Affordances for Creativity in Mathematics Learning: A Quintain Multiple Case Study in Upper Primary Education

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ABSTRACT

Through the theoretical lenses of James Gibson's ecological psychology and Anna Craft's 'little-c', everyday creativity, this research attempts to understand the conditions under which affordances for creativity are made available to pupils while learning mathematics. This study characterises creativity in relation to mathematics learning and details why such creativity is so important. From the data generated through a quintain multiple-case study in upper primary education, the study explores pupil opportunities for creativity during mathematics learning and examines the constraints that hinder creativity. The findings illustrate the complex dynamic relationship between the environment, teacher practices and pupil practices, showing how these interrelated factors provide the conditions under which affordances for creativity are made available to pupils during mathematics learning. The study concludes by emphasising the need for pedagogical reform and changes to education policy. New approaches to pedagogy are required to support the development of classroom environments, teacher practices and pupil practices conducive to affordances for creativity during mathematics learning that can be acted on and realised.

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LIST OF ABBREVIATIONS

DfE:	Department for Education
KS1:	Key Stage 1 (pupils aged five to seven)
KS2:	Key Stage 2 (pupils aged seven to eleven)
NACCCE:	The National Advisory Committee on Creative and Cultural Education
NCETM:	National Centre for Excellence in the Teaching of Mathematics
Ofsted:	The Office for Standards in Education
PRQ:	Primary Research Question
RSQs:	Research Sub-questions
SATS:	Standard Assessment Tests
SEN:	Special Educational Needs
STEAM:	Science, Technology, Engineering, Arts, Mathematics
STEM:	Science, Technology, Engineering, Mathematics
TATE:	Thinking At The Edge
Y6:	Year 6 (pupils aged 10 to11 in their final year of primary school)
ZPD:	Zone of Proximal Development

CHAPTER ONE
Introducing the Research Problem

The statement at the heart of the research problem that shaped this study can be found at the beginning of the National Curriculum for Mathematics:

> Mathematics is a **creative** (my emphasis) and highly inter-connected discipline that has been developed over centuries, providing the solution to some of history's most intriguing problems.
>
> (DfE 2013a: 99)

The intention of this study is to explore the conditions under which affordances for creativity are made available to pupils while learning mathematics, and to investigate how these affordances are acted on and realised. This is an important focus of research because, as Craft (2000) argues, enabling pupils to engage creatively with mathematics promotes a learning culture that allows pupils to conjecture, take risks, make mistakes, and explore ideas; in doing so pupils develop confidence in themselves as mathematicians, able to think and act creatively to find resolutions to challenging problems (Craft 2000). The importance of creativity during mathematics learning is supported by many sources in the literature, for example: Skemp (1989); Sririman (2004); Mason et al. (2009); Levenson (2011, 2013, 2015); Du Sautoy (2015). My own interest in mathematical creativity has developed from my background in mathematics education, both in primary schools and universities. I passionately believe that creativity should be embedded into the whole primary school curriculum, and that pupils should experience mathematics as a creative subject.

To put this research in context, at the time of my data collection in 2016, there was considerable attention from central government on mathematics teaching and learning; this attention was not on creativity but on pupil performance and mastery. Ministers were concerned that 'poor maths skills' were hindering the UK's growth and prosperity (Kershaw 2014: para 2). In September 2013 a new Primary Curriculum for England was published, replacing the statutory curriculum first introduced in 1989. The new curriculum for mathematics was part of government policy to reform mathematics education. To support this reform, the government instructed advisors to investigate the teaching of mathematics in countries ranked highest in international league tables, focussing in particular on Shanghai in China and on Singapore (DfE 2014a). This led to a drive to replicate in classrooms in England teaching practices observed in Shanghai and Singapore. Tasked with leading the reform in mathematics education, new Maths Hubs were established across England (DfE 2013b); the main role of these hubs was to support schools in introducing and developing Shanghai and Singapore practices, under the name of the 'Mastery Approach' (DfE 2014b; Boylan 2019). A Shanghai/England teacher exchange programme was created to further support teachers in implementing the mastery programme in their schools (Maths Hubs 2017). In addition, the National Centre for Excellence in the Teaching of Mathematics (NCETM) was given responsibility for providing extensive training for teachers wishing to adopt the Mastery Approach (NCETM 2016a). The key objectives behind this reform were to improve pupils' performance in mathematics and to raise England's position in international league tables (Kershaw 2014; DfE 2014a). Since 2014, over 76 million pounds of funding has been injected into the implementation, development and resourcing of the Mastery Approach (Boylan et al. 2019). As explained by Blausten et al. (2020), there has been widespread support for the mathematics mastery reform, including from Ofsted. The Mastery Approach has become central to mathematics education policy.

In May 2016, new statutory Standard Assessment Tests (SATs) were implemented in Year 2 and Year 6 to assess pupils' mastery of the curriculum. A new Ofsted Inspection Framework was published in 2015 (DfE 2015) so that schools could be held to account for adhering to the statutory requirements, for the quality of teaching, and for their SATs results. The stringent accountability system led to much scrutiny of pupil performance in the tests (Coughlan 2016).

Even before these changes to mathematics education were introduced, Craft et al. (2013: 541) expressed concern that 'curriculum overload and the backwash of high-stakes testing was limiting primary practice' and therefore 'opportunities for nurturing children's creativity might be compromised in the upper end of primary school'. It seemed likely that a renewed drive to improve pupil outcomes in tests would further restrict opportunities for pupil creativity.

Although current practices of mathematics teaching and learning in primary schools are strongly associated with terms such as 'mastery', 'ability' and 'test results' (Pells 2017), the first sentence of the new primary mathematics curriculum describes mathematics as a 'creative' subject (DfE 2013a: 99). This is the only time the word 'creative' is mentioned in the primary mathematics curriculum; the word 'creativity' does not occur at all. After reading the words at the beginning of the curriculum, I began to wonder firstly how they would be perceived and interpreted by practising teachers and secondly how the word 'creativity' is defined when associated with mathematics. My, study evolved from asking the initial questions, what does mathematics as a 'creative and highly inter-connected discipline' (DfE 2013a: 99) look like in practice, and what does the literature on this topic have to say.

These questions helped form the rationale for my study. The rationale is based on three 'sensitizing concepts' (Charmaz 2003: 4) shaped by the literature and by my own experience, both as a lead mathematics teacher in primary schools and as a university lecturer with responsibility for primary mathematics initial teacher education. The sensitizing concepts provided a framework as a starting point for the research (Patton 2002; Bowen 2006). Sensitizing concepts are used only as points of departure from which to study the data, with the understanding that other themes may emerge from the data that dispel the initial concepts (2006). As Charmaz (2003: 4) explains, sensitizing concepts are not hypotheses to be proven but rather 'those background ideas that inform the overall research problem'.

The first sensitising concept was that the subject 'mathematics' offers very different learning experiences to pupils, depending on whether they are taught through a 'relational' approach or through an 'instrumental' approach (Skemp 1989: 2). Those pupils who experience only instrumental mathematics are given rules, procedures and prescribed exercises, many of which rely heavily on memory (Skemp 1989). Those who experience relational mathematics are asked to explore, conjecture and to look for relationships; in doing so, they learn to make connections between the concepts and procedures they have studied (Schoenfeld 1988) and are able to be creative (Skemp 1989).

The second sensitising concept was concerned with mathematical tasks and the way these tasks are framed. As Levenson (2015) explains, tasks are the key medium for promoting pupil creativity during mathematics learning. However, because of the demands of the curriculum and the pressure of statutory tests, I thought it was possible that pupil creativity might not be the primary consideration for teachers when choosing and presenting a task. I was keen to explore if, when, and how pupils are provided with tasks that enable them to engage with mathematics creatively.

The stated intention of the new curriculum is that pupils should experience a mathematics education that 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: 99). The third sensitising concept was based on a notion that words like 'beauty', 'enjoyment', 'curiosity' and 'creativity' are not always strongly associated with mathematics. However, as shown in the literature and emphasised by eminent mathematicians (Devlin 2000; Boaler 2009; Du Sautoy 2019), mathematics can and should be a creative subject.

It is important to emphasise that my study is concerned with 'everyday', 'little-c' creativity' (Craft et al. 2013: 543), creativity of which all pupils are capable when operating in classroom environments where such creativity is understood and encouraged. 'Little-c' creativity is distinguished from 'Big-C' creativity (Craft 2001) that is 'reserved for the great' (Kaufman and Beghetto 2009: 1) and those 'who possess genius' (Banaji and Burn 2007: 62), such as Mozart or Archimedes who have excelled in their field. Craft (2000) describes 'little-c' creativity as the everyday creativity that enables all pupils to engage positively and effectively in problem-solving activities; it allows pupils to be imaginative, to take risks and to pose and respond to questions with intentionality and self-determination (Craft et al. 2013). Craft (2000: 7) explains that 'possibility thinking' is 'at the core of creativity', 'whether collective or individual' (Craft et al. 2007: 2). Possibility thinking involves the discovering, refining and solving of problems and the refusal to be defeated (Craft et al. 2007). Little-c creativity is fostered in classrooms where the 'language of possibility' is encouraged (Craft 2000: 79), where children pose and respond to questions through imagining 'what if' (Craft 2000: 8) and asking 'what can I or we do with this?' (Craft et al. 2013: 359). As Craft et al. (2013: 539) articulate, exploration of possibilities transforms 'what is to what might be' The notion of 'little-c' creativity has been influential in the development of my own conceptualisation of creativity as it occurs during mathematics learning.

Based on my initial review of the literature, it seemed that in order for pupils to experience a sense of enjoyment and curiosity during mathematics learning, and for mathematics to be a truly creative subject, teachers need to take a relational approach to mathematics as described by Skemp (1989). Also important is that tasks offer affordances for 'little-c' creativity (Craft 2001), with pupils given the time and space to puzzle over and explore complex problems, collaborating with each other as they do (Craft et al. 2013). Claxton (2006) emphasises the importance of pupils having time to engage with the process of TATE (Thinking At The Edge). TATE is a 'softer, slower' process of attempting to understand and explain something that needs puzzling over and grappling with before understanding is reached and the problem is solved (Claxton 2006: 352).

Through the theoretical lenses of ecological psychology (Gibson 1986) and 'little-c' creativity (Craft et al. 2013), my intention is to present an exploration of the ways in which affordances for creativity are made available to pupils while learning mathematics. The theoretical framework of James Gibson's ecological psychology combined with Anna Craft's theoretical models of creative pedagogy in an enabling context are particularly suitable for this study; in both theories, learning is characterised as an interactional process between agents and their environment (Greeno 1994), in this case between teachers and pupils operating together in their classroom environments, influenced by the wider school contexts (Burnard et al. 2006; Chappell et al. 2015).

My study aims to fill a gap that exists in current research by contributing new knowledge to the field about the ways in which affordances for creativity are made available to pupils during mathematics learning, and about the constraints that hinder such affordances.

In order to achieve my research aim, my primary research question (PRQ) is:

> **Under what conditions are affordances for creativity made available to pupils while learning mathematics?**

This question will be explored in five case-study primary schools, involving teachers and pupils in Year 6, the final year of primary school in England. In each case the main focus will be on one teacher and four pupils.

The primary research question (PRQ) is broken down into four research sub-questions (RSQs):

1. What are teachers' perceptions of creativity related to mathematics learning?
2. What are the distinctive features of mathematical tasks that promote creativity?
3. What are the constraints on pupil creativity when learning mathematics?
4. How do pupils perceive and engage with different types of mathematical tasks?

The central methodology of this qualitative research is a reflexive, multiple case study, conducted using field research, to enable me get to the heart of the research phenomenon: affordances for creativity during mathematics learning. The intention is to compare the five case-study primary schools to look for themes, commonalties and differences (Stake 2006), and also to relate the participants' perceptions and experiences to the wider culture of education policy and practice (Kvale 2007).

The next chapter provides a literature review of previous work that informed my research design and helped shape my study.

CHAPTER TWO
The Literature Review

2.1 Introduction to the Literature Review

My research design, including my research questions and methodology, was informed by my review of the literature (McGhee et al. 2007). Through familiarity with previous research, this review has helped ensure that my study brings new insights and contributions to the field. I conducted an initial literature review before the data collection, to provide justification for the study by identifying any gaps in the literature (McGhee et al. 2007). However, the review was ongoing throughout the research process as part of my reflexive methodology (Ramalho et al. 2015), detailed in the next chapter.

My literature review includes a wide range of sources, spanning six decades; the earliest was published in 1961 and the most recent in 2021. These sources are by authors speaking from an English context and authors from other countries. While there will be some social, cultural and political differences to take into account, creativity in mathematics learning is not exclusive to one particular educational setting or to one particular country; therefore, it was deemed appropriate to use literature from a range of international contexts.

Overall, the purpose of this literature review is to present a summary and analysis of existing research relevant to my study, to provide context for my own research and establish why my study is needed.

2.2 Defining and Characterising Creativity in Mathematics Learning

As Prentice (2000:145) points out:

> Creativity is a complex and slippery concept. It has multiple meanings, and for anyone writing about creativity in an educational context it is necessary at the outset to acknowledge that an established, precise and universally accepted definition does not exist.

Levenson (2013, 2015) notes that while there is no single, universally accepted definition of creativity, there is agreement among mathematics educators globally, that creativity should be a central aim of mathematics education.

Banaji and Burn (2007) explain that the concept of creativity is composed of a series of rhetorical claims that have emerged out of a mixed background of policy, practice, theory and research. The rhetoric of ‘creativity and cognition’ (Banaji and Burn 2007: 63) provides important insights into creativity during mathematics learning and includes two alternative traditions. The first is related to the internal creativity of individual minds; the second is rooted in Vygotsky’s theory of learning, that creativity is situated within social contexts (Vygotsky 1998). In classroom contexts, the two traditions of the rhetoric of creativity and cognition are closely inter-linked (Banaji and Burn 2007). As Askew (2004) argues, intrapersonal cognitive activity and interpersonal social activity are both important aspects of mathematics learning. The rhetoric of ‘democratic creativity’ is important because it presents an anti-elitist, more equitable view of creativity (Banaji and Burn 2007). Unlike the rhetoric of ‘creative genius’ (Banaji and Burn 2007: 62) that associates creativity with the select few, democratic creativity conceptualises creativity as a phenomenon that should be available to all, not just to the high achievers (Banaji and Burn 2007; Adams and Owens 2015). For a culture of democratic creativity to succeed in schools, all pupils need to be given the learner agency to make choices and decisions about their learning (Adams and Owens 2015). Also important is the rhetoric of ‘ubiquitous creativity’ (Banaji and Burn 2007: 63) concerning ‘everyday creativity’ (Craft 2003); this can be fostered in school children and helps to ensure that pupils are equipped to deal flexibly and effectively with the challenges and changes they face in their day-to-day lives (Banaji and Burn 2007). As argued by Craft (2003: 114), everyday creativity ‘is not for the few, but an everyday phenomenon of everyday people’.

The rhetorics analysed by Banaji and Burn (2007) raise important questions both about the practices of creativity in school settings and about the repercussions of different perceptions and interpretations of creativity linked to mathematics learning. For example, is the nature of creativity democratic and ubiquitous, an entity available to all pupils, or is it only accessible to the exceptionally gifted; is creativity ‘an internal cognitive function’, or is it something that occurs ‘as an external cultural phenomenon’ (Banaji and Burn 2007: 62); or more likely, is a it a complex mix of elements from several different rhetorics? The main criticism levelled against these rhetorics of creativity is that they are in danger of overlooking how creativity can be distinguished from other aspects of learning; it is important to distinguish between ‘good’ pedagogy and ‘creative’ pedagogy (Banaji and Burn 2007: 68).

Skemp (1989) provides an influential conceptualisation of creativity, specific to mathematics learning; he argues that mathematical creativity evolves from relational rather than instrumental learning. He explains instrumental learning as that which ‘consists of the learning of an increasing number of fixed plans, by which pupils can find their way from particular starting points (the data) to required finishing points (the answers to the questions)’ (Skemp 1989: 14). In contrast, he argues that ‘learning relational mathematics consists of building up a conceptual structure (schema) from which its possessor can (in principle) produce an unlimited number of plans for getting from any starting point within his schema to any finishing point’ (Skemp 1989: 14-15). A pupil’s schema plays a fundamental role in creativity; it is defined by Drew and Hansen (2007: 20) as a ‘mental “storage system” which allows learners to make predictions and to retrieve relevant information from past experiences to extrapolate to new situations’. According to Skemp (1989: 74), the building of this cognitive structure involves three modes: personal experience, communication with others, and creativity. ‘A schema is never complete’ and as it grows so the possibilities it provides also grow (Skemp 1976: 15). Emphasising the importance of creativity, Skemp explains that during mathematics learning ‘creativity’ refers to mental creativity in which pupils use ‘existing knowledge to create new knowledge’ (Skemp 1989: 77). He writes:

> Mathematics, like the arts, has an aesthetic quality of its own which gives much pleasure to those who can experience it. It is good if we can put children in the way of experiencing this pleasure.
>
> (Skemp 1989: 77)

Skemp (1989: 79) asserts that creativity is founded on structured knowledge that ‘involves intelligent learning, not habit learning’; he defines intelligent learning as learning that has adaptability at its heart. Intelligent learning allows the learner to reach an intended goal by many different routes. This type of learning leads to the construction of the mental abilities to recognise mathematical patterns and to appreciate mathematical relationships; when engaging in such learning, the learner is required to understand rather than to simply memorise (Skemp 1989). In contrast, habit learning is rote learning; these habits are persistent and are unlikely to afford adaptability or flexibility. However, it is important to note that Skemp (1989) clearly distinguishes between fluency and habit learning. Skemp (1989) affirms that fluency is essential for mathematics learning and that, unlike habit learning, fluency is determined by the ways in which the pupils make use of their knowledge and how adaptable and flexible they are in doing this. For example, if a pupil is asked to calculate 25 x 19 x 4 and understands that multiplication is commutative, their fluency should help them to notice that it is much easier to calculate by reordering as 25 x 4 x 19. Fluency supports creativity because it provides cognitive space for creative thinking.

