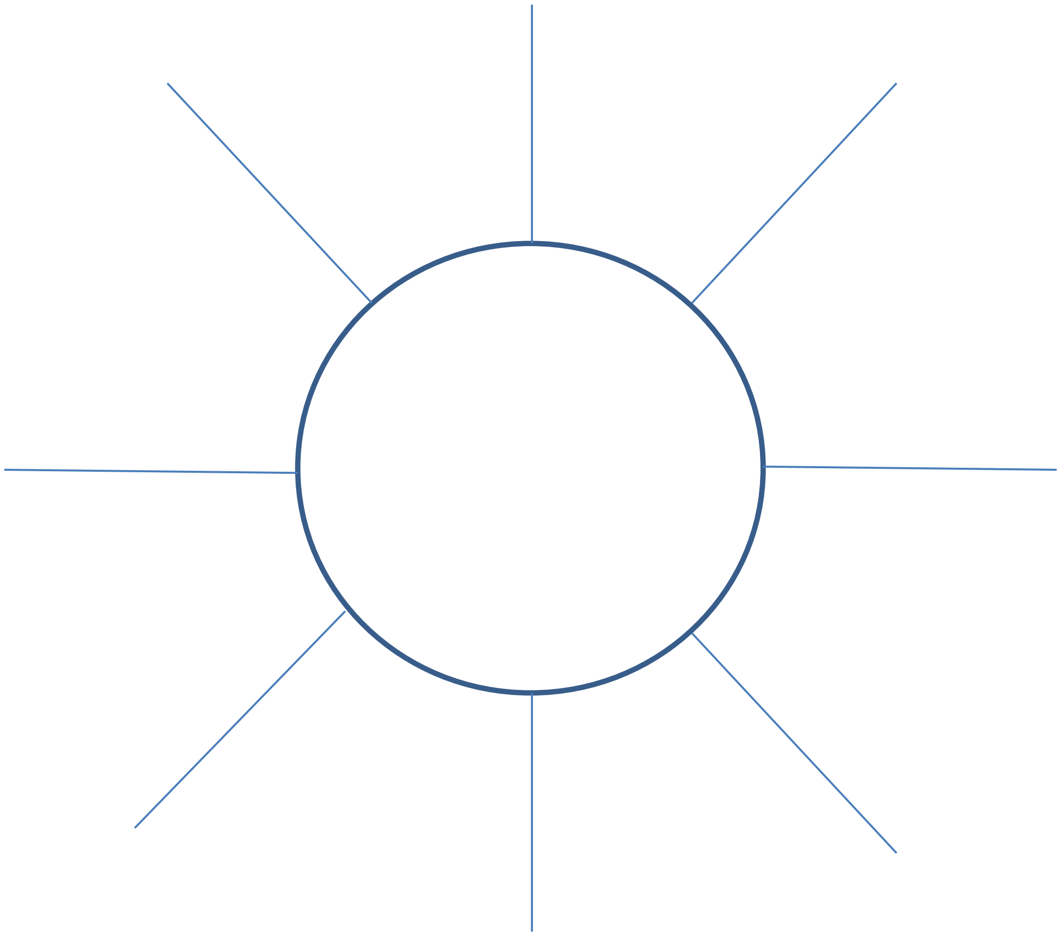
Some things to think about:

- It's fine to talk about the scrapbooks with your teacher, family and friends
- It's up to you what you put into them, as long as it is about maths
- You can draw, write and stick things in, put in questions, treat it like a diary – anything that you think will help me to understand what maths means to you
- It really helps if you label your pictures to tell me about them.

Using the cameras:

- Remember to avoid showing people's faces on your photographs
- Think hard about which photographs you want to print out at school – pick ones you think are particularly important.

Appendix 5 Blank relationship wheel template



Appendix 6 A book is like…

A Book Is Like

A book is like an open flower, scented pages, fragrant hours.

A book is like a crafty fox, surprising in its clever plots.

A book is like a fairy's wings, with princesses, enchanted kings.

A book is like a windowsill, where breezy thoughts are never still.

A book is like an hour glass, whose pages flow as hours pass.

A book is like a lock and key that opens doors and sets minds free.

A book is like an ancient clock that speaks the times but never talks.

A book is like an open letter, when read again the friendship's better.

A book is like an apple core with seeds inside for growing more.

A book is like a trusted friend that keeps its secret to the end.

~~Kathy Leeuwenburg

Appendix 7 If mathematics were a…

If mathematics was a …

Name:

If mathematics was a food it would be

....

because

....

....

....

....

If mathematics was a kind of weather it would be

....

because

....

....

....

....

If mathematics was a colour it would be

....

because

....

....

....

....

If mathematics was an animal it would be

....

because

....

....

....

………

………

If mathematics was a vehicle it would be

………

because

………

………

………

………

………

University of Reading

Appendix 8 Focus group topics June 2014

Girls' perceptions of mathematics

Areas for exploration within focus groups – June 2014

What they included within their scrapbooks and why

- Pick something to tell the group about in your scrapbook
- What made you pick that?

How they use mathematics in their everyday lives

- Did you find it easy to find things to write about, draw, stick in or take photographs of?

Who they talk to about mathematics or do mathematics with

- Think about the things you have put into your scrapbook. Who did you do them with, or were you doing them on your own?
- Have you talked about your scrapbook with anyone?

How they think they will use mathematics in the future

- Do you think there is any maths in your scrapbook you will use when you leave school? Tell me about it.

How they define home mathematics and school mathematics

- Is the maths you do at home like the maths you do at school?
- What is the same or different?

Who and what influences their views of mathematics

- Were all of the ideas in your scrapbook yours?
- Did you get ideas from anyone else?
- Where did you get your ideas from for what to include?

Processes

- How did you get on with the camera? Is there anything you think we should do differently next time you keep the scrapbooks?

Appendix 9 Pupil conference schedule June 2016

Girls' perceptions of mathematics – individual pupil conference schedule

Name: **Date:**

Research question	Interview themes/questions	Discussed
Introduction	Paperwork completed Pre-session briefing completed	☐ ☐
	Turn on digital recorder!	☐
Drawings	Tell me about your drawing Possible follow-ups: - Where are you? - What are you doing?	☐
Photographs	Tell me about your photograph Possible follow-ups: - What does it show? - Tell me more about… - So are you saying that… - What made you choose this photograph?	☐
Concept maps	(only discuss if something specific) Can you tell me more about…	☐
Relationship wheels	(only discuss if something specific) Can you tell me more about…	☐
Scrapbooks	Is there anything you would like to show me in your scrapbook? - What makes you say this is 'maths'? - Where did the idea to put this in come from?	☐

Perceptions of mathematics	What groups of children do you think enjoy doing maths? What kind of person do you think is good at maths? Are there any particular jobs you think maths might be useful for? What do you think most people think about maths? What makes you say that? What kind of person do you think makes the best mathematician?	☐
Mathematical identity	How do you think your teacher would describe you? What about at maths? What would your friends or family say? How do you see yourself using maths in the future? Do you think you will continue to study it when you don't have to? What kind of job do you think you might like to do in the future? Where do you think people get their ideas about maths? If you had to sum up your confidence in maths, what would you say?	☐
	Is there anything else you think I should know about you and maths?	☐

Thank you for taking part!