Sriraman (2004) also identifies fluency as key to mathematical creativity, together with flexibility and originality. Flexibility refers both to a pupil’s use of different strategies and representations and to the way a pupil responds when experiencing a learning challenge or meeting a learning obstacle (Sriraman 2004). Sriraman (2004: 20) defines mathematical creativity ‘as the ability to produce novel or original work’ and also ‘the process that results in unusual and insightful solutions to a given problem, irrespective of the level of complexity’. Creativity, he explains, is fostered through problem solving and problem posing (Sriraman 2004; Van Harpen and Sriraman 2013).

Schoevers et al. (2019) claim that the definition of mathematical creativity provided by Sriraman (2004) is incomplete as it restricts creativity to problem solving and problem posing; they argue that creativity during mathematics learning can also occur through creative thinking, supported by teacher-pupil dialogue (Schoevers et al. 2019). Though dialogue, pupils can gain insights into mathematical ideas that are new to them. Schoevers et al. (2019) revise the definition provided by Sriraman (2004); they define creativity in mathematics as ‘the cognitive act of combining known concepts in an adequate, but for the pupil new way, thereby increasing or extending the pupil’s (correct) understanding of mathematics’ (Schoevers et al. 2019: 324).

Claxton (2006: 351) provides a definition of creativity as ‘soft creativity’ in which pupils are encouraged to think at the edge (TATE). ‘TATE offers a set of methods for encouraging people to engage in the slow, hazy thinking that is so often an essential precursor to full-blown creativity’ (Claxton 2006: 359). The notion of TATE provides insights into the complex cognitive processes that occur when pupils think creatively while learning mathematics. Mathematical creativity does not require ‘the acquisition of new information so much as the intelligent use of the rich impressions and information one already has’ (Claxton 2006: 360). Similarly, McWilliam (2009: 282) discusses the significance of ‘a propensity for epistemological agility’. According to McWilliam (2009), epistemological agility is fundamental to creativity in mathematics learning, promoted by tasks that are accessible but only through much effort and perseverance; such tasks require pupils to experience ‘the grey of knowing’ before new insights emerge (McWilliam 2009: 286).

In their study of mathematical creativity, Leikin and Lev (2013: 195) emphasise the importance of imagination stating, ‘knowledge is a necessary condition for a person to be creative, while having imagination is a necessary condition for knowledge construction’. Imagination is also identified as a key feature of possibility thinking, with Craft et al. (2013: 543) stating that the ‘role of imagination in creativity appears undisputed’. In his essays on creativity, Vygotsky (2004: 9-10) affirms that imagination is fundamental to all acts of creativity:

> … in actuality, imagination, as the basis of all creative activity, is an important component of absolutely all aspects of cultural life, enabling artistic, scientific, and technical creation alike. In this sense, absolutely everything around us that was created by the hand of man, the entire world of human culture, as distinct from the world of nature, all this is the product of human imagination and of creation based on this imagination.

Vygotsky (1987) perceives imagination to be equally important in both the arts and in mathematics and the sciences; all these disciplines require a school curriculum that facilitates the development of both a child's imagination and their abstract thinking. Children need tasks and tools that stimulate imaginative activities; 'creating an imaginary situation can be regarded as a means of developing abstract thought' (Vygotsky 1978: 103).

Being capable of abstract thinking is critical for mathematics learning (Watson 2008; Aharoni 2014). In her study of creativity across the primary curriculum, Craft (2000) reports that mathematical thinking is a specific way of thinking that is abstract, made up of figures and symbols; mathematics has its own language which is predominantly about representing and manipulating relationships. When learning mathematics, pupils need to have building blocks of existing knowledge and an understanding of previous concepts in order to be able to explore them and to think mathematically (Craft 2000).

Together with abstract thinking, 'possibility thinking' supports creativity during mathematics learning (Craft 2000: 244); 'possibility thinking includes problem solving as in a puzzle, finding alternative routes to a barrier, the posing of questions and the identification of problems and issues' (Jeffrey and Craft 2004: 83). When engaging creatively with a task that presents a problem, children pose questions and then try ideas and strategies to respond to these questions in order to reach a resolution (Craft et al. 2013).

For the purposes of my study, creativity during mathematics learning is defined as the ways in which pupils use their existing knowledge to create new knowledge and new ideas (Skemp 1989). This is achieved through creative thinking (Schoevers et al. 2019), through question posing and question responding (Craft et al. 2013), through problem solving and problem posing (Silver 1997), and through teacher-pupil and pupil-pupil dialogue (Littleton and Mercer 2013; Schoevers et al. 2019; Cremin and Chappel 2019). My study is concerned with 'little-c' creativity, defined by Craft (2000) as the everyday creativity in which pupils use a range of creative skills, in particular their imagination (Vygotsky 2004), to engage in possibility thinking. In this study, creativity in mathematics learning is also considered to be the ‘soft’ creativity defined by Claxton (2006) as the process in which pupils think at the edge (TATE) and engage in creative thinking as they make connections with mathematical knowledge already learnt, so that they can use this knowledge in a different way (Skemp 1989; Levenson 2011; Schoevers et al. 2019).

2.3 The Creative Press, Product, Process and Person

Some literature identifies four key elements of creativity, referred to as the four ‘Ps’: the creative press; the creative person; the creative product; and the creative process (Cropley et al. 2019: 2). This notion derives from Rhodes (1961: 305) who defines creativity as ‘the phenomenon in which a person communicates a new concept’. However, the person or group of people who generate a new concept, both individually and collectively, do not do so in a vacuum; the ‘ecological press’ can influence creativity both positively and negatively by the way in which it affects the creative mental activity of the individuals involved (Rhodes 1961: 307).

2.3.1 The Creative Press

‘The press’, used to conceptualise the relationship between individuals and their environments, can either ‘inhibit or potentiate creativity’ (Garcês et al. 2016: 170). As detailed in the next chapter, both theories underpinning my study are concerned with the environment. Gibson (1986) explains how an environment can both afford and constrain an agent’s activity, while Burnard et al. (2006) highlight the importance of an enabling context for supporting possibility thinking. Classroom norms, organisation, resources and relationships will all have an impact on whether the press inhibits or potentiates creativity (Garcês et al. 2016). In a school setting, much of the control of the environment is in the hands of teachers, influenced by their leadership teams and by external policy. The relationships between teachers and pupils and between pupils themselves all influence the complex process ‘in which agents participate cooperatively with other agents and with the physical systems that they interact with’ (Greeno 1994: 341).

Sriraman (2004) and Schoevers et al. (2019) identify a supportive environment as beneficial to mathematical creativity. While, there is no definitive list of elements that combine to create a supportive learning environment, there are some clear indications of positive features. It is important that teachers have high expectations of all pupils' capability of creative activity, with value placed on learner agency to support their creativity (Craft 2014); in addition, teachers anticipate ambiguity and uncertainty as pupils engage with unfamiliar tasks, supporting learning with strategies such as open questioning and prompts (Shaughnessy 1991; McWilliam 2009). It is important that teachers respect pupil ideas and imaginative thinking, with pupil contributions encouraged, listened to and valued (Shaughnessy 1991; Schoevers et al. 2019). Pupils are able to express their ideas without fear of making mistakes (Hannula 2020) and feel safe to participate because they feel 'valued and respected for their intellect, creativity and passions' (Hébert et al. 2014: 101). The 'language of possibility is valued' and pupils feel able 'to speak up when they are not certain' (Craft 2000: 79). In a supportive environment pupils are able to position themselves as active co-constructors of their learning (McWilliam 2009; Cremin and Chappell 2019); they are able to 'make choices, act on their intentions, and take actions in their efforts to develop their own stance in the learning context' (Vaughn 2020: 116). Such environments provide context for 'rich learning' opportunities and are conducive to pupil creativity (Vaughn 2020: 116).

2.3.2 The Creative Person

2.3.2.1 Characteristics of a Creative Person

A review of previous research undertaken by Leikin and Pitta-Pantazi (2013: 162) suggests 'curiosity, intuition, tolerance for ambiguity, perseverance, openness to experience, broad interests, independence and open-mindedness are some of the commonly accepted characteristics of creative individuals'.

Craft et al. (2013) offer insights into important learning tools and skills that enable a person to engage with possibility thinking, in particular imagination, questioning, self-determination, the ability to collaborate and the willingness to take risks. Sriraman (2004) also highlights risk-taking, motivation and persistence, together with the resilience to tolerate confusion and uncertainty, as important personal qualities that aid mathematical creativity.

However, my research is concerned with the ways in which affordances for creativity can be made available to all pupils. The characteristics and attributes that support individuals in being creative are not considered fixed; instead they can be nurtured and developed. Everyday creativity can appear in many different forms and in a wide variety of contexts. As Helson (1996: 303) argues:

> Creativity takes place in diverse contexts, and we cannot expect the personalities of people who create in different domains to be the same, or to differ in the same ways from comparison subjects. We have seen that they are not and do not.

Articulated in the rhetoric of ‘the creative genius’ (Banaji and Burn 2007: 63), there are studies that associate creativity with those of exceptional ability, often measured by scores in IQ tests, for example: Sririman (2004) and Leikin and Lev (2013); however, this rhetoric is not helpful to my study. As Silver (1997: 75) asserts, while ‘creativity is often viewed as being associated with the notions of “genius” or exceptional ability’, it is more much productive for teachers to regard creativity ‘as an orientation or disposition toward mathematical activity that can be fostered broadly in the general school population’. This view is supported by Qian et al. (2019: 1), who affirm that creativity is not exclusive ‘to a certain group of people like geniuses’, rather, it is a necessity for all; ‘creativity along with critical thinking, communication and collaboration’ are ‘four major 21st century skills’ (Qian et al. 2019: 1). It is therefore important that all children are perceived as capable of creativity during mathematics learning, possessing talents and capabilities that are not fixed but that can be developed (Craft 2000).

Dweck (2006) identifies two mindsets that help determine how an individual’s talents and abilities develop: fixed and growth. Individuals with fixed mindsets perceive their talents and abilities to be unchangeable (Dweck 2006), holding the view that some people have a talent for mathematics and some do not. As Carey et al. (2019: 6) report, ‘many people mistakenly hold the belief that maths is a skill we are born with, rather than one you can learn'. Those with a fixed mindset support the metaphor that some are born with a 'maths gene' that others simply do not possess (Devlin 2000: 4). Alternatively, a person can have a growth mindset which means that with effort, practice and determination, combined with good teaching and input from others, they can develop and improve their talents and abilities (Dweck 2006). A growth mindset develops as part of a learning journey, requiring practice, hard work and perseverance; learning hurdles have to be revisited and new strategies tried, sometimes with help from others (Dweck 2015, 2016). By helping children to develop a growth mindset, teachers encourage flexibility, resilience and collaboration (Dweck 2015, 2016), all of which support a child's creativity (Burnard et al. 2006; Leikin and Pitta-Pantazi 2013; Craft et al. 2013).

2.3.2.2 Agency, Affect and Self-efficacy

Burnard et al. (2006) and Craft et al. (2013) identify learner agency as a necessary feature of pupil creativity. For the purposes of this study, learner agency is broadly defined as an individual's capability and opportunity to act, combined with their willingness and motivation to do so (Manyukhina and Wyse 2019). During mathematics lessons, learner agency allows pupils to take different paths to achieve common outcomes (Clay 2014); it is important that 'tasks are not rigidly structured but allow space for children to participate in different ways, with different resources' (Dyson 2020: 126).

However, there is little to be gained by giving pupils learner agency if they do not use it, either by choice or because they lack the tools to do so. Self-efficacy beliefs play an important role in how pupils use learner agency; they also influence how pupils position themselves in the classroom and how they perceive themselves in relation to others (Bandura 2001; Mercer 2011). Self-beliefs about learning tend to be associated with an individual's previous learning experiences combined with their self-constructed beliefs about each curriculum subject and their perceived ability to succeed in any particular subject; therefore, self-efficacy beliefs can vary across subject domains (Mercer 2012). Much research has been undertaken to explore affect and mathematics learning (McLeod 1994). The affective domain concerns a pupil's attitudes, beliefs and emotional reactions to mathematics and the influence this affect has on both their engagement in learning and on their performance (Hannula 2012). It is widely recognised that mathematical thinking is 'influenced much by affective features' such as anger, frustration, shame, anxiety and boredom (Hannula 2020: 23).

Therefore, although learner agency is considered a necessary factor in facilitating creativity in mathematics learning, empowering pupils with learner agency is not sufficient; pupils also need a strong sense of self-efficacy and the motivation to act on the agency, influenced by a positive inclination towards mathematics learning. Gresalfi et al. (2012: 250) use the term 'effectivity' to conceptualise an individual pupil's ability to realise the learning affordances made available to them by the environment they operate in. While pupils must perceive and be attuned to both the affordances and the constraints that exist in their learning environment (Gibson 1986), the realisation of affordances is dependent on the pupils' intentions and motivations (Gresalfi et al. 2012); a particular task might make the realisation of an affordance possible, but certainly does not make it compulsory (Gresalfi et al. 2012). Improving a pupil's sense of self-efficacy, so that they recognise the gains and rewards of their effort and hard work, can positively affect their motivation and their willingness to exercise learner agency (Bandura 2000; Mercer 2011).

There is also a close relationship between self-efficacy and a growth mindset (Dweck 2006). When provided with challenging, unfamiliar tasks that promote creativity, requiring the reordering and connecting of mathematical concepts already learnt, all pupils are likely to experience moments of ambiguity, frustration and self-doubt (Claxton 2006; Martinsen 2011; Leikin and Pitta-Pantazi 2013). During these moments of difficulty that can result in negative affect, a growth mindset can equip pupils to tolerate ambiguity and to persevere. When pupils engage with challenging mathematical tasks, the affective domain may move from the negative to the positive as ambiguity is dealt with and a positive solution is achieved (Beltrán-Pellicer and Godino 2019). It is also likely that as pupils become more accustomed to engaging with the creative process, they will develop meta-cognitive/self-regulatory skills that enable them to understand that ambiguity is part of the process (Mercer 2011; Conradty and Bogner 2020). However, if pupils regularly engage with challenging tasks that cause frustration, without ever reaching the stage where positive solutions are reached, it is likely that their willingness to persevere will decrease. As Beltrán-Pellicer and Godino (2019: 14) report, ‘a negative affective attitude to mathematics’ is often the consequence of a succession of ‘negative affective’ mathematical learning experiences.

2.3.3 The Creative Product

Leikin and Pitta-Pantazi (2013: 163) argue that it is generally recognised that creative behaviour is manifested in a creative outcome or product because creative products are the creative ideas converted into ‘tangible form’. Sririman (2004) defines a creative product as the discovery of a new contribution to the domain that is then accepted by the field and disseminated over time. However, while exceptional individuals in the field of mathematics may discover a new theorem to add to what is already known about mathematics, this type of creative outcome is extremely unlikely in a primary school setting.

Levenson (2011) argues that the products of creativity that occur in school mathematics lessons take the form of new mathematical ideas; however, these are not ideas that are new to the domain, but ideas that are new to the pupils that think of them. A creative product in mathematics learning can manifest itself in ‘original ideas that are personally meaningful to the students and appropriate for the mathematical activity being considered’ (Levenson 2011: 217). In much of the research concerning creativity, the terms ‘novel’ and ‘unique’ are used interchangeably; however, in practice there is a subtle difference in their meaning, with novel meaning ‘new’ and unique meaning ‘one of a kind’ (Levenson 2013: 271). The type of creative product that emerges during mathematics learning in primary schools can differ from other subjects. In domains such as art, music or English the creative product may be one of a kind; in mathematics learning, the solutions, ideas and outcomes produced can be new to the pupils who think of them but are seldom one of a kind and are rarely new to the discipline as a whole (Levenson 2013).

For the purposes of this study, creative products are conceptualised as the mathematical ideas that are new to the pupils that generate them (Silver 1997; Levenson 2011); creative products are also the positive outcomes achieved by pupils from reordering and connecting mathematical concepts already learnt in a new way, often in an unfamiliar context (Skemp 1989; Leikin 2009; Levenson 2011; Schoevers et al. 2019).

2.3.4 The Creative Process

The creative process that occurs during mathematics learning is complex. Van Harpen and Sriraman (2013: 202) suggest that ‘a large part of the creative process remains a grey area so to speak, particularly the role of the unconscious in the incubatory period before any insight (or the Aha! moment) occurs’.

Claxton (2006: 351) discusses the process of TATE ‘in which hazy, pre-conceptual ideas are given time to unfold into novel forms of talking and thinking’. The preliminary thoughts and initial explorations that occur in creative learning, that pupils are often asked to record on ‘scrap paper’, should be valued and encouraged (Claxton 2006: 353). The drafting of ideas, and initial notes and sketches are a very important part of the creative process; rather than discarded as messy first drafts, pupils’ first thoughts and early ideas should be kept as part of the learning journey and regarded as a key aspect of the creative process. These preliminary thoughts often lead to ‘the gradual emergence of an idea, or a way of thinking or talking, that gives a novel purchase on an interesting and previously intractable problem’ (Claxton 2006: 352). The process of TATE begins with the question: ‘What is this whole thing (whatever it is) about?’ (Claxton 2006: 354). Instead of expecting a quick answer or any dramatic ‘Eureka’ moments, the question has to be puzzled over and explored ‘slowly and patiently’ (Claxton 2006: 353). TATE is also ‘a highly collaborative and interactive process’ (Claxton 2006: 358) that promotes discussion and consultation, as children help each other to notice things. Children need time to share their preliminary thoughts and to discuss and reflect on why some ideas were dead ends, while others were more fruitful. ‘Successive drafts’ should be celebrated as much as the best and final version of children’s work (Claxton 2006: 353). By recording and discussing jottings, sketches and ideas, children develop meta-cognitive skills as they begin to understand the creative process (McAuliffe 2016).