Appendix 10 Child consent form April 2014

Girls' perceptions of mathematics

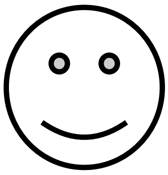
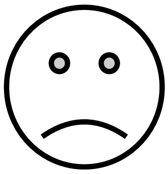
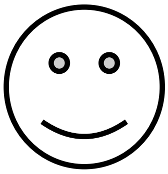
<u>My Consent Form</u>

I have read the Information Sheet about the project and been given a copy of it.

I understand what the purpose of the project is and what I am being asked to do. All my questions have been answered.

My name: ____

Please colour in the faces as appropriate:

	Yes	No
I give permission for my scrapbook to be used within the research project		
I am happy to take part in a recorded group or paired discussion about mathematics		

Signed: ____________________________

Date: _____________________________

Appendix 11 Final child information leaflet

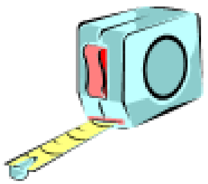
University of Reading

Girls' perceptions of mathematics

Catherine Foley

This project is part of my educational Doctorate at the University of Reading. By doing this I hope to learn more about teaching and learning in mathematics.

This project has been reviewed following the procedures of the University of Reading Research Ethics Committee and has been given a favourable ethical opinion for conduct.



University of Reading
0118 378 2661
c.m.foley@reading.ac.uk
www.reading.ac.uk/education

Will I be able to keep my scrapbook?

Because I am interested to see what you put into your scrapbook, if you give me permission I would like to take it in and make copies of some of the pages. After that, if you would like it back you can have it to keep!

What happens next?

Your parents have been sent a letter asking for their permission for you to take part in this project.

I will check with you before using any of your information in my project and ask you to sign a form to show that you are happy.

If you have any questions please speak to your class teacher. Or you can contact Catherine Foley via c.m.foley@reading.ac.uk

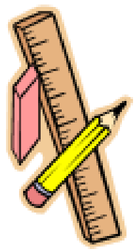
Information sheet

I am doing a research project about learning mathematics, and what different people, in particular girls, think about mathematics.

I have already asked your Head teacher if they are happy for you to help.

I am very interested in your views – if you think I should be asking any other questions, or there are other ways I can find out about how you feel about mathematics, please tell me!

Why have I been invited to take part?



You have been invited to take part because you are learning mathematics in a primary school, and your Head teacher is interested in children in your school taking part in this project. Because you are in Year 4, you are old enough to give me clear opinions and to talk, draw and write about your mathematics.

What will I have to do if I agree to take part?

As part of your maths work over the next few months, you will be asked to keep a scrapbook about your mathematics at home and at school. As long as you look after it carefully, you can put whatever you like into this scrapbook!

You might like to write, draw, sketch or stick things in – anything is fine, as long as it is about the mathematics you use at home and at school. You will also be given a camera and you can use this to take photographs of anything at home to do with mathematics.

If you give me permission, I would like to study what you put into your scrapbook as part of my project.

Will anyone know about my scrapbook?

Your parents and teachers will see your scrapbook because it is part of your mathematics work. I will make sure that no one else knows about what you put in your scrapbook and say about it by changing your name.

Will I need to do anything else? If you are happy, I might also ask you to take part in a 'focus group' or paired interview. This is a special group, where we will talk about your scrapbook and what you have put into it. I will need to record this group so that I can remember and think about what you have said.

Will it help me if I take part?

I think you will find it interesting and fun to keep the scrapbook and to talk about it with me and your friends.

I hope this project will help me to tell your teachers what you like and don't like about mathematics, so that we can all work together to make it something you enjoy.

Do I have to take part?

No, not at all. You do need to keep the scrapbook, because this is part of your mathematics work. But you don't have to let me use your scrapbook in my project if you would prefer not to, or talk to me about it. And you can stop helping me with my project at any time – *just tell your parents or class teacher to tell me if you want to stop.*

University of Reading

Appendix 12 Letter home to parents

Dear Parents

I am writing to tell you about some research I will be carrying out at xxx, beginning in the summer term, and invite you to come along on after school on Tuesday 29th April to find out more and ask any questions.

I am fully DBS checked and trained as a primary teacher and have extensive experience of working with children having taught in West Berkshire and Oxfordshire. I currently work at the University of Reading as mathematics tutor for our trainee teachers and am well known to the school.

<u>Girls' perceptions of mathematics</u>

The project aims to explore what girls think about mathematics – what mathematics actually is and how and why mathematics is important for them now and in the future. It is targeted specifically at girls because, although the national statistics show that results for girls and boys are similar in mathematics, it is very common for girls to be under-confident in mathematics, to think that they are not as good at it as boys, or to believe that mathematics just isn't for them.

By carrying out the research I hope to find out whether the gap between 'real-life' and school mathematics can be closed through involving children in researching their own mathematical lives. I hope to be able to make recommendations to the school and the wider education community regarding how we can best engage children in mathematics as a meaningful and relevant subject.

I will be introducing the project to the children on Tuesday 29th April, and will be available after school at 3.30pm to give a short talk about the research and answer any questions you may have. On the same day, children will bring home a detailed information sheet and consent form which explains the project in more detail, as well as giving information about important issues such as how all the data is kept anonymous so that neither the school or the children can be identified.

The girls will be asked to keep a journal of mathematics in their lives over the next few terms. As part of the project they will be loaned a digital camera, so that as well as drawing and writing they can take and print out photographs of whatever they think of as being to do with mathematics. If you and they give permission, I will collect in their scrapbooks from time to time to use within my research, and come to talk with them about their scrapbooks in pairs or small groups.

I very much hope you will feel able to give permission for your child to be involved in the research project, and looking forward to answering any questions on Tuesday 29th April.

Yours sincerely,

Catherine Foley

Appendix 13 Parent information and consent form

University of Reading

Parent/carer information sheet

Research Project: Girls' perceptions of mathematics

I would like to invite your child to take part in a research project about learning mathematics. The project aims to investigate what mathematics means to primary-aged girls, and whether the gap between 'real-life' and school mathematics can be closed through involving children in researching their own mathematical lives. It hopes to make recommendations regarding how we can best engage children in mathematics as a meaningful and interesting subject.

Why has my child been chosen to take part?

Your child has been invited to take part in the project because she is in Year 4, the target age for the project, and a girl – the focus group for the project.

Does my child have to take part?