Van Harpen and Sriraman (2013) explore the beginning, middle and end phases of the mathematical creative process, arguing that it is the middle phase that is most difficult to understand and therefore of particular interest. The beginning phase involves working on a mathematics problem using logic, mathematical reasoning and trying different strategies (Van Harpen and Sriraman 2013); this stage often includes ambiguity and confusion. If a solution is not reached during the first phase, taking a break from the problem is recommended; this is when the middle, incubation phase begins (Sriraman et al. 2013). The end phase is demonstrated through the new ideas and solutions to the problem that are generated and then verified; it is the complex cognitive processes that occur during the middle phase when illumination eventually begins to take place that is more obscure (Van Harpen and Sriraman 2013). During the middle phase, allowing an incubation period has been identified as important in supporting successful creative problem solving; this is because incubation often precedes illumination (Sriraman et al. 2013). McWilliam (2009: 291) describes this period of the creative process as ‘the grey of unresolvedness’, as pupils mull over a problem, searching for clues. Periods of rest can help generate new insights, often resulting in moments of illumination as the mind continues to puzzle over the problem subconsciously (Sriraman 2004; Van Harpen and Sriraman 2013; Sriraman et al. 2013). This finding has implications for teaching as it suggests that when pupils are working on challenging, unfamiliar mathematics problems, returning to the problems after a break or lunchtime, or making time for pupils to continue to work on unresolved problems during subsequent lessons, may support them in achieving positive outcomes.

During the creative process, it is important that pupils have the opportunity to collaborate so that they can share ideas and thoughts. Group collaboration may help spark illumination and lead to resolution, as ideas are shared and distributed (Glăveanu 2014; Harris and De Bruin 2018).

The complex creative process enables pupils to transfer already acquired mathematical knowledge from a familiar schema, to help them solve unfamiliar, open-ended problems and challenges (Kraft 2019).

2.4 Creative Pedagogy

As detailed above, Rhodes (1961: 307) uses ‘the four Ps’ to explore human creativity. However, in a classroom environment pedagogy is clearly one of the biggest influences on pupil creativity. Therefore, in relation to creative learning I feel there should be five ‘Ps’, with the fifth being creative pedagogies.

While there is no ‘one-size-fits-all’ approach to creative pedagogies (Cremin and Chappell 2019: 2), there are seven interconnected factors that they have in common: ‘generating and exploring ideas; encouraging autonomy and agency; playfulness; problem-solving; risk-taking; co-constructing and collaborating; and teacher creativity’ (Cremin and Chappell 2019: 27). A key aspect of creative pedagogies is the way learning is co-constructed between teachers and pupils; teachers step-back to provide pupils with some ownership of their learning and step-in to engage in dialogue with pupils, providing support and scaffolding when required (Craft 2013; Cremin and Chappell 2019).

McWilliam (2009) distinguishes between three different approaches to pedagogy. A teacher can position him/herself as ‘sage-on-the stage’, ‘guide-on-the-side’ or ‘meddler-in-the-middle’ (McWilliam 2009: 281). A sage-on-the-stage imparts information that a pupil memorises and then regurgitates for tests; the guide-on-the side steps in too quickly with explanations and solutions if pupils show signs of confusion or stress when a correct answer does not immediately come to mind. When pupils are given ill-defined, open-ended mathematics tasks intended to promote pupil creativity, the meddler-in-the-middle approach is considered the most effective (McWilliam 2009); this is because meddlers-in-the-middle avoid stepping in too soon to protect pupils from the learning challenges that lead to creative thinking. The meddler-in-the-middle approach facilitates an ‘active interventionist pedagogy in which teachers are mutually involved with students in assembling and/or disassembling knowledge' (McWilliam 2009: 288); it is also an inclusive approach that assumes that all pupils, not just the highest attainers, can engage in the creative process. Teachers who position themselves as meddlers-in-the-middle, provide hints, prompts and suggestions to encourage pupils to persevere through cognitive struggles (McWilliam 2009); they give all the support necessary without actually providing pupils with the answers, and in doing so they help pupils to act on and to realise affordances for creativity.

Craft et al. (2012) apply McWilliam's (2009) concept of meddler-in-the-middle to the theory of possibility thinking, exploring how practitioners working with fifteen four year olds in a nursery setting balance the act of stepping back and stepping forward. Craft et al. (2012) conclude that the meddler-in-the-middle pedagogy values pupil agency, providing sufficient time and space for children to direct their own learning and to command their own creativity. They also highlight the dilemmas for teachers 'around the extent of stepping back, and how far to enable children's agency to guide the amount of time and space appropriate' before stepping in (Craft eta al. 2012: 25). Teachers have a difficult balancing act to manage that varies depending on the nature of the tasks and the needs of different groups of pupils.

Creative pedagogies contrast sharply with pedagogical practices in which mathematics is 'shaped by social constructions of ability' (Swanson et al. 2017: 172). When the assumption is made that mathematics 'is purely an intellectual exercise', pupils are often labelled by 'ability' (Swanson et al. 2017: 172-173); those of high ability are expected to perform well, while those of low ability are expected to underachieve or fail. Creative pedagogies can help reconstruct mathematics as a subject in which it is anticipated all pupils can participate and succeed, making mathematics learning more equitable, inclusive and socially just (Boaler 2009; Das et al. 2011; Levenson 2013; Craft et al. 2013; Luria et al. 2017; Swanson et al. 2017). As Boaler (2009: 2) articulates:

> 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 … When the real mathematics is taught instead – the whole subject that involves problem solving, creating ideas and

> representations, exploring puzzles, discussing methods and many different ways of working, then many more people are successful.

2.4.1 Peer Collaboration

An important aspect of creative pedagogy is pupil collaboration. Creativity in mathematics learning occurs both as an intrapersonal process of individual mental activity and as an interpersonal, social process in which creative ideas are built and distributed within a group (Askew 2004; Banaji and Burn 2007; Glăveanu 2014; Cremin and Chappel 2019). During mathematics learning, creativity can evolve through peer collaboration when pupils explore, question and puzzle together to reach a positive solution (Craft et al. 2013). Creativity can be both co-constructed and distributed as ideas are shared and built collectively (Sawyer 2003; Glăveanu 2014; Cremin and Chappel 2019). Seeds of creative thinking that originate in the minds of individuals can grow and expand when reflected on and discussed collaboratively in the social context of a classroom.

However, while it is argued that peer collaboration can support and foster creativity, it is also recognised that the quality of collaborative learning relies on several factors. As stated by Warwick et al. (2010: 353): ‘Research into pupil collaboration and dialogue in groups suggests that there are numerous elements that contribute to success’. One important aspect is how teachers model expected group behaviour and productive dialogue; pupils need to be actively engaged in discussions about the rules of collaboration and what their individual roles and responsibilities might be (Warwick et al. 2010). The ways a teacher scaffolds expectations and rules of behaviour are key to constructive peer collaboration (Warwick et al. 2010).

A classroom ethos conducive to peer collaboration is one that enables pupils to develop their social skills and to become more adept at sharing their knowledge (Williams and Sheridan 2010). Williams and Sheridan (2010) conducted a study involving interviews with 66 children and 25 teachers from schools in Sweden, to explore the conditions conducive to pupil collaboration and constructive competition during learning. They report: ‘equality among group members' is 'a strong motivational force for constructive competition to develop' (Williams and Sheridan 2010: 346). They define equality 'as having respect for each other's knowledge, opinions and ways of acting' (Williams and Sheridan 2010: 346). It is important that pupils perceive themselves as having an equal position in the group, aware of their own strengths and expertise and respectful of those of others (Williams and Sheridan 2010). Collaboration is unlikely to succeed if one or more members of the group regard themselves as superior to others and attempt to dominate. Equality among group members is also important for pupils' social identity and their self-efficacy beliefs (Bandura 1994). If they perceive themself as a respected and equal member of the group, a child will be more likely to develop a stronger sense of self-efficacy. A sense of belonging promotes participation, decision-making and the confidence that positive outcomes can be achieved (Bandura 1994; Cremin and Chappell 2019). Constructive competition also contributes to peer collaboration, acting as a motivator and encouraging pupils to persevere when challenged or under pressure (Williams and Sheridan 2010). Williams and Sheridan (2010: 347) argue that for group collaboration to be productive, the learning task should be 'meaningful', 'interesting' and 'challenging'.

Another important aspect of peer collaboration is 'cognitive apprenticeship' (Dennen and Burner 2008: 426), based on Vygotsky's theory of the Zone of Proximal Development (ZPD). Vygotsky defines ZPD as: 'the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers' (Vygotsky, 1978: 86). Through cognitive apprenticeship, 'learners are challenged with tasks slightly more difficult than they can accomplish on their own and must rely on assistance from and collaboration with others to achieve these tasks' (Dennen and Burner 2008: 427). By allowing pupils to collaborate, explore and support each other, creativity can be distributed among the group (Sawyer 2003; Glăveanu 2014).

2.4.2 Mathematical Tasks

As Watson et al. (2013: 12) affirm, tasks are considered ‘the mediating tools for teaching and learning mathematics’; of central importance is ‘how tasks are used pedagogically’ to support learning. During mathematics lessons, affordances for learning are largely determined by the nature of the tasks and the ways in which the tasks are framed (Gresalfi et al. 2009). Teacher expectations, dialogue, artefacts, and the structure and organisation of the lesson all help to determine how the tasks are framed (Gresalfi 2012). Tasks also need to be both accessible and suitably challenging; if the prior learning of some pupils has not equipped them for the chosen tasks, or if the tasks lack the challenge required to extend the capabilities of others, negative affect such as anxiety or boredom can occur (Hannula 2020).

For my study, I use ‘task’ in a broad sense to include all of the following: the artefacts that a teacher employs to demonstrate and model mathematics; anything a teacher uses to engage interactively with students, including resources and materials; and anything a teacher asks pupils to do related to their mathematics learning. ‘Task’ is also taken to mean all the learning-related activities that pupils decide to undertake themselves (Watson et al. 2013).

Creativity in mathematics learning requires tasks that foster exploration, the development of abstract thinking, and regular opportunities for both convergent and divergent thinking. Through divergent thinking pupils generate creative ideas by pursuing different paths and by using a variety of strategies to investigate all the possible solutions to a problem (Aljughaiman and Mowrer-Reynolds 2005; Levenson 2013). Haylock (1997) reports that when tasks have multiple solutions, some of these solutions should be obvious to the pupils in order to build their confidence, while others should really challenge their thinking. The more challenging solutions may trigger a process of TATE (Claxton 2006) and may involve the middle, incubation period of the creative process before illumination takes place and new ideas and solutions are generated and verified (Sriraman 2013; Van Harpen and Sriraman 2013).

Both Land (2013) and McAuliffe (2016) argue that in STEM subjects (Science, Technology, Engineering and Mathematics) the focus tends to be on developing pupils' convergent thinking, while it is the arts subjects that focus more on divergent thinking. Convergent thinking in mathematics is prompted by tasks with one right answer, whereas divergent thinking is facilitated through tasks that require the learner to search for and explore multiple solutions (Haylock 1997; McAuliffe 2016). Land (2013) argues that high-stakes tests that assess pupils' speed to single correct answers encourage the use of tasks that promote convergent thinking. Creativity during mathematics learning requires both convergent and divergent thinking (McAuliffe 2016). 'Divergent thinking alone does not result in true creativity; convergent thinking is needed to sift through and evaluate the confusion created by divergent thinking' (McAuliffe 2016: 3). As Craft (2000:7) argues, 'possibility thinking, which is the basis of creativity, is involved in both convergent and divergent thinking'.

Devlin (2000) emphasises the abstract nature of mathematics and explains that the reason many people find mathematics difficult, or even incomprehensible, is because they are unable to cope with mathematical abstractions; therefore, children need tasks that support their developing understanding of abstraction (Aharoni 2015). Mathematicians enjoy playing with and exploring problems; these problems invariably reflect 'the discipline's primary strength: abstraction' (Aharoni 2014: 6). According to Aharoni (2015) children can learn the beauty of mathematics through an investigational approach that is interactive, experimental and involves discussion. He argues that the 'beauty of mathematics lies in creative activities' (Aharoni 2015: 196).

While much emphasis has been placed on the role of unstructured, unfamiliar tasks to engage pupils in the creative mathematical process, it is important to recognise that mathematics teaching has several different purposes and the types of tasks required for each one are different. Pupils need tasks that develop their procedural fluency, including an understanding of mathematical structures and relationships (Skemp 1989; Mason et al. 2009); they also require knowledge of arithmetical computations, described by Aharoni (2015) as boring exercises needed to access the creative tasks. Bell (1993) stresses the importance of tasks that enable pupils to firmly and securely connect new concepts with knowledge already learnt. Mathematical fluency and conceptual understanding enable pupils to build the complex cognitive structures, fundamental to mathematical creativity. Mason et al. (2009: 11) explain:

> By providing pupils with the opportunities to explore structures and mathematical relationships, pupils construct cognitive structures and develop schemas that are crucial to mathematical creativity.

As Levenson (2013) reports, there are a multitude of different mathematics tasks for teachers to choose from and many different reasons why they make their choices. For example, a teacher could be motivated by pupil outcomes in mathematics test results; alternatively, or possibly additionally, the desire to instil in their pupils an enjoyment of and a curiosity in mathematics could be the primary motive (Pring 2003). Some teachers may feel pulled in two directions, wishing to make mathematics more creative while feeling constrained by a culture of 'performativity' (Ball 2003: 216; Perryman 2006: 148). The term 'performativity' is used in the literature to explain the relationship between accountability and school practices (Ball 2003). Performativity describes the ways the performance of teachers and schools are judged and how this accountability influences behaviour and decision-making. Perryman (2006: 158) argues that 'performativity in education can lead to a sense of deprofessionalization as teachers can feel that they are performing in order to demonstrate their competence'. Performativity can limit what teachers perceive as possible to do in terms of pedagogy and task design.

2.5 Pedagogy, Accountability and Creativity

As presented in Chapter One, the first sentence of the National Curriculum for Mathematics describes mathematics as a 'creative and highly inter-connected discipline' (DfE 2013a: 99). However, the literature indicates that for the past two decades there has been tension between creativity and accountability in the delivery of mathematics curricula. In England, pupils in Year 6 are required to take externally marked tests (SATs) to assess their knowledge and understanding of the mathematics curriculum. In the current tests much emphasis is placed on speed, methods and procedures, with additional marks awarded for efficient methods. It seems that finding room for creativity in a curriculum driven by a standards agenda poses difficulties for many schools (Galton 2000; Boaler 2009; Jones 2010; Craft et al. 2013; Craft et al. 2014; Brill et al. 2018; Ogier and Eaude 2019). Maisuria (2005) states that government interventions of standardisation, rubber-stamping and testing have all but killed the place for creative pedagogy, playful exploration and creative practices in the classroom. Dobbins (2009) reports that while teachers can see the value of creativity as a vehicle for making learning more enjoyable and more inspiring, they feel that external policy places far more importance on the delivery of curriculum content and on measurable outcomes than on creativity.

In England during the first decade of this century, there was a government drive to establish more creative practices in primary education (Craft 2003; Troman et al. 2007; Craft et al. 2014). National initiatives were introduced to persuade schools to integrate creativity into the curriculum. In 1999, the National Advisory Committee on Creative and Cultural Education (NACCCE) was established, led by Sir Ken Robinson on behalf of the government; this was followed by the ‘Excellence and Enjoyment’ initiative (DfES 2003); then in 2009 the Rose Review added further support for creativity to be a key aim of the primary curriculum. Although creativity was promoted as part of education policy during this period, Craft (2003) emphasises the difficulties of fostering pupil creativity against a backdrop of a ‘centrally controlled pedagogy’ (Craft 2003: 124). She argues that everyday creativity can only ever be regarded as a ‘good thing’ (Craft 2003: 113) and should not be determined or controlled by educational policy; it should always be unlimited. While highlighting the problems posed by centrally controlled practices, Craft et al. (2014: 3) report that during the first decade of this century (‘the creative decade’) the drive for creativity to be integrated into the curriculum led to a more inclusive, ubiquitous view of creativity; opportunities for creative practices inspired many teachers to ‘reconstruct pedagogy’ (Craft et al. 2014: 4).

In 2010 a change in government resulted in changes to education policy, bringing an abrupt termination to the previous decade of creativity in English

primary schools (Craft et al. 2014). During the second decade of this century, incorporating creativity into the curriculum was left to the discretion of individual schools, and primarily to the judgement of individual headteachers.
As the Creative Industries Federation (2017: 3) notes:

> England is the only nation in the United Kingdom not to have a national plan that ensures that all children and young people are offered a high quality cultural and creative education.

Craft et al. (2014: 2) state: ‘Unlike the previous decade’s emphasis on children’s curiosity and agency and valuing arts and partnership, emphasis on knowledge and attainment was now foregrounded’. Nevertheless, some schools still managed to include some creative pedagogical practices. In particular, creative practices continued in schools with high regard for learner agency to promote creative thinking, and with high expectations of pupils’ capabilities to engage in skillful creative activity (Craft et al. 2014). However, as reported by Ogier and Eaude (2019) there are many schools in which the accountability system has all but eradicated any chance of creative pedagogy: ‘Under a political agenda that forces schools to battle in a ‘survival of the fittest’ educational jungle, competition and accountability are top priorities for leadership teams’ (Ogier and Eaude 2019: 3).

2.6 Why is Creativity During Mathematics Learning Important?

Many of those renowned in the world of mathematics, both in mathematics education and in mathematics as a discipline, perceive and characterise mathematics as the creative discipline the National Curriculum for England declares it is (DfE 2013a). To name a few: Jo Boaler, Anne Watson, Marcus Du Sautoy, Andrew Wiles, Bharath Sriraman, Ron Aharoni, Grace Alele-Williams and Esther Levenson. However, these eminent professors and mathematicians have reached the top of their field; they have succeeded in mathematics and they experience it as a creative subject. Unfortunately, the literature indicates that during school mathematics lessons many pupils are not sharing this experience of mathematics as a creative subject (Skemp 1989; Watson 2008; Boaler 2008; 2009; Ogier 2019). Many children and young people suffer with maths anxiety, which Carey et al. (2019: 54) report ‘may be a major factor of suppressing maths performance in many children and ultimately keeping them away from mathematics related careers’. Watson (2008) claims that while a minority of pupils are ‘introduced to authentic mathematical activity such as is practised by professional mathematicians’ (Watson 2008: 3) most pupils are not taught as if they are apprentices to adult mathematicians. At its worst, ‘school mathematics can be a form of cognitive bullying that neither develops students’ natural ways of thinking in advantageous directions, nor leads obviously towards competence in pure or applied mathematics as practised by adult experts’ (Watson 2008: 3).