It is entirely up to you and your child whether they participate in the research project. All of the girls in your child's class are being asked to keep a scrapbook about their mathematical lives, and being loaned a digital camera to help them gather information. However, if you would prefer your child's scrapbook and data not to be used within the project, you can indicate this on the response slip provided.

What will happen if my child takes part?

Along with others in her class, your child will be asked to keep a scrapbook about mathematics at home and at school. They might like to write, draw, sketch or stick things in – anything is fine, as long as it is about the mathematics they use at home and at school.

All girls in your child's class will also be loaned a digital camera during the project. They will be encouraged to use it to take photographs of anything they think is to do with mathematics, or of mathematical objects or activities in the home. The ethics of photography will be discussed with children when the project is introduced to them. Only photographs which do not feature identifiable people or locations will be printed and used within the project.

If you and your child both give permission, I will take in their scrapbook to make copies of some of the pages to analyse. Scrapbooks will be returned to children as soon as possible. I will also gather some background information such as National Curriculum mathematics levels. Your child may also be asked if they would like to take part in a focus group or paired discussion, when we will talk about their perceptions of mathematics, using the scrapbooks as a stimulus. These discussions will be recorded so that I can transcribe and analyse the results.

The focus groups will take place during school time and will be carried out by myself. I am fully DBS checked and trained as a primary teacher, am well known to the school, and have extensive experience of working with children. I currently work at the University of Reading as mathematics tutor for our trainee teachers.

What are the risks and benefits of taking part?

Neither you, your child nor the school will be identifiable in any way. Time taken during school for the project will be carefully monitored to ensure that there is no negative impact on their curriculum time.

I believe that children will enjoy being involved in the research project. Some children can struggle to see the relevance of mathematics and I hope this project will help them understand and be more confident in their own mathematics. I hope that the findings of the project will be useful in helping teachers make mathematics teaching interesting, meaningful and accessible to children, in particular girls.

What happens if people are shown on the photographs?

Children will be encouraged to take photographs of objects or activities rather than people. If any people are accidentally shown on the photographs, their identity will be obscured through blurring or cropping of the image.

What will happen to the data?

Any data collected will be held in strict confidence and no real names will be used in this project or in any subsequent publications. Nothing linking you, your child or the school to the project will be included in any sort of report that might be published. The recordings from the focus group discussions will be transcribed and anonymised before they are analysed.

What happens if I/ my child change our mind?

You/your child can change your mind at any time without any repercussions about letting me use their scrapbooks and discussions in my project. During the research, your or your child can withdraw permission by contacting me (0118 378 2661, email: c.m.foley@reading.ac.uk) or the class teacher, and I will discard your child's data.

What happens if something goes wrong?

In the unlikely case of concern or complaint, you can contact my supervisor Dr Carol Fuller, University of Reading; Tel: 0118 378 2662, email: c.l.fuller@reading.ac.uk.

Where can I get more information?

If you would like more information, please contact me using the contact details above.

I do hope that you will agree to your child's participation in the project. If you do, please complete the attached consent form and return it to your child's class teacher.

Yours sincerely,

Catherine Foley

This project has been reviewed following the procedures of the University of Reading Research Ethics Committee and has been given a favourable ethical opinion for conduct.

Research Project: Girls' perceptions of mathematics

Parent/Carer Consent Form

I have read the Information Sheet about the project and received a copy of it.

I understand what the purpose of the project is and what is required of my child and me. All my questions have been answered.

Name of child: ____

Please tick as appropriate:

	YES	NO
I consent to my child's scrapbook being used as part of the research project	☐	☐
I consent to my child taking part in recorded focus group discussions	☐	☐

Signed: ______________________________

Date: __________________________________

Please return this form to the school office or class teacher by ***Tuesday 6th May.***

Appendix 14 Updated HT information and consent form

Research Project: **Girls' perceptions of mathematics**

Dear Head Teacher

Thank you for allowing your school to take part in the study so far – this letter is to update the ethics documentation in the light of emerging findings of the research.

What is the study?

I am conducting the study as part of my Educational Doctorate at the University of Reading. It aims to investigate what mathematics means to primary-aged girls, and whether the gap between 'real-life' and school mathematics can be closed through involving children in researching their own mathematical lives. It hopes to have an impact on improving girl's disposition towards and engagement with the subject. It hopes to make recommendations regarding how we can best engage children in mathematics as a meaningful and interesting subject.

Why has this school been chosen to take part?

During an initial conversation, you indicated an interest in your school being involved in this project. In addition, your school has an appropriate catchment for the aims of the study, and is geographically accessible to the University.

Does the school have to take part?

It is entirely up to you whether you give permission for the school to participate. You may also withdraw your consent to participation at any time during the project, without any repercussions to you, by contacting me using the contact details above.

What will happen if the school takes part?

Girls within one class of children will be asked to participate in the study. They will be asked to keep scrapbooks to document their mathematical lives. They will be encouraged to take ownership of these, choosing to incorporate evidence such as photographs of objects and activities at home, drawings of themselves or others engaged in mathematics, and/or journal writing about their responses to mathematics.

<u>In the Spring term 2015, they will also be given the opportunity to take photographs of 'mathematics' at school as well as at home. It will be explained that they should not include recognisable images of other children or adults in their photographs, and they will select a very small number of photographs to print out and use as a focus for discussion.</u>

The girls willl also be loaned a digital camera for the purposes of the research. We will need to give them access to a printer to print out selected images to include within their scrapbook.

In addition to this main focus for data collection, some of the children will be invited to participate in focus groups or paired interviews to discuss their perceptions of mathematics, based on their scrapbooks and photographs. These focus groups will be digitally recorded for the purposes of transcription and analysis.

If you agree to the school's participation, I will seek further consent from parents/carers and the children themselves. Children and parents/carers will have the right to withdraw their data from the project at any point.

Will there be any further data collection?

Depending upon the analysis of initial rounds of data collection, it may prove beneficial to conduct interviews with adults working with the children. In this instance, further consent will be sought. Background data in terms of children's age, National Curriculum assessment levels, free-school meal status and will be gathered on receipt of parental consent.

<u>In late Spring and early Summer 2015 it would be useful to conduct interviews with the participants to extend and summarise the range of data collected. Additional parental permission will be sought at this point.</u>

What are the risks and benefits of taking part?

I anticipate that the children will enjoy taking part in the study and reflecting on their own relationship with mathematics, and that the findings of the study will be useful for teachers and the wider education community in planning how they teach mathematics. Children will be supported to feed back the key points of their findings to the school community, thus empowering them and potentially improving their confidence and mathematical outcomes.

The information given by participants in the study will remain confidential and will only be seen by myself and my supervisor. Neither you, the children nor the school will be identifiable in any published report resulting from the study.

The ethics of photography will be discussed with children when the project is introduced to them. Only photographs which do not feature identifiable people or locations will be used.

The study will be integrated into the children's curriculum time and homework policy to ensure that taking part does not have a detrimental effect on their time.

What will happen to the data?

The children will be asked to give consent for me to copy their scrapbooks and photographs to use in my study, and the scrapbooks will be returned to them when they are no longer needed within the study.

Any data collected will be held in strict confidence and no real names will be used in this study or in any subsequent publications. The records of this study will be kept private. No identifiers linking you, the children or the school to the study will be included in any sort of report that might be published. A spreadsheet linking children's ID numbers and names will be kept separately from their original data to preserve security. Participants will be assigned a pseudonym and will be referred to by that pseudonym in all records. Research records will be stored securely in a locked filing cabinet and on a password-protected computer and only the research team will have access to the records. The data will be destroyed securely once the findings of the study are written up, after five years. The results of the study will be presented within my thesis and potentially at national and international interviews, and in written reports and articles. I can send you electronic copies of these publications if you wish.

What happens if I change my mind?

You can change your mind at any time without any repercussions. If you change your mind after data collection has ended, I will discard the school's data.

What happens if something goes wrong?

In the unlikely case of concern or complaint, you can contact my supervisor Dr Carol Fuller, University of Reading, Tel: 0118 378 2662, email: c.l.fuller@reading.ac.uk.

Where can I get more information?

If you would like more information, please contact Catherine Foley

Tel: 0118 378 2661, email c.m.foley@reading.ac.uk.

I do hope that you will agree to participation in the study. If you do, please complete the attached consent form and return it to me.

Thank you for your time.

Yours sincerely

C.M.Foley

Catherine Foley

This project has been reviewed following the procedures of the University Research Ethics Committee and has been given a favourable ethical opinion for conduct. The University has the appropriate insurances in place. Full details are available on request.

Girls' perceptions of mathematics

Head Teacher Consent Form

I have read the Information Sheet about the project and received a copy of it.

I understand what the purpose of the project is and what is required of me. All my questions have been answered.

Name of Head Teacher: ____

Name of primary school: _______________________________________

Please tick as appropriate:

I consent to the involvement of my school in the project as outlined in the Information Sheet

YES ☐ NO ☐

Signed:____________________________

Date: ________________________________

Appendix 15 Example pupil conference transcript

Interview transcription – Millie (4th June 2015)

Would you like to start by telling me about this photograph. What made you choose it?

Well, I decided to do this because … so people could estimate how many pencils in the pot? But, I haven't actually counted myself, but, I think there are roughly about 25.

Ok, so is estimating something that you think you use a lot in your mathematics?

Well, that's what I wanted to pictures of, of like estimating, so people could estimate it. And I quite like estimating because you like… you don't say like the proper answer, but you don't say the exact answer, because if you estimate, then you know that you … it's better to get things wrong than right, because is you always get everything right, then that means you're perfect, but nobody's perfect.

Ok. And who might like to estimate that, do you think?

Me (laughs)

Anybody else?

I don't think so…erm…I think my mum and my sister like estimating. I definitely like estimating.

Ok, let's have a look at your next picture shall we? Tell me about this one.

This is when I did my 10 to 20 times tables. And I got every single question right. And I decided to do this because I was bored, and I love maths, so I decided to challenge myself, and do the 20 times table up to 10.

So where were you when you did this?

I was on my bed, and then I brought it into school.

Ok, so this is something you did of your own choice is it?

Yes

So tell me a bit more about that.

Erm, well I … did it up to 10, but I don't know, but I did it really quickly. I didn't really know the times tables, but I managed to do them quickly somehow… and I already knew the 10 and the 11s and 12 times tables, but I didn't know the rest of them, but … I did get a little bit stuck on the 17 times table because it was a bit hard.

I'm not surprised! How did you figure it out?

Erm, well, I just managed to keep on doubling them then I filled in the gaps.

Woah. And who did you show this to? Did you show this to anyone?

Erm… I remember showing it to the class for show and tell. I think I showed my mum, and my sister wasn't bothered about it.

Ok. Should we look at your last one? So, what's on here.

This is a picture of my watch. I decided to do this because it's a clock, and I just wanted people to estimate what the time is, and I know that the time is 1.41 and 16 minutes past, exactly.

That's very precise, isn't it. Whose watch is it?

My watch. I got it for Christmas one year.

Did you?

Yes. But it keeps on stopping, it's stopped now.

So is this a photograph you took at home?

I took it at school because of the blue table, but it was during reading time so I just quickly took a picture of it.

I've noticed that two of your pictures are about estimating. Do you think estimating is important in maths?

Yes. Because if you get like, really precise, then what's the point? Because if you… you want to estimate, so you'll be close to the answer, and then actually do the calculation, to see if you were close to your estimate.

Ok, very interesting…tell me about your drawing.

Well, this is the whiteboard in the classroom. And I was pretending that it had these squares, like you can get it on the board, and then I put down my calculation and I asked the children… the rest of the class a quite… what the answer was to the question, and then I wrote the answer in, then I said the answer is '98, 698' then I put a tick beside it as if I got it right.

So what is your role, what were you doing with the children?

I was asking them the questions so they could fill in the answers.

Do you think… how come you were at the board?

Because I… I put my hand up as a volunteer and the teacher picked me.

So how do you think you would have been feeling when you were doing that?

Erm… I would feel… probably a bit scared slash nervous because it would be maybe like three tables of the maths, so … I don't really like telling people stuff and going up the front, but… I quite like doing it but it's a bit scary sometimes and nervewracking.

So if you had a choice, would you go to the front or not go to the front?

Well, I would , but I wouldn't, it would depend what it would be about.

Ok. Then we've got your concept map. I just had one question about this, I think… when it says here 'really long sums', is that a good thing or a bad thing?

Well, I do like it but it does sometimes take quite a long while to do. So… erm… it depends if it's hard or easy to do for me. Because sometimes I find it hard or easy.

Which do you prefer? Things that are hard or easy?

Well I like both, but if it's easy, then I usually just whizz through them. But if it's hard, then I like get stuck… on some questions I can do them, because I remember one of the times, it wasn't that long ago, we did these questions about timesing, and I remember that the challenging one was like… seven hundred thousand and something something times by 52, which was quite hard. But the next day after, wait no, after lunch, I did that in my book during reading time, but I couldn't work it out so I did it on the calculator.

Ok. So what do you do when I get stuck.

Well we like work in pairs on our table. Because between one actual table 4 people sit on it, including me, so it's a bit difficult, but my partner is one of my friends, then my two other friends are partners, but me and my partner work together, so if we get stuck we just help each other.

Ok. Sounds sensible! Right then, … you mention on here that your teacher inspires you to more challenging work. Tell me a bit more about that.

Erm… well, I used to be in the second to highest in maths, but now I'm at the top. Mrs xxx kept on saying that she knew that I could do it, and that she knew I could keep on doing it even if I got stuck, and I remember the day that I got to go to the top table, but I thought I wouldn't be staying there but I was, but that day Mrs xxx was in the classroom as well…

How did that make you feel?

Over the moon!