There are two very good reasons why pupils should experience mathematics as a creative subject and why they should be given the opportunities to develop their creative skills. Firstly in the here-and-now as part of their rights as children, pupils should experience an education that promotes exploration and discovery. The Committee on the Rights of The Child ‘insists upon the need for education to be child-centred, child-friendly and empowering … the goal is to empower the child by developing his or her skills, learning and other capacities, human dignity, self-esteem and self-confidence’ (UNICEF 2001: para 2). Children should be challenged, inspired and enthralled by mathematics through working in a positive environment where they develop the confidence to take risks, conjecture and explore without the fear of making mistakes; they should be given tasks that allow them to puzzle, use their creative skills and on reaching a resolution, experience excitement and a sense of satisfaction (Claxton 2008; Boaler 2009). It is important that children experience mathematics as a creative subject in the here-and-now so that they can become confident mathematicians, positively disposed to the discipline.

The second reason why children should experience mathematics as a creative subject is to support and enhance their future lives. As Hodgen and Marks (2013: 3) explain: ‘Mathematics is becoming ever more important to our lives. It is at the heart of everyday technology from our smartphones and tablets to the increased automation in daily tasks from driving to shopping’. This view is supported by Du Sautoy (2011: xi) who writes, ‘mathematics really is at the heart of all that we see and everything we do’.

Kraft (2019: 5) explains why developing creative skills that ‘support cognitively demanding processes’ are crucial for so many types of employment:

> These skills allow individuals to classify new problems into cognitive schema and then to transfer content and procedural knowledge from familiar schema to new challenges. Examples include writing computer programs, directing air traffic, engineering dynamic systems, and diagnosing sick patients.

While much emphasis is placed on the importance of success in STEM subjects for pupils’ future employment prospects, there seems to be little effort made by governments to reform the pedagogical approaches to these subjects (Morrison and Bartlett 2009). As Richard Dawkins (2002: para 28) articulates:

> What matters is not the facts but how you discover and think about them: education in the true sense is very different from today's assessment-mad exam culture.

The late Sir Ken Robinson, who led the NACCCE committee (1999) and believed passionately in the importance of nurturing creativity in young people, spent much of his career trying to initiate curriculum reform. He believed that an education system that ‘makes creativity the cornerstone of its teaching’ (Ward 2009: 1) is crucial in securing Britain’s success in the 21st century global economy. Many experts in education with a forward thinking view of pedagogy advocate prioritising the four ‘C’s: creativity, collaboration, critical thinking and communication (Harari 2018), arguing that these four ‘Cs’ have become fundamental lifelong skills.

The late Professor Anna Craft, whose influential work on creativity is widely respected, argued that as patterns of life in the twenty first century become more and more unpredictable, with the world and the future full of uncertainties, it seems increasingly important that pupil creativity is supported and nurtured through education (The writings of Anna Craft, cited in Chappell et al. 2015).

2.7 Conclusion to the Literature Review

Many previous studies have focussed on creativity; however, I have been unable to find any that focus specifically on conditions under which affordances for creativity are made available to pupils while learning mathematics, using the same research focus and methodology that I have chosen. On nearing the end of my thesis, I returned to the literature to search for studies undertaken from 2018-2021; the only recent study I could find that bears similarity to mine is Schoevers et al. (2019). However, this was a single case study conducted in the Netherlands, with a specific interest in **creative thinking skills** during mathematics learning. The study had a different research focus and the methods of data collection did not include pupil interviews.

Other studies with connections to mine are those of Gresalfi et al. (2012) and Craft et al. (2013). However, while Gresalfi et al. (2012) did explore affordances for mathematics learning, their study, situated in secondary school classrooms in the United States, was not concerned with affordances for mathematical creativity. Although, Craft et al. (2013) did focus on creativity in learning in upper primary classrooms, their interest was in creativity across the primary curriculum, not specifically creativity during mathematics learning.

Therefore, by casting greater light on the conditions under which affordances for creativity are made available to pupils while learning mathematics, the intention of this study is to fill a gap in current research and to provide a new contribution to the field

The next chapter focuses on the theoretical and methodological frameworks.

CHAPTER THREE
The Theoretical and Methodological Framework

3.1 The Theoretical Framework

My study is framed by two different theories: Gibson's theory of ecological psychology with its key concepts of affordances and constraints (1986), and Craft's theory of 'little-c' creativity (Craft 2000) and its related concepts of possibility thinking and enabling contexts (Burnard et al. 2006). These two theories were selected to underpin my study because the concepts of both 'affordances' and 'little-c creativity' are fundamental to my research problem.

The notions of affordances and constraints are central to Gibson's theory of ecological psychology (Gibson 1986). The term 'affordance' was created by Gibson and is conceptualised as the interaction between an agent and their environment (Gibson 1986: 127). 'The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill' (Gibson 1977: 127). For an affordance to be acted on, an agent must be attuned to the affordances and constraints that exist within the environment (Gibson 1986). The construct of 'affordances' has been 'widely used in mathematics education' (Monaghan and Mason 2012: 132), and has been applied and developed by researchers such as: James Greeno (Greeno 1994); Anne Watson (Watson 2004); Jo Boaler (Boaler 1999); and Melissa Gresalfi (Gresalfi et al. 2012). The theory of ecological psychology enables researchers to gain insights into 'the complexities' of classroom environments and the activity that takes place during mathematics learning (Watson 2004: 25). Through the lens of ecological psychology, researchers are able to consider 'the affordances of various aspects of the classroom systems' and the ways these affordances are acted on (or not) by participants (Gresalfi et al. 2009: 56).

The Gresalfi et al. (2012) application of ecological psychology to mathematics learning has been influential in informing my study. Gresalfi et al. (2012: 250) explain, 'the extent to which an affordance can be acted on has to do with one's effectivities, an individual's ability to realize those affordances'. Gaps in mathematical knowledge, misconceptions, the absence of learning resources, lack pupil of motivation and low self-efficacy can all constrain a pupil's ability to act on affordances. Individual pupils working on the same task, in the same classroom environment, will perceive and act on the affordances in different ways, depending on their individual effectivities (Gresalfi et al. 2012). It is important that effectivities are not seen as fixed and that actions can be taken to try to remove the constraints preventing a pupil from benefitting from available affordances. A pupil's perceptions and actions will also be influenced by what Gresalfi et al. (2012: 252) refer to as 'intentions'; intentions include the classroom culture, norms and expectations. Gesalfi et al. (2012: 253) conceptualise this activity as the 'dynamic intention', the interplay between intentions and pupil effectivities that determines how the affordances are realised and the nature of the learning that takes place. To illustrate how Gibson's theory of ecological psychology can be applied to a learning environment, Gresalfi et al. (2012: 252) created a model of 'the dynamic relations between affordances, effectivities, and intentions'.

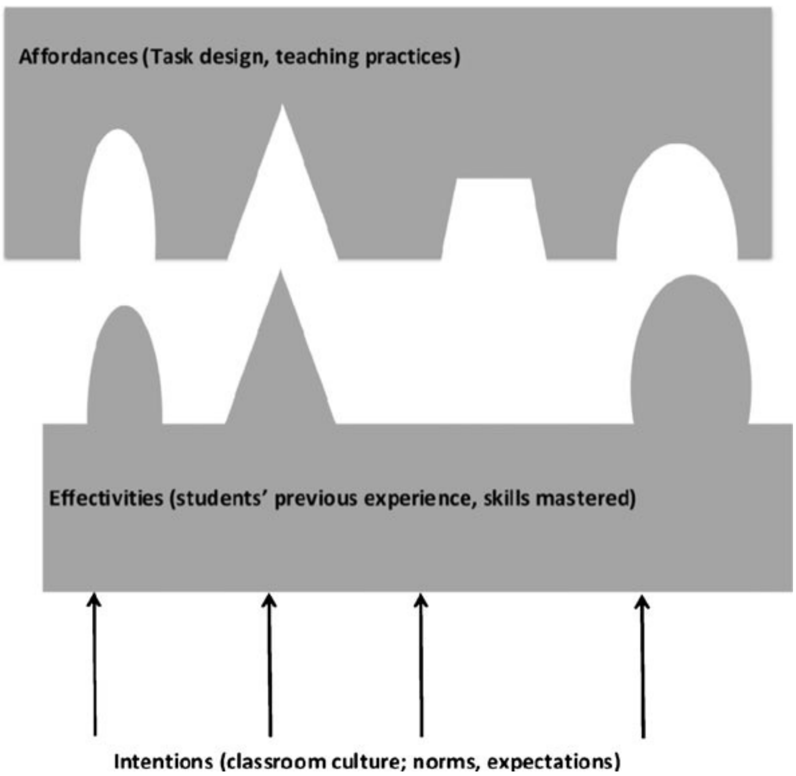


Figure 1: A model for the dynamic relations between affordances, effectivities, and intentions (Gresalfi et al. 2012: 252)

My theoretical framework was also shaped by Craft's theory of 'little-c' creativity and its key concept of possibility thinking (Craft et al. 2013). Therefore, the Burnard et al. (2006: 257) model of pedagogy and possibility thinking developed by Craft and her team (Craft et al. 2013; Chappel et al. 2015) also provided an influential starting point for my study (see Figure 2). This model conceptualises the dynamic interplay between learning and teaching in an 'enabling context' (Burnard et al. 2006: 257).

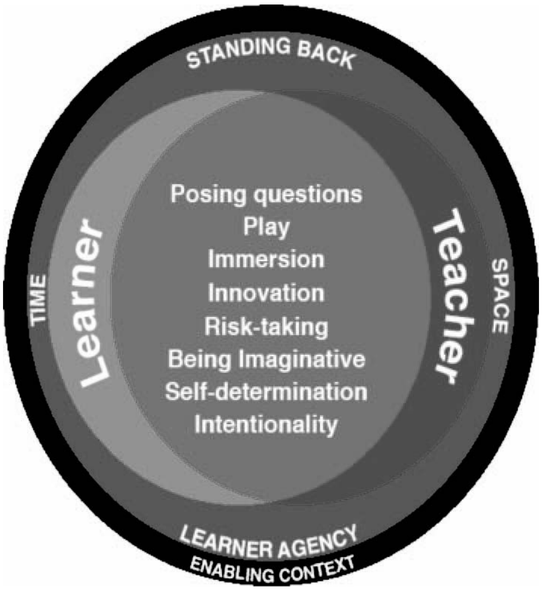
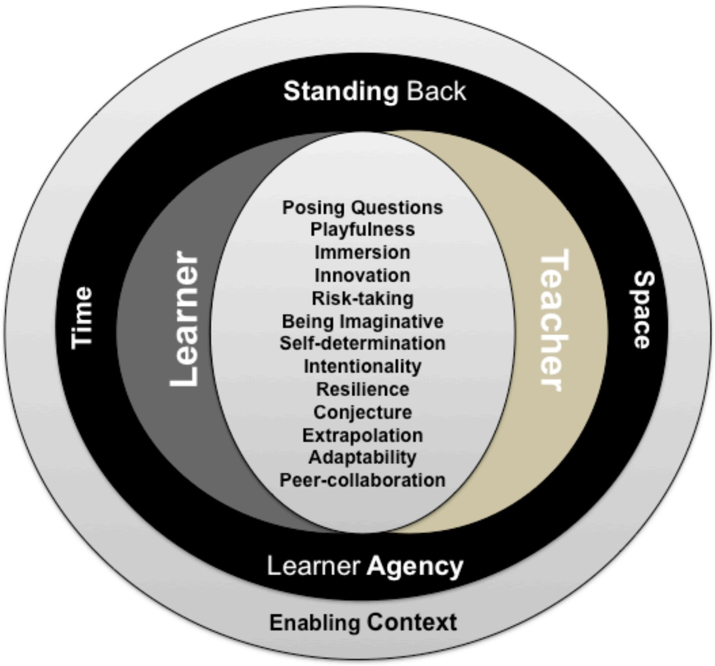


Figure 2: Model of pedagogy and possibility thinking (Burnard et al. 2006: 257)

However, this model was originally constructed from research conducted in school settings with pupils aged three to seven (Burnard et al. 2006). As detailed later in this chapter, I adopted a reflexive approach to my methodology and research design. One important aspect of reflexivity is the careful appraisal of theoretical models used to shape the research (Neufeld 1994; Alvesson and Skolberg 2009); therefore, any models used as a starting point for my study have been critically evaluated. As a result, based on my review of the literature, I adapted the Burnard et al. (2006) model to represent a model of pedagogy and possibility thinking specifically suited to mathematics learning of pupils aged ten and eleven. I tweaked and also added to some of the creative skills listed in the centre of the model as features of possibility thinking: 'play' was changed to 'playfulness'; 'peer-collaboration', identified as an emerging feature of possibility thinking by Craft et al. (2013), was added; 'resilience', 'conjecture', 'extrapolation' and 'adaptability' were also added, based on my literature review of skills considered essential for creativity in mathematics learning (Skemp 1989; Craft 2000; Claxton 2006; Boaler 2009). Initially, I pondered over how to conceptualise 'innovation'. Marcus Du Sautoy (professor of mathematics at the University of Oxford) defines creativity as 'the drive to come up with something that is new and surprising and that has value' (Poole 2019: para 1). He describes his own mathematical discoveries as "Eureka!" moments (Orr 2009: para 5). I decided that for the purposes of this study, innovation concerns pupils' own "Eureka" moments when they think of or discover mathematical ideas that are new and valuable to them, even though it is extremely rare that their ideas are new to the field. In mathematics learning in Year 6, innovation is closely linked to extrapolation, which requires each pupil to use their schema to interpret, organise and reuse knowledge. The key difference between extrapolation and innovation is that innovation is part of the thinking process that enables pupils both to extrapolate and to decide what to do with the information that they have extrapolated. My revised model, specific to mathematics learning, is displayed below.

Figure 3: Revised model of pedagogy and possibility thinking (Burnard et al. 2006)



Linking the revised model of pedagogy and possibility thinking (Burnard et al. 2006) to my theoretical framework of ecological psychology (Gibson 1986), the enabling context is the school environment, made up of both 'the classroom setting and in the wider school environment' (Burnard et al. 2006: 258). The ethos, values and relationships of the wider school environment (Burnard et al. 2006) influence the 'complex socially organised activity' (Greeno1994: 336) that takes place in each classroom environment. Within each classroom, the interplay between teaching and learning influences the ways in which affordances for creativity during mathematics learning are both made available to pupils and constrained (Watson 2004).

3.2 The Methodological Framework

3.2.1 Reflexivity

A reflexive methodological approach was adopted for this study (Alvesson and Skoldberg 2009), with an understanding that being reflexive is different from being reflective; reflexivity requires greater introspection and the need to continually challenge assumptions and beliefs (Coghlan and Brannick 2005; Ryan 2012). As stated by Keso et al. (2009: 53): 'Reflexivity challenges a researcher to understand the ways by which her ontological and epistemological presumptions guide decision making and the choices she makes throughout the whole research process'. The importance of a reflexive methodology is that the researcher has a heightened awareness of their own role in making interpretations of the data (Alvesson and Skoldberg 2009).

> Reflexivity is a hallmark of excellent qualitative research and it entails the ability and willingness of researchers to acknowledge and take account of the many ways they themselves influence research findings and thus what comes to be accepted as knowledge.
>
> (Sandelowski and Barroso 2002: 222)

The decision to take a reflexive methodological approach for this study was an important one; it helped ensure that any tensions between my roles as a doctoral researcher, teacher educator and primary school teacher were recognised and addressed. Developing my researcher identity became a crucial part of my doctoral journey. Prior to the main data collection, I had attended taught modules and completed assignments that included a focus on research methods and conducting research ethically. I also completed a pilot study that greatly contributed to strengthening my research identity (see section 4.5).

By taking a reflexive approach I have endeavoured to conduct this study with integrity and rigour, to produce results that are reliable (Bazeley 2013).

3.2.2 Field Research

The ontological assumption of ecological psychology is that learning occurs through interaction between agents and their environment; it is not possible to separate the two. The nature of this interaction is unique to each social setting; therefore, to gain an understanding of individual contexts, it is necessary to use a methodological approach that allows direct contact with participants in their natural settings (Weinberg 2001: 8). Appreciating the importance of experiencing the social situations first-hand, the methodology selected for this qualitative study was field research (Weinberg 2001). With its roots in anthropology, field research is a method of collecting qualitative data for which it is essential that the researcher goes into the field to directly observe the phenomenon within its social settings (Weinberg 2001). The extent to which researchers immerse themselves in the settings varies depending on what is appropriate in terms of research questions, the number of participants, time and resources (Blackstone 2012). During the data collection process, I was not fully enough immersed in each of the five school settings, nor in each setting long enough, for this to be an ethnographic study. However, at certain times ethnographic methods of researcher participation were used to collect the data (Kramer and Adams 2018). As explained in Chapter Four, during the pupil interviews I was a full participant.

My study has been guided by the six principles of field research provided by Kapiszewski et al. (2015: 26-27), ‘engagement with context, flexible discipline, triangulation, critical reflection, ethical commitment and transparency’. (However because a reflexive methodology is central to this study, the principal of critical reflection goes beyond reflective to a process of reflexivity, acknowledging the need to challenge assumptions and interpretations and to be aware of my role as the researcher in the research process.) Kapiszewski et al. (2015: 27) argue that these six principles underpin good field research and in doing so enable fieldwork to make an important contribution to ‘knowledge accumulation and theory generation’.