Over the moon! I noticed you put on your word wheel a couple of times that your grandpa and grandma and Mrs xxx saying well done. Do you think that's important for you?

Well I think it's quite special for me, because that sort of… inspires me to keep on doing more work, and more harder work at home about maths.

And does anything make you feel the opposite?

Well… my sister sometimes does, because she's in the middle group in her school for maths, and I say that I'm in the top so I can help her, but she says you don't do as difficult work as me so you won't be able to get the answers. But once I remember my sister was stuck and my mum was helping her, but she got a little bit stuck on doing my sister's work and I told them the answer.

[looking at scrapbook]

I haven't done much in here.

Don't worry! Is there just one thing you want to show me? Then I can take it away and have a look?

[flicking through scrapbook]

So tell me about that page.

This page is about when I did adding. I did quite high numbers, because I like working with harder numbers, but I didn't want to make them really hard so I can't do them. So I sometimes did 4 or 5 digit numbers, but I mainly did 4, because I find it easier, but if I do 5, I find it a bit tricky for me, but on this one I did 4 and 5 because I wanted to see what would happen. And the highest number I got on here was this one I think, no this one, which was 9 909. But my lowest one was this one, which was 6 264.

So what do you think made you want to put those into your scrapbook?

Well, I like doing addition, that's my favourite thing out of addition, subtraction, division and times tables, because … I just like find it simple, because I know that I don't really struggle doing it, I can just do it even if I find it hard.

And is this something you think you will use in the future?

Erm… yes, because if I'm baking something, because I need the kilograms, and if I had another thing I would want to know how much, if I was adding them together.

Right, I'll leave that with you for the moment, I'd quite like to take it away today if I can. So perhaps if we can find time today just to stick in those remaining pictures, if that's ok. Ok, so, what groups of children do you think enjoy doing maths then.

Certainly me, and probably the people on my table, except for Sally because she sometimes struggles, and I remember one of the times when we were doing word problems, she couldn't understand the first question, but she didn't actually do it because she got the teacher to help her. So I think that she started to not enjoy maths as much as she used to.

And what about in the whole school. Do you think there are groups of children who like maths in the school?

Well, I think it's the HAG people, because they're in HAG so I think they enjoy maths, that's why they're in the top group, but… they all sit on the high table, or like the furthest table that's good at maths, and so do I but I'm not in HAG though.

Is that something you would like to be?

Yes.

Is it?

Yes, by the end of the year I really want to be in HAG.

Why do you say that?

Well, I just want to really be in it because I just want to do more harder maths… and I just really want to go there, because I've got a happy dance, I want to do my happy dance [laughs]

Well, it will be good to see what happens. So, what kind of a person do you think is good at maths?

Well, I know one of my friends, she is in the lower group, she's Tilly, but I think she should be in the middle group because she's quite good, and so is Lauren, because they're quite good at maths, even though they're on the lower table. They don't get everything right, because you shouldn't be perfect, but they don't get everything wrong.

So what does it take to be good at maths, do you think? What does it mean, to be good at maths?

Well, you have to always practice a variety of things, because… if you didn't then you wouldn't really know many things, and i… I'm not really good at fractions, but I still try to practice them, and I am getting better at fractions. But I find it hard when you do percentages and fractions and decimals connected together. And percentages, some people did in year 4, but I'm not very good at it because I can't really work it out sometimes, how you sort it out.

So are there any particular jobs you think maths might be useful for?

Well certainly for baking, and maybe for people who are like buying stuff as well, because… say if something is like £5.97 and something was like £5.40, then you'd have to work it out, and it would be over £11 or more, because it would be like… you had to add them to work out, and if you had more money, you would have to work out if they had the right change as well.

What do you think… thinking about older people now, perhaps after people have finished school or been to university if they want to go, and they're doing their work, what do you think most people think about maths?

Well, I think that some people think they're not really good enough for it. But if you try harder then you will succeed. But if you're already good at maths, and even though you think you're good enough, you think 'well I won't do any more because I know I'm good at it', still do some extra work, because then you'll be even better…

So, how do you think your teacher would describe you, as a pupil?

Erm…do you mean in maths, or in any subject?

Talk about any subject to start with, then we can talk about in maths.

Well I know that in literacy, I'm not doing very well at sentence starters. So I decided to make a game of sentence starters, of 30 words, and every night before I go to sleep I do one of them. Basically it's this piece of paper that's in 3 sections, and then 10 lines, so it's 30 sections, then I wrote words in, and now I describe them. So on a smaller piece of paper I put two columns down, then I did the same as I did on the other piece of paper. Then I go across to find which column, then I go down to find which word, then I put it at the front of the sentence or in the middle.

Whose idea was it doing all of that?

I did it to practice for rapid recall, and I had loads of spare paper left, so I decided to do something from literacy to help me in my work.

And what would your teacher say about you in maths, how would she describe you?

Well, I know that I'm… I sometimes get quite a lot of questions right, and I sometimes make some really silly mistakes, because I remember that once I did… two or four questions, that I didn't read the questions properly, because I couldn't see the book, and instead of writing a 4-digit number I wrote a 3-digit number, I missed one of the numbers out, so that was a bit silly because I didn't read the question. I think the teachers think that I could do better, and then maybe succeed to go to HAG, maybe, and if I try even harder each time I do maths, then I could succeed to go further.

And what do you think your friends or family might say?

Well, I know that my mum might get me a gift, because … once in my report card I did well, so my mum got me a 'beanie boo'.

And what do you think they would say about how you are as a mathematician. Do you think you are a mathematician?

mmm… sometimes. But if I feel like I get too many questions wrong, and only a few questions right, I feel like I've sort of disappointed myself.

How do you see yourself using maths in the future?

Maybe like when I go into the shop and baking. And maybe putting stuff on the scales for baking.

Do you think you'll carry on studying it when you don't have to any more? So when … you have to carry on maths until you're 16 (that's a long way away isn't it). Do you think you'll carry on doing maths after that when you don't have to?

Well, I would either like to be a vet or a maths teacher at school because I love maths. And sometimes… because I'm quite good at science too. So science and maths equal vet, being a vet, so I would like to study maths even if I don't have to, so I would always choose maths and science.

Wow, that's amazing. Where do you think people get their ideas about maths from?

I think they… decide that they're going to study maths. And then they're going to … like decide to do like a twist on what they are going to do, so they decide to do it differently from how people would normally do it. Then maybe they think of even harder questions that might be a bit too challenging, but maybe be able to do them because they're still possible.

Do you think anybody or anything influences you and your friend's opinions of maths.

I'm not quite sure, I don't really know… I don't know. It's a hard question.

That's ok. If you were going to sum up your confidence in maths, what would you say?

Erm… I would probably say… … I would probably keep on telling myself just 'you can do it, just be confident even if it's too hard', and maybe tell myself just… don't think about how hard it is, but focus and ask the three Bs, because we have 'brain', and then 'book', then 'buddy', then the 'boss' which is the teacher. And I sometimes use that in maths. But if my friend can't help me then I ask everyone else on the table… but if they can't then I ask the teacher afterwards.

And is there anything else you think I should know about you and maths?

Well sometimes in maths, because on my table is Polly, me, Taylor and Sally, and we have to pull the table out, and if… but always, if we are doing a piece of work there's one person who is good at it, then we explain it to the other person, then we tell the other people. But mainly Sally gets stuck, and Polly is good at things, but I'm good at things, so then I explain it to the rest of the table, but then I explain it to Taylor because sometimes she doesn't understand. And… but Sally, she doesn't really get it sometimes because she doesn't understand the questions, especially word problems. I find word problems quite easy depending upon, like how they're worded, because if they are worded like I can't understand them, then I pronounce the word. Because I remember we did word problems yesterday, and I did the wrong thing, because I looked in Polly's book to see how she'd done it… and then I understood how to do it. And we also did… we have these grids, and we plus something point something, then we put a number in, then we plus it or take it away from that number that we started with, then we carry on the sequence. It's either hard or easy, it depends on what you do it from, what number you add or subtract.

Thank you very much!

Appendix 16 Focused coding of pupil interviews

Initial code	Frequency	Focussed code
Identifying own limitations/showing self-awareness	√√√√√√√√√√	Making/receiving judgements
Comparing with family/peers	√√√√√√√√	
Showing awareness of own level	√√√	
Judging/aware of level of others/comparing self with peers	√√√√√√√√√√√√√√√√√√√√√√√	
Seeing self as slow/needing time	√√√√√	
‘Othering’ of able mathematicians	√√√√	
Being chosen for top group / moved up	√√	
Being moved/held ‘down’	√	
Reflecting on own progress	√	
Aspiring (maths)	√√√√√√√√√	Looking to the future
Aspiring (other)	√√√√√	
Associating maths with career/future prospects	√√√√√√√√√√	
Not associating maths with career/future prospects	√√√√√	
Associating poor education/prospects with being ‘bad’ at maths	√	
Expressing intention to continue	√√√√√√	
Not wanting to continue	√	
Seeing maths in home/wider environment	√√√√√√√√√√√	Seeing or not seeing relevance
Linking maths and science	√	
Making connections between maths and other subjects (eg music)	√√√√√	
Struggling to explain/see how maths might be used/useful	√√√√√√√√√	
Preferring home maths/not seeing point of school maths	√√	
Maths = getting things right/wrong	√√√√√√√√√√	Characterising mathematics
Maths = speed/quick/fast	√√√√√√√√√√√√	
Maths = mental activity	√	
Maths = knowing facts/remembering	√√√√√√√√√√√√	
Maths = believing in self	√	
Maths = skills	√	
Maths = answering a question	√√√√√√√√	
Maths = posing questions/puzzles	√√√√√√√√√√√√√	
Maths = enjoyable	√	
Maths = a lot/big/endless	√√√√√√	
Maths = boring	√	
Maths = journey/progression/gets harder	√√√√√√√	
Maths = in school	√√	
Maths = useful (in wider/later life)	√√√√√√√√√√√√√√√	
Maths = everywhere	√	

Maths = calming	√	
Maths = desk/school activity	√√	
Maths = adventure	√	
Seeing maths as hard/easy	√√√√√√	
School maths as practice for real life	√	
Seeing maths level as changeable	√	
Contrasting maths with other subjects	√√√	
Making connections within maths	√√√√√√	
Rejecting precision	√√√	
Seeing differences in home/school maths	√√√√√	
Good at maths = not good at other things	√√√	Characterising mathematicians
Liking maths = not liking other subjects	√√	
Girls = collaborative	√√	
Gendering being good at maths	√√√√	
Boys = competitive/working alone/thinking they are better	√√√√√	
Good at maths = doing hard maths	√	
Good at maths = finding maths easy	√	
Good at maths = clever	√	
Contrasting people who are good/bad at maths	√√√	
Liking maths = finding maths easy	√√√	
Identifying self-concept	√	
Associating struggling with not liking	√	
Associating enjoying maths with being good or success with happiness	√√√√√√√√√	
Associating confidence with enjoyment	√	
Associating confidence with being good	√	
Associating finding maths hard with not enjoying/boring	√√√	
Maths aptitude/attitude = inherited	√√√√√√√	
Liking part of maths	√√√√√√√	Personal relationships with/reactions to maths
Liking/enjoying maths	√√√√√√√√√√	
Not liking maths	√	
Maths = favourite	√√	
Being ambivalent towards maths	√√√	
Changing attitude to maths	√√	
Feeling safe/comfortable in ‘ability group’	√√√	
Worrying about maths	√√√√	
Being a mathematician	√√√	
Not being a mathematician	√√√√	
Identifying as ‘bad’ or not good at maths	√√√√√	
Feeling scared/apprehensive	√√√√√√√√√	
Feeling conflicting emotions	√√√√√√√	
Feeling alone/isolated	√√√√√√√	
Being disappointed in self/getting annoyed/frustrated/angry	√√√√√√√	
Finding maths hard	√√√√√√√√√√√	
Feeling satisfaction/elation/pride	√√√√√√√√√	

Being confident	√√√	
Being determined	√	
Accepting confusion (positive)	√√	
Feeling sad	√	
Being blown away	√	
Seeking/accepting/relishing challenge	√√√√√√√√√√√√√√√	
Feeling pressure/finding maths painful/harmful	√√√√	
Not wanting to feel vulnerable	√	
Losing, lacking or rebuilding confidence	√√√√√√	
Managing/coping	√	
Getting stuck	√√√	
Hiding own work	√	
Enjoying concrete/practical	√√√	
Enjoying straightforward/easy maths	√√√	
Enjoying hard maths	√√√√√√√	
Feeling confused/not getting it/not knowing what's going on (negative)	√√√√√√√	
Recalling practical/positive maths experience	√√√	
Recalling past negative experience/not 'getting it'	√√√√√√	
Getting better/making progress	√√√√√	
Needing to be in the mood	√	
Linking games with building confidence	√√	
Associating 'failure' with not working hard enough	√√	Displaying resilience and perseverance
Persevering/showing resilience	√√√√√√√√√√	
Valuing practice/effort/perseverance	√√√√√√√√√√√√√√√√√√√	
Practising	√√√√	
Lacking motivation/aspiration	√√√√	
Struggling/striving	√√√√√	
Doing homework	√	
Finding it hard to concentrate	√	
Overcoming gender bias	√	
Challenging self	√√√√	
Doing extra maths at home	√√√√√√√	
Taking responsibility/ownership/ being willing to try	√√√√√√√√√√√	
Doing maths away from classroom/home	√√√	
Valuing understanding	√	
Familiarity leading to confidence	√	
Being rejected by sibling	√√	Being influenced by others
Seeking affirmation from friends/family/teachers	√√√√	
Being influenced by family (positive)	√√√√√√√√√	
Building attitudes through influences from 'significant others'	√√√√√√	
Receiving positive feedback from others	√√√	
Resisting influence of family/others	√√	