During field research, the researcher is involved in many different tasks, moving backwards and forwards, ‘shifting from collecting data to analysing them; from analysis back to research design; and from research design on to data collection, and on to analysis again’ (Burgess 1990: 22). Therefore, careful monitoring of the research as it progresses is crucial (Kapiszewski et al. 2015). To help monitor my research, I kept a research diary; ideas were recorded in the diary from the beginning as I started making decisions about the research design and the methodology. As explained by Nadin and Cassell (2006), a diary is a useful research tool during a field study. Keeping a diary was part of my engagement in reflexivity, as a process of continually evaluating my assumptions (Coghlan & Brannick 2005).

One possible limitation of my field study, highlighted by Burgess (1990), is that it was conducted in a social setting familiar to me. A research project usually begins with a literature review and through this review a research idea is formed; however, the idea is sometimes shaped by the personal experiences of the researcher (Burgess 1990). For this study, the research idea was generated both by a review of the literature and by my own experiences as a teacher educator and as a primary school teacher. Most researchers have personal experiences of educational settings; for me this is certainly the case, with twenty years’ experience as a primary school teacher, ten spent as a lead teacher for mathematics, and twelve spent teaching Year 6. More recently, I have had seven years experience as a lecturer in primary education, with responsibility for the mathematics training of primary trainees on initial teacher education courses; during these seven years, I made visits to over fifty different primary schools. Because of my familiarity with primary school settings, it was important to avoid making assumptions based on personal experience (Burgess 1990). This is why I chose three synthesizing concepts as a starting point for my study rather than beginning with a hypothesis that I set out to prove (Charmaz 2003). Hypotheses, particularly when working in a familiar social setting, can lead to misconceptions and assumptions (Burgess 1990). Because of the possible tensions between my role as a teacher and my role as a doctoral researcher, I took a reflexive approach to help me avoid making false assumptions based on my own past experiences (Alvesson and Skoldberg 2009).

3.2.3 Multiple Case Study

My field research took the form of a quintain multiple case study, as defined by Stake (2006), involving five cases. While each of the cases in my sample had its own stories to tell, the focus of my study was on the phenomenon of interest as it was exhibited in those cases; the fives cases were bound together as examples of a phenomenon (Stake 2006). As Yin (2009: 18) explains:

> A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.

I selected case study research because I wanted to be able to explore the phenomena of interest in depth, in real-life contexts (Farquhar 2012). I chose a multiple case study to enable me to analyse the data both within each individual situation and also across situations to look for and understand the similarities and differences (Stake 1995; Yin 2009). A case study method enables the researcher to explore 'a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information' (Creswell 2013: 97). My units of analysis were five cases, made up of five Year 6 teachers and five groups of four Year 6 pupils (Yin 2009); these were the important stakeholders in my research who consented to be my cases (Farquhar 2012). Each single case was a bounded system of one teacher and four pupils operating in their classroom environment, influenced by wider school culture and policy. The five cases also formed a multiple bounded system through which I was able to explore answers to my research questions (Yin 2009) and get to the heart of the phenomenon of interest. To conceptualise this phenomenon, Stake (2006: 4) creates a new term – 'quintain'. The quintain is ‘the holding company or umbrella’ for the cases; the single cases are bound together as ‘members of a group’, known as ‘the quintain’ (Stake 2006: 6). Single cases are sought as examples to enable an in-depth study of the quintain. Stake (2006: 6) explains:

> Multiple case studies start with the quintain. To understand it better we study some of its single cases – its sites or manifestations. But it is the quintain we seek to understand. We study what is similar and different about the cases to understand the quintain better … The ultimate question shifts from “What helps us understand the case?” towards “What helps us understand the quintain?”

A multiple case study is problematic in that the researcher has to consider the two different essential aspects, the single case and the quintain, as both are ‘worth knowing’ (Stake 2006: 7). This can present an epistemological dilemma because a decision has to be made about how much available time to spend focussing on each single case (Stake 2006). During a multiple case study, it is also important to question: ‘what is more important for understanding the quintain – that one thing is common to the cases or that another is dissimilar about them?’ (Stake 2006: 7). The five cases in my study each presented a multi-layered view that included interpretation of external policy, individual school policy and context, plus individual profiles of participating teachers and pupils. Each case was important both because of its uniqueness and because of the commonalities between it and the other four cases. Gaining an understanding of the quintain required an in-depth analysis of cross-case categories to look for themes, commonalities and differences (Stake 2006).

The quintain at the heart of this multiple case study is ‘affordances for creativity during mathematics learning’.

The next chapter will focus on the data collection and the methods used to collect the data; it will also provide a rationale for my decisions regarding these methods and procedures.

CHAPTER FOUR
The Data Collection

4.1 Overview

As presented in the previous chapter, my research is a multiple case study that seeks to get to the heart of the quintain (Stake 2006): affordances for creativity during mathematics learning. I focus on five cases, allowing rich data to be collected and analysed in depth. Stake (2006) argues that ideally multiple case studies should include more than three but fewer than ten cases; this is big enough to allow analysis of cross-case categories to look for themes, commonalities and differences without presenting the researcher with an unmanageable amount of data.

In each of the five cases, the main focus was on one Year 6 teacher and four Year 6 pupils. In total, data was collected from interviewing and observing five teachers and twenty pupils from five different primary schools.

Before conducting the main study I carried out a pilot study involving a Year 6 teacher and a group of four Year 6 pupils in one school. I wanted to test the reliability of my data collection tools and to evaluate my techniques as a researcher. More detail about the pilot study is given in section 4.5.

4.2 Ethical Process

Permission to conduct this research was given by the University of Leeds' Faculty Research Committee (reference: AREA 13-173), with the University of Leeds' Research Ethics Policy adhered to throughout the study. After reading the participants' information letters (see Appendix 1), all participating teachers and parents of participating pupils gave their informed consent; the pupils also gave their informal consent before any data were collected. The participants were made aware of their right to withdraw from the project at any point and anonymity of participants was ensured.

Ethical considerations and limitations of this study are explained and reflected on in detail during this chapter; they are interwoven into the discussions about the choice of both the data collection methods and the selection of the sample, linked closely to the research methodology and to the research questions.

4.3 Gaining Access

As Burgess (1990) points out, the ways in which the researcher gains access to research participants in school settings is important. Clearly, a school study should not be undertaken without the permission of the headteacher. However, participants may not have the same level of trust in a researcher who gains access through someone who holds a position of authority in the school (Burgess 1990); therefore, my point of contact was the Year 6 teachers. The teachers then discussed the project with their headteachers and informally asked for permission to participate in the research. Once an informal expression of interest had been given, I contacted the headteachers with an information letter and a formal request for access.

My role as a teacher educator provided contacts with a large number of primary schools. This made it easier for me to select a sample of information-rich cases (Patton 1990) that would potentially provide some answers to my PRQ. Purposive sampling was used (Patton 2002; Etikan et al. 2016) so that I could select participants who were likely to allow in-depth analysis of the research objectives. As Etikan et al. (2016: 2) explain, purposive sampling is often used in qualitative research:

> … the researcher decides what needs to be known and sets out to find people who can and are willing to provide the information by virtue of knowledge or experience. It is typically used in qualitative research to identify and select the information-rich cases for the most proper utilization of available resources.

The criteria used to select the sample were that all teachers were interested in the focus of research, all teachers were willing and able to be both observed and interviewed, and all participants were in Year 6. All schools selected were within a 40-mile radius of my location, making travel to schools manageable; these were urban schools in the north of England. Twenty teachers were contacted by email; of these, eight were keen to take part and six were given permission to do so by their headteachers. These six cases formed the sample for my multiple case study, five for the main and one for the pilot study. Profiles of each case in the main study are provided in section 4.6.

Gaining access to classrooms for research can be difficult. Because teachers are observed so often for reasons such as performance management or as part of an inspection process, many are keen to avoid further observations, even for research purposes (Hancock 1997). Therefore, gaining the trust of the teachers was hugely important. I was aware that I was putting extra pressure on them by making demands on their valuable time. As articulated by Hancock (1997), teaching is an extremely demanding job and it can be very difficult for teachers to find the time and energy to engage with research. My hope was that the teachers would benefit from their participation in terms of their own professional development. I was very fortunate that six busy teachers were prepared to engage with my research to make this study possible.

4.4 The Methods of Data Collection

Four different methods of data collection were chosen: a scrutiny of key documents to help build individual case profiles; semi-structured interviews with both teachers and pupils; classroom observations; and a review of pupils' mathematics workbooks. I chose these methods as the most appropriate for answering in depth my PRQ: **Under what conditions are affordances for creativity made available to pupils while learning mathematics?**

As explained in Chapter One, the PRQ is broken down into four RSQs:

1. What are teachers' perceptions of creativity related to mathematics learning?
2. What are the distinctive features of mathematical tasks that promote creativity?
3. What are the constraints on pupil creativity when learning mathematics?
4. How do pupils perceive and engage with different types of mathematical tasks?

Used together, the interviews and observations provided the opportunity to build a rich picture of the quintain (Stake 2006). The interviews allowed me to explore perceptions, while the observations enabled me to witness actions and behaviour first-hand in the social settings of interest, as they were acted out (Burgess 1990).

Data was also collected before and during the schools visits to enable me to construct profiles of the schools and participants; this data provided important background information and contextual details about each individual case.

In addition, having access to the pupils' mathematics workbooks allowed me to review work they had already completed in Year 6 and provided further insight into their everyday mathematics learning.

Table 1 below provides details of the data collection sets and the order in which they were collected. (Year 6 has been abbreviated to Y6.)

Table 1: The Data Collection Sets

Data Collection Sets				
Order	Method	Participants	Collection Method	Purpose
First Step	Collect and read documentation and reports about participating schools: Ofsted reports, school websites, pupil data	None	Online	To build profiles of the individual cases
Second Step	Individual introductory meetings and first episode of teacher interviews	Five Y6 teachers	Audio recordings Field notes	To gain fully informed consent To build relationships To plan the timescale To create teacher profiles To collect data about the teachers' perceptions of mathematics teaching and learning To select the groups of 4 pupils
Third Step	First and second lesson observations – two lessons in each school Review of pupil workbooks	Five teachers and Five Y6 classes	Audio recordings Field notes Pupils' written work	To observe classroom norms and the classroom environment during mathematics lessons before researcher intervention To begin to explore the RSQs To build a picture of pupils' previous mathematics learning
Fourth Step	Second episode of teacher interviews	Five Y6 teachers	Audio recordings Field notes	To collect data about the teachers' perceptions of lessons 1&2 and also of mathematics and creativity To gain further insight into RSQ 1 To plan the third lesson observations
Fifth Step	First episode of pupil interviews	Five groups of four Y6 pupils	Audio recordings Field notes	To collect data about the pupils' perceptions of mathematics learning and to collect data on how they perceive and engage with different tasks To gain further insight into RSQs 2,3&4
Sixth Step	Third lesson observation – one in each school	Five teachers and five Y6 classes	Audio recordings Field notes Pupils' written work	To answer all four RSQs in depth To collect more data about teachers' perceptions of mathematics and creativity
Seventh Step	Third episode of teacher interviews	Five Y6 teachers	Audio recordings Field notes	To gain further insight into the teachers' perceptions of RSQ1, 2&3
Eighth Step	Second episode of pupil interviews	Five groups of four Y6 pupils	Audio recordings Field notes Pupils' work	To gain further insight into RSQs 2,3&4

4.4.1 The Semi-structured Teacher Interviews

Three teacher interviews were conducted in each school, one before and one after the first two classroom observations and another one after the third classroom observation. Semi-structured interviewing is considered an important and useful method in the conduct of fieldwork (Denzin and Lincoln 2008), allowing researchers to explore the perceptions and behaviour of participants. As Mason (2002) asserts, semi-structured interviews generate the type of rich data that cannot be gained through social surveys and questionnaires. There is no 'one-size-fits-all' approach to semi-structured interviews (Mason 2002: 64). Unlike rigidly structured interviews, semi-structured interviews allow the probing and diverting of questions to promote a conversation between the researcher and the respondent that leads to deep and meaningful dialogue, closely related to the research questions; these purposeful conversations permit the understanding of 'the world from the subject's point of view' (Kvale and Brinkmann 2009:1). Using semi-structured interviews, contextual knowledge was created through interaction between the researcher and the respondent, allowing each teacher's perceptions to be explored in depth (Mason 2002).

The first interviews took the form of an introductory meeting during which the aims and intentions of the study were explained and a timescale agreed on. Teachers were also asked to sign a participants' agreement form. These meetings provided the opportunity to begin to build relationships of trust and understanding so that each teacher felt comfortable and confident about participating in the research. I emphasised to the teachers that they could withdraw from the project at any time, if they felt they wanted to. I also explained to them that while I had previously been a primary school teacher and now worked at a university, my role in their school was as a researcher; I impressed on them that they were doing me a favour by engaging with my research. In my role as a researcher I was keen to explore their perceptions and experiences and to understand their stories (Kvale 2007); I considered them to be experts in their field.

During this introductory meeting, I also conducted the first interview; the table below provides an outline of the questions asked.

Table 2: Questions for the First Teacher Interviews

Questions	Probes
IQ1 How long have you been teaching?	1.1 Do you have any additional roles of responsibility within school?
IQ2 In comparison with other National Curriculum subjects, how much do you enjoy teaching maths?	2.1 Which aspects of maths do you most enjoy teaching and why? 2.2 Which aspects of maths do you least enjoy teaching and why? 2.3 What are the greatest challenges? 2.4 What/who has most inspired you in your teaching of maths?
IQ3 How is the mathematics curriculum structured and delivered in your school; are there any current changes underway in response to the new curriculum?	3.1 What was the reasoning behind this? 3.2 Is there some flexibility to allow for teacher choice? 3.3 What are the greatest restraints on the ways you teach mathematics? 3.4 Has the school had any INSET to support the delivery of the new maths curriculum?
IQ4 How do you choose/design the mathematical tasks?	4.1 What factors influence your choice? 4.2 Which resources are most useful in supporting these choices? 4.3 Would the availability of additional resources make a difference to your task choices?
IQ5 How many pupils are there in your class and how wide is the attainment range across the class? How are tasks differentiated for different pupils?	5.1 Can you give an example of how tasks are differentiated? 5.2 How are pupils grouped during maths lessons? 5.2 What sort of support is available for lower attaining pupils? 5.3 How are higher attaining pupils challenged?
IQ6 Thinking about the three National Curriculum aims (fluency, reasoning, problem solving), how do you plan/organise lessons so that you can try to cover and achieve these aims?	6.1 Could you talk me through how problem solving is included in your curriculum planning? 6.2 Do some pupils do more problem solving than others? If so why? 6.3 Do some children find problem solving more difficult? If so, why? 6.4 There is a lot of talk now about a

	mastery approach to maths. What does 'mastery' mean to you?
1Q7 If the SATs tests in Year 6 didn't exist, would you teach maths differently? If so, how?	
IQ8 I need to ask you to choose a group of 4 pupils for me to focus on during the lesson observations.	8.1 What is the current maths attainment of these pupils? 8.2 Why would this group of four be interesting to focus on?

During the first interview, I explained to the teachers that for the first two lessons observations I would like to see the lessons they had already planned as part of usual classroom practice. This was discussed, agreed and dates were arranged. I also asked each teacher to select the four pupil participants for me to observe and interview. Rather than selecting pupils randomly, I explained that I wanted the teachers to choose pupils who would be happy to participate and willing to talk to me about their mathematics learning; these were the only two selection criteria. Once the pupils had been selected, an information sheet and a parental consent form were sent to all parents concerned; the pupils also gave their own consent verbally.

I used the second teacher interviews to explore what I had observed during the first two lesson observations. I was able to ask for further detail or clarification about particular aspects of the lessons based on the field notes I had made. The second interviews provided the opportunity to explore teachers' perceptions of the learning that had taken place and their decision-making concerning the chosen tasks. During the second interviews, I also began to collect data about the teachers' perceptions of creativity in relation to mathematics learning. I waited until this point because I wanted to get a sense of the classroom norms and structures as they usually are, before discussing creativity. I understand that my presence in the classroom inevitably changed the environment to an extent, but for the first two lessons I was keen to keep the influence of my presence to a minimum. The participants and their headteachers were all aware of my interest in mathematics and creativity before the project started, as these details were given in the participants' information sheet; it is possible that knowledge of my interest in creativity may have influenced and changed some of the usual classroom practices. While aware of the possible limitations, I refrained from discussing my own (developing) conceptualisation of creativity before the first two observed lessons, as I wanted to influence teacher practices as little as possible.

Table 3: Questions for the Second Teacher Interviews

Questions	Probes
IQ1 Thinking about the 4 pupils that I am focussing on, did they all respond to the lessons and engage with the tasks the way you expected? Was the learning intention achieved?	1.1 Did you have to make any changes to your planning during the lessons to support/challenge any of the four pupils? 1.2 Will you need to follow anything up in the next lesson?
IQ2 The new National Curriculum states that mathematics is ‘a creative and highly inter-connected discipline’. What are your thoughts about mathematics and creativity?	2.1 What do you think is meant by creativity in relation to maths? 2.2 What do you think a mathematics task that enables children to be creative needs to include? 2.3 What skills would the children need to succeed at the task?
IQ3 In what ways do you think the maths curriculum lends itself to creativity?	3.1 Can you think of an example of a mathematics lesson in which pupils were able to be creative? 3.2 Was this lesson different from your everyday mathematics lessons and if so how?
1Q4 Are there any restrictions on you making maths lessons creative? If so, could you outline those restrictions?	4.1 Are there any changes that could be put in place to make it easier for you to promote mathematical creativity? If so what are they?
IQ5 When compared with other National Curriculum subjects, how creative do you think maths is? Can you explain your thinking?	5.1 What are the key differences in this respect between maths and other subjects? For example, how does maths compare with English or art as a creative subject?
IQ6 For the final lesson that I observe, would it be possible for you to plan a task/tasks that you think will particularly offer opportunities for pupil creativity?	(To be explored with the teachers in preparation for the next lesson observation.)

During the second interviews, I also asked the teachers if they would plan and deliver a third mathematics lesson, for which they would choose tasks they felt would provide opportunities for pupil creativity. My intention during the third observed lesson was to explore how the teachers' interpretations and perceptions of creativity in relation to mathematics learning influenced their choices and delivery of mathematical tasks. I was aware of the difficulties this request might create for the teachers but hoped that they would be comfortable with planning one mathematics lesson that might be different in approach and content from their usual lessons; they were all willing to try. During the third interviews, I had the opportunity to discuss with the teachers their decision-making about the tasks they chose and their assessment of the lessons in terms of opportunities for creativity. I was also able to further explore their perceptions of mathematics and creativity.

Table 4: Questions for the Third Teacher Interviews

Questions	Probes
IQ1 Thank you for agreeing to plan and deliver a maths lesson that provides opportunities for creativity. Can you talk me through the decisions you made about this lesson and what you were hoping the children would get out of the lesson in terms of opportunities for creativity?	1.1 Was this lesson different from the usual day-to-day maths lessons? If so, how? 1.2 In what ways did you think the task would promote creativity? 1.3 Did the children engage with the tasks in the ways that you expected? 1.4 Would you change anything if you planned this lesson again? 1.5 How often do you think you will be able to fit lessons like this into your curriculum planning?
IQ2 Could you talk to me about if and how you thought the pupils were being creative during the lesson?	2.1 Which particular creative skills did you notice the pupils using? 2.2 Was there anything about today's lesson that surprised you?
1Q3 Is there anything else you'd like to add related to opportunities for pupil creativity in maths lessons that you think is important/interesting?	3.1 Have you had any further thoughts about creativity and mathematics learning since our last meeting?
IQ4 Is there anything else you'd like to say related to my project.	

During the course of all three episodes of interviews, I was very aware of the importance of building good relationships with the participants and of gaining their trust. I was also conscious of the need for sensitivity and tact when asking difficult questions and receiving honest answers. I understood 'that creative ideas have impacts on individuals and communities and that these impacts need to be ethically considered’ (Chappell 2018: 282). Discussing mathematical creativity with the teachers could potentially cause conflict and tensions; it could also instigate change. As a researcher, I had to be reflexive in considering the questions I was asking the teachers and in considering what I was asking them to do. Throughout the process I contemplated the ethical implications of my actions (Chappell 2018).

4.4.2 The Lesson Observations

In each school, three Year 6 mathematics lessons were observed, two after the first interview and then another after the second interview. I then triangulated the data from the teacher interviews with the data from the observations. Reliance on interviewing alone would have led to an analysis that was locked into participants’ perceptions and memories (Somekh and Lewin 2011). Through combining observation and interview data, I was able to investigate the research problem in depth.

For a lone researcher, one of the challenges of classroom observations is being able to notice everything (Bresler et al. 1996; Gregory 2019). This is why some researchers choose to video record the lessons. I did consider this but concluded that setting up a camera in the classrooms would more likely influence and alter usual classroom practice than using an audio recorder. I decided that rather than focussing on all the pupils in the class, I would be able to collect richer data by focussing in depth on four pupils grouped around the same table. In addition to the audio recordings, I kept detailed field notes to help me keep account of the details of each lesson. The teachers gave their permission for this, and I referred back to my notes during the interviews following the lessons. The pupils also knew that I was taking notes. Because I was working in close proximity with them, the pupils were able to see some of what I was writing or drawing. Therefore, I had to be careful about the information I included while I was with them; if there was anything I noticed that I felt unable to record while in school, I made a mental note and recorded it later the same day.

One limitation of the observation method was the ‘observer’s paradox’, explained by Labov (1972) as the way in which the researcher’s presence in a classroom can change the context of the environment, particularly if the observer is an unfamiliar agent (Gordon 2013). While researchers do their best to obtain data in natural settings as close as possible to how they would be without the observer and their audio recorder, the presence of both can to some extent influence and change the social setting (Johnstone 2000).

Recognising the influence my presence could have on classroom activity (Coffey 1999), it was important for me to consider what my scale of participation would be. To allow me to observe details and make field notes, I realised that some of my time spent in each classroom would need to be non-participatory (Woods 2006). However, as the study was conducted in a social setting with children, and in order to collect as much rich data as possible, there needed to be some researcher participation to enable me to interact with pupils in connection with their learning. For most of this study, particularly during the time spent in the classrooms observing lessons, a halfway position of involved participation was taken, allowing me to take part in activities informally without having all the responsibilities of a full participant (Woods 2006). I interacted with the pupils at certain points during the lessons, exploring their understanding of the tasks and discussing the mathematics with them. However, when I conducted the pupil interviews my scale of participation changed and I became a full participant (Woods 2006). This was because during the interviews I was working with the children alone with sole responsibility for them, being the only adult present.

4.4.3 Research with Children ─ Pupil Interviews

I decided that conducting pupil interviews would allow me to explore the pupils’ perceptions and experiences of mathematics learning and enable me to fully answer my fourth research sub-question: How do pupils perceive and engage with different types of mathematical tasks?

However as part of my reflexive methodology, prior to the interviews it was important for me to consider and clarify my theoretical position about the contribution of children to research. Based on both personal experience and a review of relevant literature, I decided that children should be seen as 'competent research participants with particular communication skills that researchers can draw upon in social research' (Morrow 2008: 51). My standpoint was that the children possessed important knowledge and perspectives relevant to my study that I wanted to hear first-hand (Clark & Moss, 2001). As argued by Einarsdóttir (2007: 199), 'children, just like adults, hold their own views and perspectives, have the right to be heard, and are able to speak for themselves if the right methods are used'.

When planning the pupil interviews, I also needed to consider the balance of power between the pupils and myself as an adult researcher; it was important to understand the influence my identity as a researcher could have on the pupils. Power differences between adult researchers and child participants can pose a challenge during all stages of the research process (Einarsdóttir 2007). As argued by Einarsdóttir (2007) 'children are potentially more vulnerable to unequal power relationships with the adult researcher than other groups'. It is important that the researcher considers these possible issues of power when both collecting and analysing the data (Morrow 2008). By engaging in reflexivity, I understood that my identity while working with the five groups of children was as a researcher and not a teacher. The pupils were able to withdraw from the interviews at will, either temporarily or permanently; they were aware that everything they said to me was solely for the purposes of my research and that the tasks they engaged with were not going to be assessed or judged. They were able to express themselves freely and to play an important role in directing the conversations we had during the interviews. The pupils were consulted to check if they were happy to engage with the NRICH tasks; they were also asked regularly if they wanted to stop or to continue. When working with the pupil participants, I was aware of possible limitations of involving children in research; however, I felt it was important that the pupils were included and that their voices were heard.

I chose group interviews in preference to individual interviews because group interviews more closely resemble the classroom dynamic, where pupils learn in a social context (Crabtree et al. 1993). I also felt the pupils would be less inhibited when talking to an unfamiliar adult if accompanied and supported by peers. In addition, I thought that interviews in small groups would increase the range of responses and be better suited to a more detailed discussion (Crabtree et al. 1993). I recognised the limitations of group interviews, in particular that the view of one child might influence others, and the need to prevent individual pupils from dominating the discussion (Crabtree et al. 1993). While understanding both the benefits and possible drawbacks of a group approach, I chose group interviews because I wanted to be able to have group discussions with the pupils about their learning. It was also important that I could observe the interaction between them during the creative process as they engaged with the tasks I had chosen. I decided to include two episodes of pupil interviews. I wanted time to talk to them about the three lessons I observed and about their experiences of learning mathematics in general. I also chose two different mathematics tasks for the pupils to try, one for each interview, so that I could further investigate how they perceived and engaged with unfamiliar tasks that promote creativity. (Details of these tasks are provided in Chapter Five.)

The conversations that I had with the pupils were planned very loosely. They were partly directed by what I had observed during the mathematics lessons, partly directed by the tasks I had chosen for them, and partly directed by the pupils themselves. I followed the advice of Gollop (2000) who suggests that when interviewing pupils for research purposes, it is more beneficial to think of the interviews as conversations; the children should be given the opportunity for their views to be listened to and heard. When collecting and interpreting the data, I endeavoured to accurately present the pupils' voices. Engaging in research with these children helped me to distinguish clearly between my teacher and researcher identities and also helped shape and strengthen my researcher identity. The rich data collected from the pupils provided valuable insights into the research questions, insights of great importance to my study.

4.4.4 Pupils' Written Work

With permission from the teachers, previous work completed by the pupils in their mathematics books was viewed and discussed with both the pupils and teachers. Notes and observations made about this work were recorded in my field notes. A review of their workbooks helped build a picture of pupils' day-to-day experiences of mathematics learning.

4.5 Pilot Study

The pilot study conducted in preparation for the main study, enabled me to test and review my research design and my skills as a researcher. It took place in a two-form entry, community primary school and involved one Year 6 teacher and a group of four Year 6 pupils. During the pilot study, I used the same research methods and processes planned for the main study.

The amount of data collected from this single case led me to reconsider the size of my sample. I needed enough data to enable me to fully explore the research problem, without the amount becoming unmanageable for a doctoral study. I had planned to include eight cases, but following the pilot study I decided that five rather than eight would allow for a deeper analysis.

After listening to the audio recordings made during the pilot study, I recognised the importance of not putting words in participants' mouths. I also realised that the teachers needed time to reflect on the questions asked, as they were not given these in advance of the interviews. I became acutely aware of how I might sway participants' opinions or affect their behaviour by giving my own views and opinions or by prompting their responses.

It also became clear during the pilot study that the teacher was encountering a conflict between the need to prepare her pupils for the Year 6 tests and the importance of enabling pupils to be creative. The teacher was open about the conflict she was experiencing and it helped me to understand that as Chappell (2018: 281) argues, creativity is not 'value neutral'; it can affect identities and bring about change. During the creative process both adults and children are on ‘a journey of becoming: developing their identities as they develop creative ideas’ (Chappell 2018: 282). Because creativity can lead to change, those who promote creativity need to be guided by ethical action, ‘mindful of the consequences’ (Chappell et al. 2016: 257). Through a process of reflexivity during the pilot study, I was conscious of some of the possible tensions and conflict my research could cause for the teacher participants. As a result of this reflexivity, the main data collection process was conducted with sensitivity and empathy, aware of possible consequences (Chappell 2018).

During the pilot study, it sometimes appeared that the teacher was not answering the question she had been asked; however, she often returned to the question later, unprompted. She also wanted time to talk about other matters she felt were related, even if indirectly, to the question. The pilot study made it clear that to collect rich data that gave me insight into teachers’ perceptions, I needed to provide them with time and space without interrupting too much. Because of other demands on the teachers’ time, the time available for each interview was limited to forty-five minutes. Managing the time effectively to fully explore the research questions, while giving teachers the opportunity to talk about related matters important to them, was critical to the collection of rich data.

During the pilot study, it also became clear that the interview questions ‘What are your thoughts about mathematics and creativity?’ and ‘What do you think is meant by creativity in relation to maths?’ were quite difficult to answer on the spot; teachers needed time to reflect on them. Therefore during the main study, I asked the teachers to think about these questions and returned to them during the third interviews. Giving the teachers time for reflection enabled their thinking around the subject of mathematics and creativity to develop, consequently providing much richer data.

Working with groups of Year 6 pupils also presented potential problems. In order to collect meaningful data, I needed to build good relationships with these pupils and to gain their trust. Having been a Year 6 teacher for twelve years, I had much previous experience of developing positive relationships with pupils of this age. However, I was only going to be working with each group of pupils for a period of three days and only meeting with them on my own twice to conduct the group interviews, each interview lasting about an hour. The pilot study emphasised the importance of making the best use of the available time. One of the two tasks I used during the pilot study, called Three Neighbours (NRICH n.d.-e), was not the best choice for prompting group dialogue and discussion during the pupil interviews. Therefore for the main study, I replaced this task with another called 'Two and Two' (NRICH n.d.-c). The second task used during the pilot study, 'Presenting the Project' (NRICH n.d.-d), was excellent for promoting creativity and collaboration; therefore I used this again during the main study.

Conducting the pilot study helped to improve my main data collection and was an important aspect of my reflexive methodology. During the pilot study my identity as a doctoral researcher developed and strengthened.

4.6 The Sample

As explained in section 3.2.3 on page 50, this research is a quintain multiple case study (Stake 2006) designed to get to the heart of the quintain of interest: affordances for creativity during mathematics learning. The sample was composed of five case-study primary schools, with a focus on teachers and pupils in Year 6. Each single case was a bounded system of one teacher and four pupils operating in their unique contexts, while the five cases formed a multiple bounded system (Yin 2009; Creswell 2013) through which I could seek answers to my research questions (Stake 2006; Yin 2009). The five single cases were bound together as 'members of a group' (Stake 2006: 6), selected to cast light on the quintain.

To ensure confidentiality, each case has been anonymised using a different, single letter. The teachers and pupils share the letter of the case to which they belong, with an additional letter for each pupil to distinguish individual children; for example: Teacher B and pupil BA belong to Case B.

Table 5: The Anonymised Sample

The Cases	The Teachers	The Pupils
Case B	Teacher B – Male	BA – Female BJ – Male BS – Female BZ – Male
Case K	Teacher K – Male	KC – Female KJ – Female KT – Male KW – Female
Case L	Teacher L – Female	LC – Male LD – Male LN – Female LT – Female
Case R	Teacher R – Female	RD – Female RF – Female RN – Male RZ – Male
Case V	Teacher V – Male	VA – Female VB – Male VF – Male VS – Female

4.6.1 Profiles

Because this study is underpinned by Gibson's theory of ecological psychology, focussing on 'how learning takes place through perception of, and interaction with, an environment' (Watson 2004: 23), it is important to recognise that each case is set in its own unique context, with its own culture and way of doing things. The socio-cultural nature of each environment, comprising different norms, practices, behaviours and beliefs, all influence pupils' perceptions of mathematics and how they participate in different mathematical tasks. In order to develop an understanding of the individual context of each case, a profile of each school was built by collecting data from the school websites, previous Ofsted reports, the DfE website and the Ofsted dashboard website. Teacher and pupil profiles were also constructed through information provided by the teacher participants.

The data presented below represent the profiles of the schools in 2016, at the time my data was collected. It is likely that some or all of the schools will have been re-inspected since then, and other data will have changed. Each school is labelled by the same single letter as the case situated within it.

4.6.1.1 Case B

Case B was situated in a mixed-gender community school for pupils aged 3 to 11 (School B). 490 pupils attended the school; 74% had English as an additional language and 21% had free school meals. The school had been graded as good in its most recent Ofsted Inspection in 2013. Ofsted reported that the teaching of mathematics had improved noticeably since the previous inspection because of the focus on helping pupils to understand mathematical concepts. School B had recently adopted the Mastery Approach as a way of implementing the 2014 mathematics curriculum, with all teachers in the school receiving a day's training in how to introduce this new approach. As part of the Mastery Approach, teaching pupils to use the Singapore Bar Model (NCETM n.d.) to support them with their calculations had become compulsory in all classes from Year 1 to Year 6. All pupils worked on the same mathematics task during lessons; the only differentiation was through levels of teacher support. While the school was mostly two-form entry, Year 6 was split into 3 smaller classes with 20 pupils in each class. In the 2015 Key Stage 2 (KS2) SATs tests, 94% of pupils made at least expected progress in mathematics.

Teacher B joined the school as a newly qualified teacher and had been teaching for four years. His first four years were spent teaching in Year 5 but in the year of this study he had moved into Year 6. Therefore, this was Teacher B's first year of teaching Year 6 and his first time of preparing for and administering the Year 6 SATs. He also had responsibility for coordinating English throughout the school. Teacher B explained that he enjoyed teaching mathematics but also said, *'I'm not the greatest at maths … I'm not the most gifted mathematician and I never was at school for instance'*. He said that he felt more confident about teaching English.

Teacher B selected four of the lowest attaining pupils in his class to take part in my research. The group consisted of three girls and one boy: BA, BJ, BS and BZ. Three (BA, BS and BZ) are all of Asian origin, while BJ had recently migrated from Poland.

4.6.1.2 Case K

Case K was situated in a mixed-gender community school that catered for 420 pupils, aged between 4 and 11 (School K). Relatively few (1.6%) of pupils received free school meals, 2.4% of pupils were on the special needs (SEN) register and 17% of pupils spoke English as an additional language. The last Ofsted inspection had been in 2013 when the school was graded as good. One of the key areas for improvement identified by Ofsted was to improve progress in mathematics, with standards of teaching deemed variable and work for higher attainers often not challenging enough. School K was a two-form entry school with two classes of Year 6 pupils. Like School B, School K had recently introduced the Mastery Approach as a way of implementing the new Primary Mathematics Curriculum; however unlike School B, School K differentiated tasks to cater for different attainment groups. The pupils were not set for mathematics but were often grouped according to assessed attainment levels. In the 2015 SATs, 97% of pupils were assessed as making at least expected progress in mathematics.

Teacher K was in his third year of teaching. He spent his first two years of teaching in Year 4 and then moved up to teach Year 6. Although only in his third year of teaching, he had recently been given the role of whole-school Mathematics Lead Teacher and was therefore tasked with coordinating mathematics teaching and learning throughout the school. Teacher K had recently attended an NCETM conference to support him in his role as Mathematics Lead Teacher. Although he had studied English at university, he expressed excitement about his new role. He told me: '*This whole maths lead teacher thing is quite new to me. I'm just getting into it*.'

The pupils in School K were a mixed-attainment group of one boy and three girls: KC, KJ, KT and KW. All four are White British. These pupils did not usually work together during mathematics lessons but the teacher moved them so that I could sit with them during the observed lessons. The four pupils varied widely in mathematics attainment, with KT being assessed as a very high attainer, KJ a high attainer, KW a core attainer working at the expected level for Year 6, and KC a low attainer. Teacher K said that he thought it would be more interesting for me to work with a mixed attainment group of pupils who he chose because he felt they would all be willing to participate and give their views freely; he was right.