Being aware of role model	√√	
Being judged/undermined/own reservations being reinforced	√√	
Recognising dislike of maths in others	√√	
Being inspired	√	
Being believed in	√	
Forming views independently	√	
Valuing feedback	√√	
Working collaboratively	√√√√√√√√√√√√√√√√√√√	Working with/without others
Working independently	√√√√√	
Seeking/being willing to help others	√√√	
Involving people in own maths	√√	
Volunteering	√	
Sharing maths with others	√	
Seeking/receiving support/help	√√√√√√√√√√√√√√√	
Estimating	√√√√√√	Using skills
Using a tool or artefact	√√√√√	
Pretending	√	
Experimenting	√√	
Applying maths skills	√√√√√√√√√√√√√√√√√	
Choosing to do maths	√√√√	Having choice and helplessness
Helplessness/not having a choice	√√	
Having a choice/control within maths (eg strategies)	√√√√√√	
Wanting to understand/improve	√√√√√√√√√	
Assigning blame	√	
Countering boredom	√√	

- √ = Millie
- √ = Aimee
- √ = Alice
- √ = Emily
- √ = Mackenzie
- √ = Tilly
- √ = Sally
- √ = Poppy
- √ = Hetty
- √ = Skye
- √ = Lauren
- √ = Taylor
- √ = Polly
- √ = Jasmine

Appendix 17 Example memo (pupil conference)

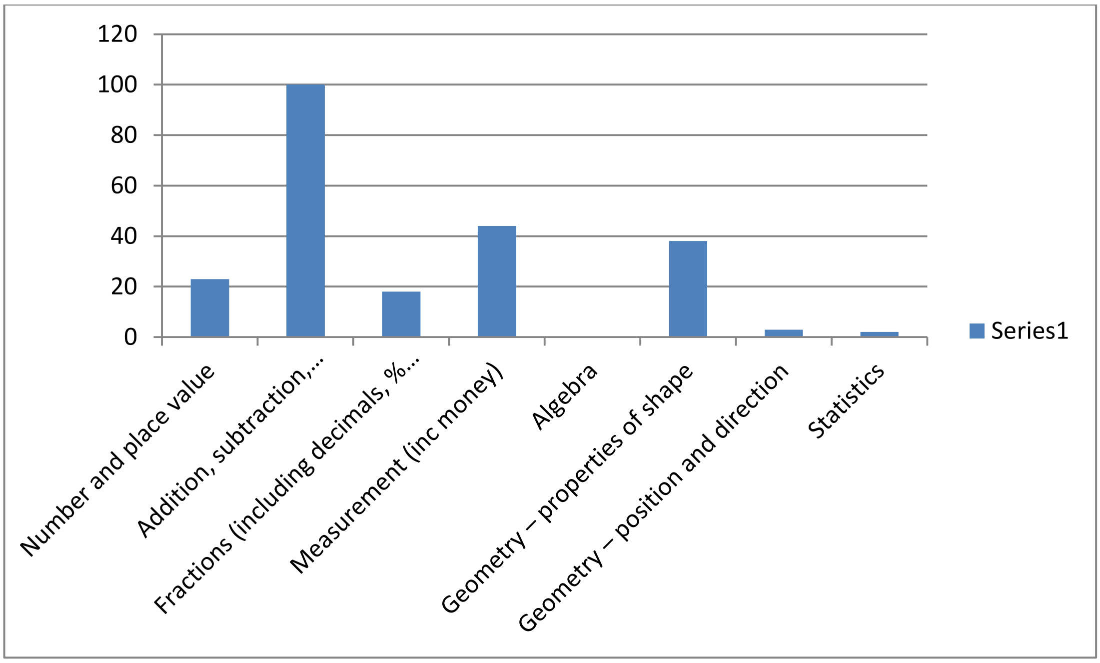
Taylor knows she is in the top group for maths and takes pride in being a member of the withdrawal group for high attainers. However, she finds it difficult to deal with the sensation of not understanding, which leaves her feeling isolated and left behind.

Within her school maths Taylor likes a challenge, preferring the harder maths to easier content and requesting a challenge if she feels the work is too easy. However, this doesn't seem to translate into thoughts about her future, within which she doesn't want to engage with harder maths.

Taylor finds it hard to identify or articulate practical applications of mathematics, and is aware of negative attitudes towards mathematics in society. She believes that people are born naturally liking or disliking maths, positioning herself somewhere in the middle.

Although she is high attaining, Taylor seems to go to some lengths to distance herself both from maths and those who are good at it: 'I just don't want that to be me!'

Appendix 18 Concept map curriculum content



Appendix 19 Examples of stages in metaphor elicitation analysis

Metaphor elicitation (2) Literal analysis

FOOD	WEATHER	COLOUR	ANIMAL	VEHICLE
Mussel =	Rain -ve	Yellow =	Moose ?	Lorry -ve
Roast dinner +ve	Rain/ hailstones =	Yellow =	Tiger +/-	Mini +ve
Sausage +/-	Windy +/-	Brown +/-	Fish +/-	Mini +/-
Orange =	Sunny ?	Blue +ve	Dog +ve	Lorry =
Sandwich ?	Sunny +/-	Red +/-	Jagoth (jaguar/ sloth) +/-	Ambulance +ve
Brussel sprouts -ve	Hail ?	Pink +/-	Lion -ve	Mobility scooter -ve
Sushi +ve	Sunny +ve	Blue +ve	Cat +ve	Car +ve
Pasta +/-	Springtime +ve	Blue +/-	Hedgehog +/-	Scooter -ve
Tuna +ve	Sun +ve	Purple +ve	Cat +ve	Lorry +ve
Pasta +/-	Rain +/-	Yellow +/-	Dog +/-	Van +/-
Spaghetti =	Storm ?	Turquoise ?	Cat +ve	Bus +ve
Pasta +ve	Sunny +ve	Purple +/-	Rabbit +ve	Car +ve
Spaghetti ?	Sunny +ve	Turquoise +ve	Blue tit +ve	Car =
Carrot ?	Rain + sun @ same time ?	Yellow ?	Dog ?	Pick-up truck ?

? 12
= 8
+ve 25
-ve 6
+/- 19

14 × 5 = 50 + 20 = 70 possible responses

+/- conflicted
+ positive reason/ response
- negative
= neutral

? impossible to say without further investigation

① Eyeball Metaphor elicitation
- 1st impression
calm/not calm
calm ✓✓✓
happy ✓
emotion
- dislike ‖
- like ⦀ (love)
conflict like v dislike ⦀ |
love maths !