4.6.1.3 Case L

Case L was also situated in a mixed-gender community school (School L); it had 490 pupils aged 3 to 11, including two nursery classes. 5% of the pupils received free school meals, 10% were on the SEN register and 15% spoke English as an additional language. The last full Ofsted inspection had been in 2007 when the school was graded as outstanding. This judgment was upheld in 2010 following an interim Ofsted assessment. There had been no further inspection of the school since 2010. School L was a two-form entry school with two classes of Year 6 pupils. At the time of my study, School L used the Kagan cooperative approach to teaching and learning (Kagan 1990), with pupils working in mixed-attainment groups of four. Pupils worked in these groups for all subjects, including mathematics; the groups were changed every six weeks. The Kagan Approach, developed in the United States in 1980s, involves teachers employing specific cooperative learning structures of which there are about two hundred. These different structures can be used for all subject areas and are intended to create a class culture in which pupils cooperate, discuss and collaborate. Full participation is expected of all pupils, who are held accountable for their participation through the use of the various structures. There is an emphasis on equal participation and equal status for all pupils. In the 2015 statutory tests, 100% of pupils were assessed as making at least expected progress in mathematics.

Teacher L started her teaching career at School L; during the time of the data collection she was in her ninth year of teaching, with nine years experience of teaching Year 6. The teachers in School L were divided into curriculum teams, responsible for coordinating and developing a particular curriculum subject. Teacher L was part of the English team; she was also a member of the senior leadership team, with whole-school responsibility for assessment. Teacher L expressed her confidence in mathematics, telling me, *'I'm confident with maths. Yeah … I'm all right with maths. I love maths'.*

The pupils in School L were a mixed-attainment group of four, consisting of two boys and two girls: LC, LD, LN and LT. LD is of Asian origin, LN is White Other and LC and LT are White British. This group of four made up one of the Kagan groups operating in the Year 6 class at the time of my data collection. School L had introduced the Kagan system five years previously and so the pupils were used to working in mixed-attainment groups.

4.6.1.4 Case R

Case R was situated in a mixed gender academy school, catering for pupils aged 4 to 11 (School R). It was converted to academy status in 2014, after an Ofsted inspection decided the school 'required improvement'. There had been no inspection since 2014. Following the academisation, significant changes were made to the senior leadership team. In 2016, School R was a three-form entry school of 541 pupils. 94% of pupils spoke English as an additional language, 30% received free school meals and 10% were on the SEN register. At the time, School R was using an old version of Abacus mathematics textbooks but was thinking of investing in the new Abacus scheme, updated in response to the new curriculum (Pearson n.d.). Because the school was considering adopting the Mastery Approach, Teacher R had recently attended a meeting about this at a local Maths Hub. In the 2015 SATs, 94% of pupils were assessed as making at least expected progress in mathematics.

Teacher R had been teaching for eight years and had taught in two different schools. She had taught in Year 3 for four years and was in her fourth year as a Year 6 teacher; she was also lead teacher for mathematics across the school. Teacher R enjoyed and felt confident about teaching both mathematics and science. She told me, *'I mean I've always liked maths*

…maths and science has always been my thing … maths and science at school and then I did a science degree'.

The pupils in Year 6 were set for mathematics by attainment. The four pupils selected to take part in my research were two girls and two boys, all from the top mathematics set (RD, RN, RF and RZ). They are all of Asian origin.

4.6.1.5 Case V

Case V was situated in a large, mixed-gender community school (School V). It catered for 615 pupils aged 3 to 11. 24% of the pupils were on free school meals, 4% were on the SEN register and 33% spoke English as an additional language. Ofsted had graded the school as outstanding in 2015. School V was a three-form entry school with three classes of Year 6 pupils. The school was considering introducing the Mastery Approach to mathematics but some concerns about the approach were causing hesitation. The pupils in School V were not set for mathematics, but it was planned to set Year 6 by attainment during the following half term. In the 2015 SATs, 87% of pupils were assessed as making at least expected progress in mathematics.

Teacher V had been in School V for two years. He had six years' teaching experience in three different schools, with responsibility for coordinating mathematics in all three. He explained that he did not have *'a background in mathematics'* but *'they just seem to think I'm good at maths.'* He had five years teaching experience in Year 6 and was currently an assistant headteacher with responsibility for whole-school teaching and learning.

The pupils from School V were a group of two boys and two girls all working at about the same attainment level. The teacher assessed them all as being high attainers, although there were a few other pupils in the class who were considered to be higher achievers than the four selected to work with me. The pupils are of mixed ethnic origin, with VF and VB both White British males and VA and VS two girls of Asian origin.

The next chapter focuses on the data analysis and interpretation.

CHAPTER FIVE
The Data Analysis and Interpretation

5.1 Focus of the Analysis

This chapter presents the data analysis, including an explanation and justification of the methods used to analyse and interpret the data. Taking an onto-epistemological position (Barad 2007) that being, knowing and ethics cannot be separated, I have fused three registers together in this chapter: the methods of analysis; the data analysis and interpretation; and ethical considerations. This onto-epistemological fusing of methods of analysis with the presentation and interpretation of the data is an important part of my research design; it represents the way I visualised 'how the chapters of the thesis fitted together' and 'how key concepts of each chapter linked together' (Murray 2017: 9).

The PRQ for this study is: **Under what conditions are affordances for creativity made available to pupils while learning mathematics?**
In order to answer this PRQ, my analysis focussed on the four research sub-questions (RSQs) around which this study is structured:

1. What are teachers' perceptions of creativity related to mathematics learning?
2. What are the distinctive features of mathematical tasks that promote creativity?
3. What are the constraints on pupil creativity when learning mathematics?
4. How do pupils perceive and engage with different types of mathematical tasks?

5.2 A Reflexive Analysis

The data from the research diary, the audio transcripts and the field notes were analysed qualitatively to identify categories and themes, through a process of reflexive analysis and iteration.

> Reflexive iteration is at the heart of visiting and revisiting the data and connecting them with emerging insights, progressively leading to refined focus and understandings.
>
> (Srivastava and Hopwood 2009: 77).

To guide the reflexive analysis, I used the framework by Srivastava and Hopwood (2009: 78-82), developed from the questions provided by Patton (2002) to support ‘triangulated reflexive inquiry throughout the research process for self-reflexivity’ (Srivastava and Hopwood 2009: 78). This framework comprises three simple questions to equip the researcher with specific points of reference during the data analysis — see table below:

Table 6: Questions used to support the data analysis

Question 1 (Q1)	What are the data telling me? (Explicitly engaging with theoretical, subjective, ontological, epistemological, and field understandings)
Question 2 (Q2)	What is it I want to know? (According to research objectives, questions, and theoretical points of interest)
Question 3 (Q3)	What is the dialectical relationship between what the data are telling me and what I want to know? (Refining the focus and linking back to research questions)

(Srivastava and Hopwood 2009: 78)

I found Q3 of this framework very helpful in sharpening my focus on the data. By using Q3 to return to the data to look for gaps in my understanding, I could then revisit Q1 with a clearer insight into what the data were telling me (Srivastava and Hopwood 2009).

Mason (2017: 197) states that an important part of the process of reflexive analysis is to test out your emerging understanding of the data by ‘trying out alternative explanations and in particular by looking for negative instances’. The reason for searching for negative instances is to look for categories or themes that contradict the account you are developing from the data. In doing so you test the rigour of your analysis by endeavouring to ensure that you have not made any unsupported generalisations.

5.3 Methods of Analysis

5.3.1 Stage One

To begin to identify categories across the cases, the 'holistic' method of coding defined by Saldana (2016: 166-168) was used; this involves grouping segments of data into categories as a first cycle of coding. This first stage is suitable for an inexperienced researcher as it enables them 'to capture a sense of the overall content and the possible categories that may develop' (Saldana 2016: 294). It is also a suitable method for studies with several different data forms (Saldana 2016).

During this first stage, I read through the field notes and interview transcripts many times (transcribed in full by myself) and returned to the recordings of the lesson observations frequently. In the data transcription, participant pauses, hesitations, and sounds of agreement or disagreement were also recorded for use in the analysis. During this process, I used different coloured highlighters to code emerging categories. As explained by Kramer and Adams (2018), at this point of analysis it becomes clear that some data are not relevant to the research questions or the quintain. Therefore, during the holistic stage I separated the relevant data from the irrelevant in a process of data reduction (Kramer and Adams 2018). I returned to the data frequently using Srivastava and Hopwood's framework (2009: 78), before finalising which data were relevant to the quintain.

I identified thirteen categories, labelled as follows: policy and high-stakes tests; time constraints; teacher negative affect; teacher perceptions of mathematics as a creative subject; teacher perceptions of creative skills; pupil opportunity for creativity (during their mathematics lessons); the framing of tasks; pupil perceptions of mathematics learning; pupil perceptions of mathematics as a subject; time and space to develop and use creative skills; pupil choice and decision making; pupil engagement with the tasks; and pupil creative skills. Data from each case were recorded case by case on separate tables using Microsoft Office, with each category highlighted in a different colour.

'Creative skills' are named in three categories. As explained in Chapter Three, the Burnard et al. model (2006: 257) of pedagogy and possibility thinking was used and adapted to inform my study; this model shows features of possibility thinking that support creativity. I use 'creative skills' as a shorthand term for the features of possibility thinking included on the modified version of the Burnard et al. model (2006). Therefore, by 'creative skills' I mean the following: playfulness, resilience, conjecture, extrapolation, adaptability, posing questions, immersion, innovation, risk-taking, imagination, intentional action, self-determination and collaboration. During the data analysis process, I also added curiosity and noticing as important creative skills when learning mathematics.

The thirteen categories are closely linked to both the four RSQs and the theoretical framework. This gives a strong indication that appropriate data collection methods were used and that questions asked were of central relevance to the PRQ.

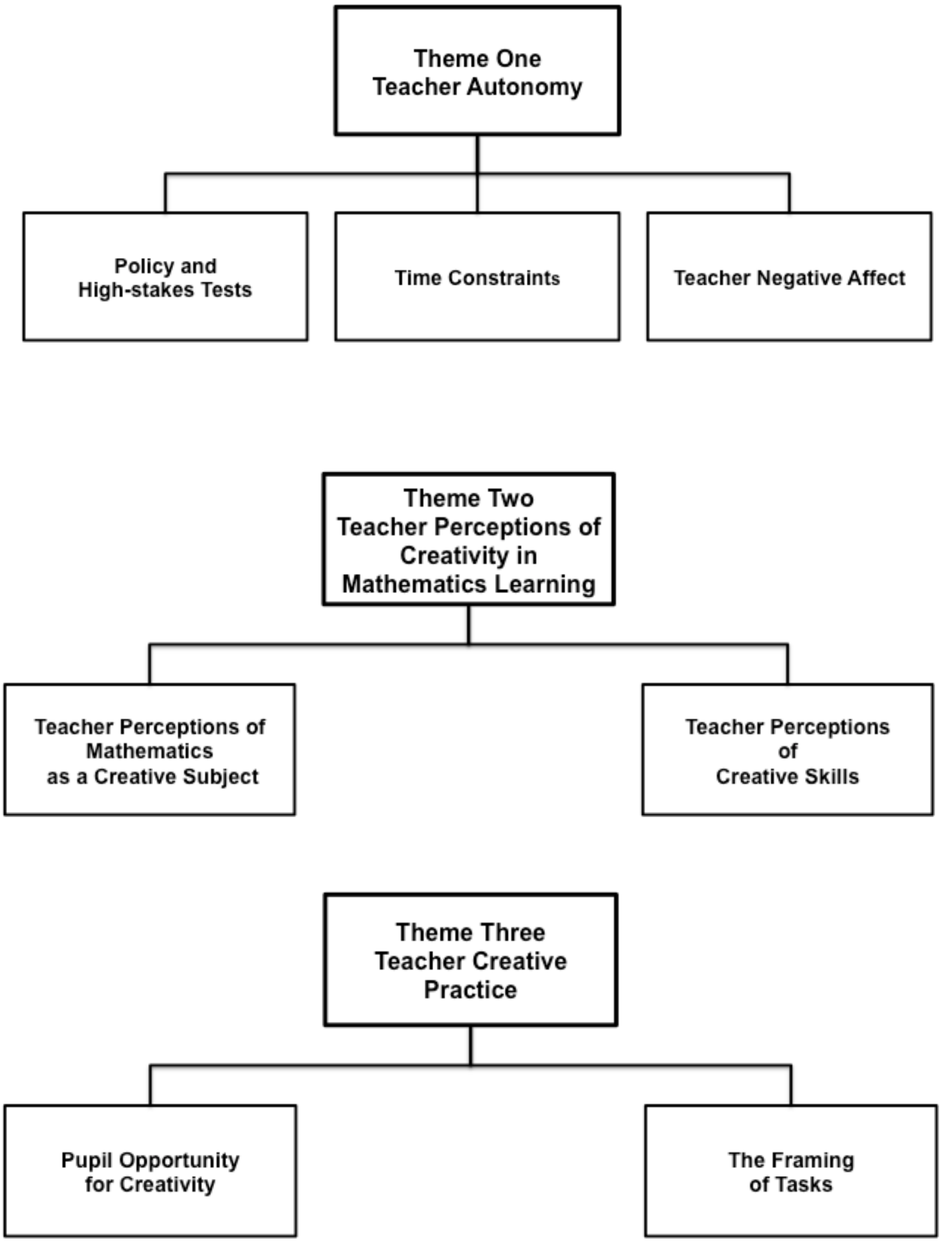
5.3.2 Stage Two

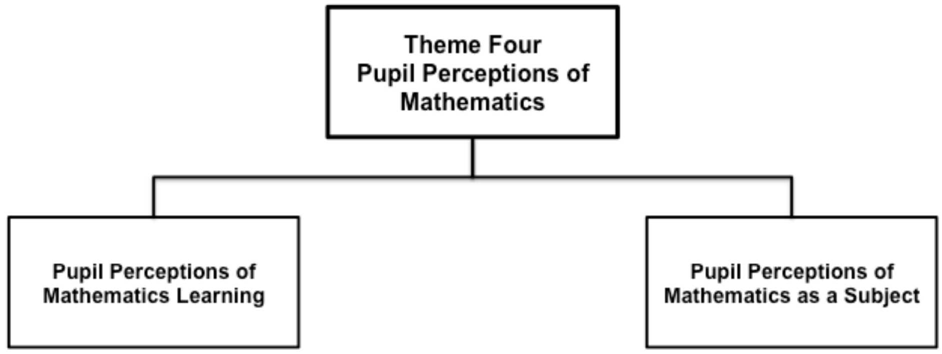
Once the holistic cycle of coding had been completed, a second cycle of coding called 'Pattern Coding' took place (Saldana 2016: 236-239). Pattern coding was used to group categories into a smaller number of themes across the cases. 'Pattern codes enable a researcher to identify an emerging theme by pulling together categories from the first cycle of coding into 'more meaningful units of analysis' (Saldana 2016: 236). Pattern coding was chosen because it is recognised as an effective and appropriate way of conducting a cross-case analysis (Miles et al. 2014).

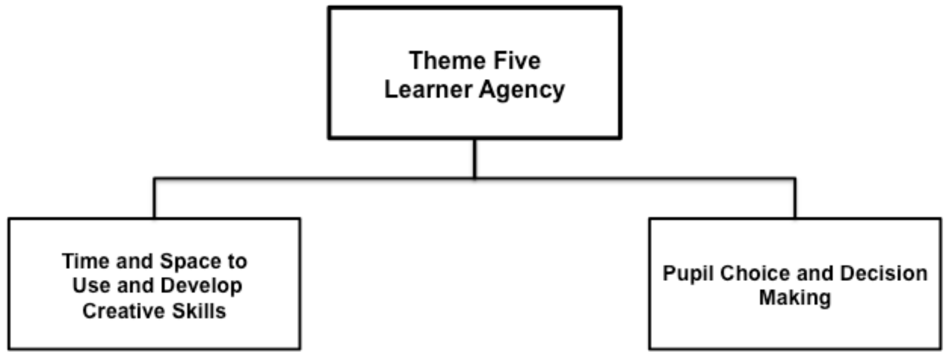
Data from each case were combined into thematic data sets, arranged in tables using Microsoft Word, each set representing one identified theme. The data from each of the five cases were clearly labelled and distinguished from the other cases, to enable cross-case comparison. Six themes were identified, three focussing on the teachers and three focussing on the pupils:

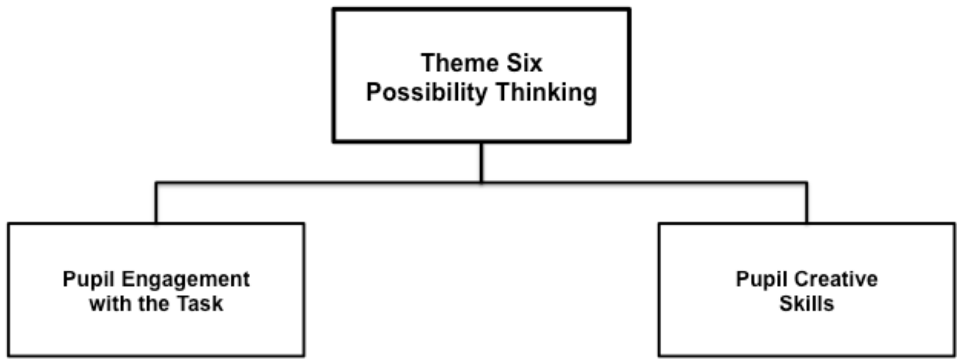
- For teachers: teacher autonomy; teacher perceptions of creativity in mathematics learning; teacher creative practice.
- For pupils: pupil perceptions of mathematics; learner agency; possibility thinking.

Figure 4: The six themes and the categories they were identified from









5.3.3 Constant Comparison

Once the data were grouped into themes, the next step was to compare the data to look for similarities and differences across the cases. ‘This process is often called a constant comparison method.’ (Kramer and Adams 2018: 6). As Patton (2001) states, as well as looking for emerging patterns it is also important that part of the data analysis includes looking for any differences or deviant findings across the cases. Evidence was taken from all five of the cases to demonstrate ‘how uniformity or disparity characterises the quintain’ (Stake 2006: 40). Constant comparison is a common aspect of data analysis used in case studies and is considered necessary in directing the researcher to both revise and confirm any patterns identified (Stake 2006). The constant comparison process was used as part of my reflexive methodology.