~~Football~~
analogy
- maths book yellow ||
- rainbow

bright
fun annoying
conflict easy/hard
"blows me away"
beliefs
- easy
- hard to get into × 2 ✓ hard to bend ✓ dig deep
- hard to work out/tricky to make
long (as position)
too small ?
size - big ✓
moose
lorry - big
on same task
hail
boring / excitement
speed - quickly / slowly
✓ car
- slow (rocket) ✓ rocket
- slow (scooter)
steady speed
- go on forever
Themes
different ideas
spaghetti
orange (lots of segments)
sandwich
many parts
lorry (lots of things in it)
turquoise
//changeable ✓
open to new ideas ✓✓✓
attitude
favourite word
like but not favourite
not favourite / all the time ✓
✓ conflict/dissonance
changing relationship
Sometimes ✓✓✓
some elements of.

helpful - ambulance ('rescue') [redacted]
enabler
- Springtime (maths looks up to) [redacted]
lotto
can go anywhere
see better
end of rainbow = arsum
Fly to new heights.
All the information

appearance - nice (not all the time)
'nasty'
bright ✓

✓ maths as living thing
Dweck
R Marks /
fixed ability thinking

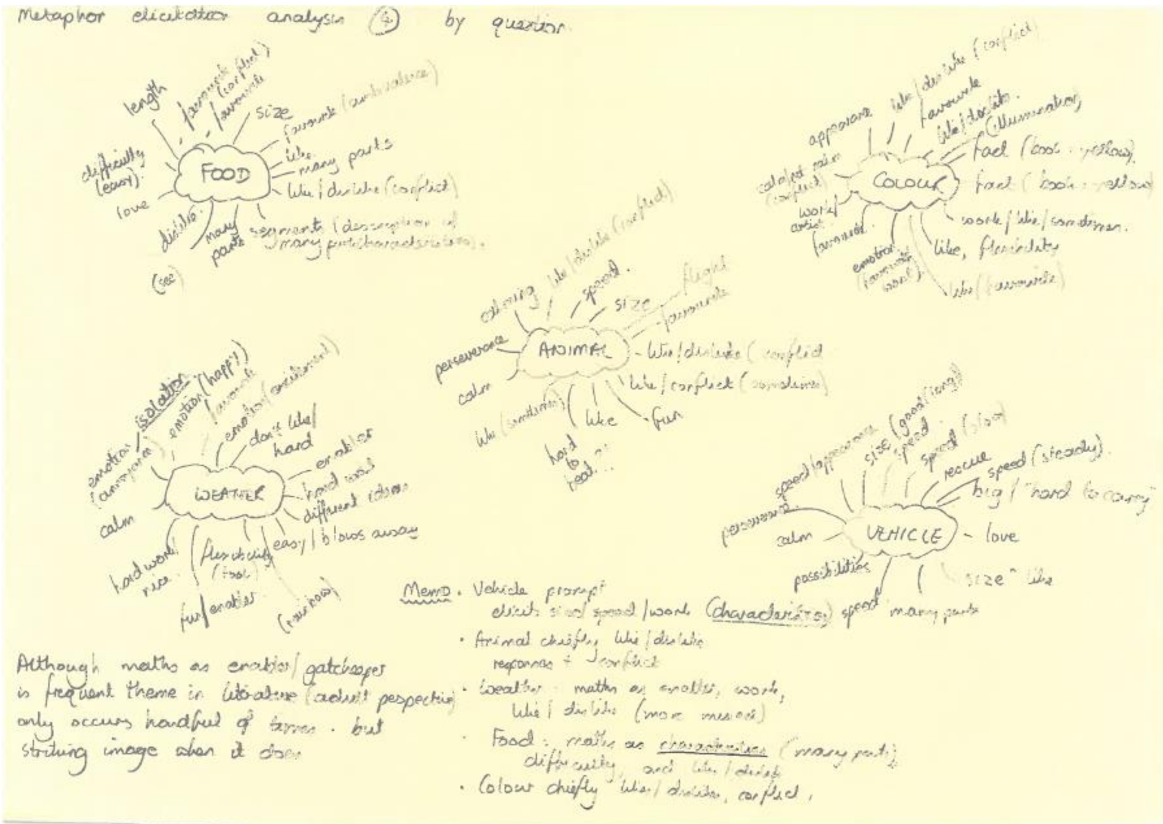
(Fraley
fixed attitude
thinking v
growth.

Emergent questions
Why do you think maths keeps you calm?
Does this link with attainment level?

Re-read
McDonough / Sullivan
Ruffell 1998
Ozgun-Koca

NB [redacted] picture

Analyse image


Metaphor elicitation analysis by question
FOOD
length
size
many parts
like / dislike (conflict)
difficulty (easy)
love
many parts
segment
ANIMAL
calming
speed
size
flight
favourite
perseverance
calm
like / conflict
like
fun
hard to read
COLOUR
appearance
favourite
like / dislike
fact
work / artist
emotion
like, flexibility
WEATHER
emotion / isolation
emotion (happy)
don't like / hard
enabler
hard work
different ideas
easy / blows away
calm
hard work
flexibility
fun / enabler
VEHICLE
speed / appearance
size
speed
rescue
speed (steady)
big / "hard to carry"
perseverance
calm
love
possibilities
"size" like
Memo. · Vehicle prompt
speed / work (characteristics) speed many parts
· Animal chiefly like / dislike
response + conflict
· Weather maths as enabler, work,
like / dislike (more mixed)
· Food: maths as characteristics (many parts)
difficulty, and like / dislike
· Colour chiefly like / dislike, conflict,
Although maths as enabler / gatekeeper
is frequent theme in literature (adult perspective)
only occurs handful of times · but
striking image when it does

Appendix 20 Analysis of relationship wheels – role and verbs

Name	Mum	Dad	Teacher	Brother	Sister	Male friend	Female friend	Friends	Grandma	Grandpa	Cousins	Other teacher	Other
Aimee	Helps		Teaches	Helps / teaches				Help					Shopkeeper asks
Poppy	Helps	Helps	Teaches		Teases								CF – feel good
Skye	Helps	Helps	Teaches		Asks			Help					Shopkeeper
Jasmine		Helps	Teaches					Help				Violin/ swimming teachers help	
Sally	Has faith	Helps	Helps					Help		Helps	Help		
Emily	Tutors	Helps	Helps	Teaches				Help		Helps			
Taylor	Help		Helps	Helps				Help					
Alice			Learns					Help				TA – learnt new skills	CF – makes more confident
Lauren	Teaches		Makes confident	Worries				Make confident				TA – helps Job-share teacher Is kind	CF – makes better
Mackenzie			Learns with	Enjoy				Encourage				New knowledge	CF – made more interesting
Hetty	Helps		Challenges			Worries	Helps	Smile				TA helps	CF – helps
Tilly	Family ask questions and help		Makes confident		Tells / helps			Support / teach				Extra practice Asks questions	
Millie	Has faith		Inspires		Tells		Supports		Well done	Well done		Pushes	HT supports