5.4 The Themes

The following sections contain the data analysis. The teacher themes will be detailed first and the pupil themes second. All verbatim quotes from respondents are italicised.

5.4.1 Teacher Autonomy

Teacher autonomy was identified from the following categories: policy and high-stakes tests; time constraints; teacher negative affect.

For the purposes of this study teacher autonomy is defined as having two dimensions:

- Freedom from control by others over professional action or development;
- Capacity for self-directed professional action in terms of both professional development and teaching practice.

(Smith 2003: 3)

Across all cases the teachers felt under considerable pressure created by the government policies of high-stakes tests and accountability. This feeling of pressure had been exacerbated by recent changes to the curriculum and to the mathematics tests. While there was a great deal of uncertainty about creativity when linked to mathematics, all teachers held the view that lessons involving creativity were more engaging and open-ended, involving some sort of problem solving. A key message that came from the teachers was that participating in my research had made them more aware of the importance of providing children with the opportunities to be creative during mathematics lessons; however, they felt that time constraints prevented them from doing this. A conflict of interests was causing them professional anxiety as they felt they were inhibited from making professional decisions about their pedagogy.

> Teacher V reported that he felt like *'a teacher of SATs',* adding: '*We don't have time in Year 6. We're not teaching the children to understand maths, we're teaching them to pass their SATs tests'.*

> Teacher R claimed: *I have the SATs in mind all the time because it's what we're judged on. So often it just has to be drills and skills. I'd like to do more of the exploration side of maths and let them go with it, but you can't just do that for a whole lesson and just not get anywhere because you haven't got time for that.*

As reported by Dobbins (2009), time restrictions are perceived by teachers to be one of the greatest inhibitors to creativity. All the teachers in my study felt constrained by time, all describing the pressure they were under to cover enough curriculum content to prepare the pupils for the tests. From their perspective, creativity was not a priority because pupil creativity was not going to be assessed in the tests. Three teachers independently described lessons that promote creativity as a *'luxury'* (Teachers B, K and V). All teachers explained that they did not have the time to teach things that were not tested. The teachers' responses on this point were so striking in their unanimity that they warrant being quoted verbatim.

> Teacher B reported: *Time restraints just mean you've got to do certain things by certain times, but if there wasn't the SATs you could have creatively stand-alone lessons because you never really know the tangents that they can come off at, and unfortunately I don't really have that luxury at this point. Creativity isn't going to be tested so maybe the way it's fully assessed at the end of each key stage may need to be changed. In Year 6 the timescale means that to a certain extent the end of year expectations means that there's not enough room for creativity.*

> Teacher K reported: *I think that's something they definitely lose ... that sort of exploration of maths - and maybe sometimes finding those patterns and relationships. I think that's often more fun or more engaging but they don't get the chance to do that because there is that pressure of time*

> Teacher L reported: *I'm sorry but I don't have time to do all singing all dancing. If there were no SATs it would change things in the fact that I'd feel I'd have more time, and more time to have fun with maths. I feel I've not got enough time and I feel like I want them to move on. I*

want them to move on because we haven't got time, we haven't got time. I feel pressured and I feel like I'm pushing them and not giving them enough time to digest it, rehearse it, come back to it, repeat it because learning's got to be something you come back to and check if you can still do it again.

Teacher R reported: *It's ticking things off a list and not having enough time to fit them all in almost. I mean they do get chances to apply, definitely, but creativity – probably not. … I think often we're filling gaps and we're pasting on top to get them through that test, on top of crumbling foundations with some children. I think sometimes as a teacher we're always getting through the content. You're worried about running out of time so you become fixated on the answer.*

Teacher V reported: *If I didn't have to teach to a test I could do more creative lessons, and any Year 6 teacher who says they don't do that is lying to you; I tell you right now. It would mean that I would have time to teach much more through practical problems, through puzzles, through games, through things that actually engage them, through physical activities, but I don't think there's any real evidence that any of that's going to help them pass the test. Would I rather teach them in a way which is all about problem solving and setting out investigations? Of course I would. What I'm saying is, I use them as a complete luxury. … They're a luxury, to do those lessons.*

All teachers felt that it was unreasonable to expect them take a creative approach to mathematics as well as expecting them to prepare pupils for high-stakes tests requiring speed and efficient methods:

We've got a new arithmetic paper and that's just on methods basically. We had Ofsted come in and talk about what's expected in the new curriculum and what's expected as a mastery answer and the new methods that they'll be looking out for. (Teacher B)

I need to make sure they've got those methods and I think that's ... I think it's important - you know, instilling a love of maths is important - but I do think it falls to the wayside sometimes. They need to know the methods for the tests. (Teacher K)

What's the point of saying that and then giving us a 30-minute arithmetic test with 36 questions to complete that rely on methods and speed? (Teacher L)

> *I also think that now they're specifying a lot of the methods that they have to use, takes away creativity … The National Curriculum has an appendices at the back of the methods they're to use.* (Teacher R)

> *If you can find me one question on that test that requires creativity to answer it I'd eat my hat.* (Teacher V)

The views of the teachers in my study were similar to those reported by Galton and Macbeath (2002) from eight teachers who spoke about curriculum pressures, time restrictions, and lack of time for spontaneity and creativity. Galton and Macbeath (2002) found that there had been a decline in the possibility of a broad and balanced curriculum with art and music in particular being squeezed out of the curriculum. While mathematics is not in danger of being squeezed out of the primary curriculum, as it is a core subject made accountable through high-stakes testing, it seems that the subject itself is being robbed of its creativity.

In the literature review it was argued that in a culture of performativity (Ball 2003; Perryman 2006), teachers lose autonomy to make choices about pedagogy because of a standards agenda underpinned by rigorous performance data, target setting and inspection (Schoenfeld 1988; Muijs and Chapman 2009). The teachers in my study could all see the benefits of delivering mathematics lessons that promote pupil creativity but, without exception, the drive to achieve good outcomes in the end of KS2 tests dominated any desire to promote a love of mathematics through a relational approach to pedagogy. It seems that in the time since I collected my data, not much has changed. A recently published book highlights the ways in which the standards agenda continues to constrain pedagogy:

> League tables exist to try and show how well teachers and schools are doing, and children themselves are often faced with a curriculum that is distant from their own human needs. Pressures are high and primary education has become a place where children are constantly being made ready for the next stage of education – and to pass the next test.
>
> (Ogier and Eaude 2019: 3)

The uniformity of the teachers' perceptions that time constraints and external policy constrained their teaching raises questions about teachers' freedom to be able to make choices and decisions based on well-considered professional judgements. The data suggest that in order for pupils to be provided with mathematical tasks that promote creativity, teachers need greater autonomy to allow them to feel comfortable in planning and delivering such tasks.

In some ways the drive to prepare the pupils for the tests acted as a security blanket for the teachers. They used words like *'unsafe'*, *'a risk'* and '*comfort zone'* in terms of changing their classroom practice to afford more opportunities for pupil creativity in mathematics. There was a strong view that teaching lessons that afford pupil creativity is a risk. There was a danger that pupils would *'go off at a tangent'* (Teacher B) and that they would *'just not get anywhere'* (Teacher R). Teacher K commented, '*I've got a book all about numbers and exploring numbers and finding patterns. I've had that for about a year now and I'd love to use it but as yet I've not found the time with the view that I'll not be safe if I do.*

Teacher L also considered the possibility that if the SATs tests were abolished teachers might feel lost. I asked: '*If you had different assessments in Year 6, or if the tests weren't there, would it change the way you teach maths?'* Teacher L replied: *'Yeah, big time! Really big. It would make us ... first of all ... and this sounds really bad ... it would make me feel really uncomfortable, because I'd think "What am I teaching to now?"'*

While the teachers were all very outspoken about time constraints preventing them from making mathematics a creative subject, the data also suggest that the teachers were putting some constraints on themselves because of fear of the implications of giving pupils more learner agency. For teachers to provide pupils with some time and space to take some ownership of their own learning, teachers need to reposition themselves as 'facilitators or mediators of the learning process' instead of 'knowledge transmitters' (Manyukhina and Wyse 2019: 236). Before delivering the third lesson, Teacher V disclosed:

> *I'm not really sure how this lesson is going to go … they're really going to have to have some sense of being sensible. I think they could just go off the wall. I don't know; we'll see.*

He was anxious that he might lose control of pupil behaviour. The norms and expectations of Teacher V's classroom seemed to be shaped by the pressure he felt under from the accountability system, which he reported caused him both stress and regrets:

> *I think it's so sad that teachers have to worry if they're not doing new maths lessons, new learning every day, because it is that reason above all that we are in this mess. Children don't have time to practice and consolidate before having to move on to the next thing. No wonder we all feel so stressed … they don't understand what they're doing and they get moved on … even if they can understand the method, which I'd settle for at this point, they don't understand why they're doing it … so if they've forgotten that method, when it comes to the tests they've got no chance of being able to work it out for themselves.* (Teacher V)

Yoon (2002) conducted a research survey of 113 teachers to explore the impact of teacher stress, self-efficacy and negative affect on the relationships between teachers and pupils; teacher stress was identified as a main cause of negative teacher affect and was found to be detrimental to relationships. Teacher V spoke of the stress he was experiencing. On the one hand, he was concerned about the impact on both pupil behaviour and pupil test results if he made changes to his pedagogy; on the other he was worried about the impact on pupils' enjoyment and conceptual understanding of mathematics if he did not change his pedagogy.

In the observed lessons, Teacher V regularly reminded pupils of time constraints and the need for speed. During the second interview he voiced his concern about the pressures of Ofsted, explaining, '*Ofsted were putting so much pressure on teachers to show visible progress in every lesson. Where was the time for children to actually practice and consolidate skills?'*

Teacher V also spoke of his responsibilities as a Year 6 teacher:

> *At the end of the day I'm a Year 6 teacher and my schools results rely on my maths scores. My job relies on me getting these children ready for a test that requires no creativity. … My headteacher is really concerned about … what if they … umm … do badly.*

Teacher V went on to say that the way mathematics is taught in Year 6 results in pupils hating the subject:

> *There's evidence that creativity's going to make maths much more fun, much more engaging, much more memorable for them, because the biggest problems that secondary schools have is children go up to secondary schools and they hate maths. We try to teach them by rote, and tell them the method that they have to use. Where's the creativity in that?*

Teacher V's description of pupil attitudes to mathematics at the end of Year 6 is disturbing. While it is very unlikely that all pupils share this negative attitude, to an extent Teacher V's views are supported by research from the University of Cambridge. In a study involving more than 1,700 primary and secondary pupils in the UK, researchers found that maths anxiety is widespread and causes a range of emotions in children 'from rage to despair' (Carey et al. 2019: 50). 'Students often reported overwhelming negative emotions which in some cases led them to act out in class and be removed from the classroom, or to become tearful' (Carey et al. 2019: 50). While the Year 6 SATs were 'the root of anxiety for some', Carey et al. (2019: 51) found that the transition from primary to secondary school was also a cause of anxiety; pupils worried 'that the work was harder, and they couldn't cope, there was more pressure from tests and an increased homework load' (Carey et al. 2019: 50-51).

Teacher V thought that enabling pupils to experience mathematics as a creative subject would improve their attitudes towards the subject; however, the data suggest that the external pressures he felt he was under prevented him giving pupils the time and space required for affordances for creativity.
After the second observed lesson Teacher V said:

> *I'm a bit annoyed that we didn't get more work done before break. They're really immature and it takes them a while to understand what you want them to do. I was hoping that they would be quicker but it was more hope than expectation.*

When a teacher feels he has to prioritise speed and thinks that the way he is forced to teach mathematics results in pupils hating the subject, the classroom environment established is unlikely to be an enabling context for creativity during mathematics learning.

There is evidence of negative teacher affect in these data, including guilt, anxiety and fear. For example: '*this sounds really bad'* (Teacher L); *'I'll not be safe if I do'* (Teacher K); '*No wonder we all feel so stressed'* (Teacher V). As Ball (2003: 221) reports, a culture of performativity can result in negative affective emotions in teachers:

> A kind of values schizophrenia is experienced by individual teachers where commitment, judgement and authenticity within practice are sacrificed for impression and performance. Here there is a potential 'splitting' between the teachers' own judgements about 'good practice' and students 'needs' and the rigours of performance.

Brighouse (2019) highlights the negative affect experienced by teachers:

> I think many teachers are dogged by fear. A persistent, low-level strain that permeates their working lives. Fear that they're not teaching effectively, that they haven't got the paperwork under control, that they're not on top of behaviour. Fear that they are simply not good enough. … Maybe it just comes down to accountability … only the brave can withstand the level of judgement and scrutiny we are under.
>
> (Brighouse 2019: para 10&14)

The data indicate that if mathematics is to be experienced by pupils as a creative subject (DfE 2013a), reform to both educational policy and to the accountability system is required. As Comber and Nixon (2009: 333) report:

> A great deal of educational policy proceeds as though teachers are malleable and ever-responsive to change. Some argue they are positioned as technicians who simply implement policy.

Jumani and Malik (2017) emphasise that to establish an environment conducive to learning, teachers need to be free to make decisions about their teaching; they need more autonomy.

Within this section there is evidence of teacher affect and of teachers experiencing tensions between understanding the importance of providing pupils with opportunities for mathematical creativity and the need to prepare pupils for the tests. Through a process of reflexivity, I considered the effect my research was having on the teachers and was aware that the reflective journey they were undertaking could result in change; participating in my study could open doors to 'new possibilities' (Chappell 2018: 282). The impact of my research on the teachers needed to be considered alongside the impact on the pupils. While I think that change is important if pupils are to experience mathematics as a creative subject, reflexive thinking helped me to appreciate that my study was causing some conflict for the teachers; it needed to be 'guided by ethical action … mindful of its consequences' (Walsh et al. 2017: 228).

5.4.2 Teacher Perceptions of Creativity in Mathematics Learning

The theme of teacher perceptions of creativity in mathematics learning was identified from the following two categories: teacher perceptions of mathematics as a creative subject; teacher perceptions of creative skills.

All teachers seemed to experience cognitive conflict around the issue of mathematics and creativity with some views changing through the course of the data collection, in particular those of Teachers K, L and R. The interview data suggest that during the project, these three teachers went on a reflective journey about mathematics learning and creativity. All three asked for time to think about some of the questions about creativity and mathematics, returning to them with thoughtful and lengthy answers during the subsequent interviews.

Teacher B repeated several times during interview two that it was not possible for mathematics to be a creative subject as often as he would like because of curriculum restrictions. His perspective seemed to have shifted a little by interview three when he stated: *'They need more opportunities to think on their feet as well and for creating their own problems. So you do, I suppose, need to give them the opportunities to be creative as well.'* Teacher B seemed to perceive creativity in mathematics learning as pupils having more time for independent thought and the time to create their own problems. His interpretation of 'creativity' appeared to be focussed on the idea of pupils thinking mathematically to create new problems, rather than on pupils using their creative skills to solve problems. As Kontorovich et al. (2011) explain, problem-posing tasks can be a powerful way of both fostering and assessing pupil creativity during mathematics learning. However, tasks that allow pupils to create their own problems have to be framed in a way that holds pupils to account for their mathematics by making the mathematics from which they pose these problems explicit (Kontorovich et al. 2011). There was no evidence in any of the five cases, from workbooks or observed lessons, of pupils being asked to use their creativity to pose mathematical problems.

It seemed that during the research, Teacher K went through an internal struggle to understand how creativity could be linked to mathematics. During interview two he reflected:

> *I was thinking about it at home the other day. I think maths can be a creative subject but it's creative in a different way, than art or English. I think there's something about maths that makes it different. I was like, "what is maths creativity?". The more I've thought about it, the more I've sort of ... opened my eyes a little bit. You know at first I thought is maths that creative?* (Teacher K)

Teacher K's views of creativity in mathematics learning during interview two were similar to those of Teacher B's at the end of interview three.

> *I think for me in terms of creativity in maths, and hopefully this is what I was thinking about for next week ... it's a little bit more about sort of building your own question or building your own problems. That's how I sort of see creativity in maths. Looking at the word 'create', with my English head on, 'create' is to make something new so 'creative' sort of follows from that.* (Teacher K)

Like Teacher B, Teacher K was thinking of creativity in the sense of creating something new, for example through problem posing (Kontorovich et al. 2011). During interview three, having had time for further reflection and having delivered the third observed lesson, Teacher K began to think more about pupils' problem-solving skills; there seemed to be a change in his perceptions:

> *Well I ... this is what I've been thinking about. I think really, creativity in maths is sort of ... ways to solve problems ... I think having your own ways to solve different things. It's ok me giving them ways but … they're actually producing their own different way of going about it. I think that's ... or develop their own way, or even, you know, developing a way that's a well known way but by stumbling upon it, or just having that problem solving sort of mindset.*

There is some recognition in these comments by Teacher K of the importance of giving pupils some ownership of their learning to make choices and decisions (Jeffrey and Craft 2004; Xiao 2014; Dyson 2020).

Teacher K continued:

> *I think that creativity in maths ... creativity in maths is different inherently. It is different to other subjects I think. Umm ... but I don't think you need to be an all singing, all dancing lesson to be creative in maths. If you're using what you've been taught, using what you know, but in a different way that's up to you, there's a choice. I think that element of choice sort of creates creativity. It's the way you give the task to them. In English or art you create something and at the end you know what they produce is theirs, different from the others. In maths the creativity is while you're solving the problem and the ideas you come up with … they don't create anything unique'* (Teacher K).

Teacher K's comparison between creative outcomes in mathematics and some other curriculum subjects supports the notion that at primary school the end product of a creative mathematical process typically takes the form of ideas and outcomes that are new to the pupils who produce them but not unique or new to the discipline itself (Levenson 2011). Teacher K's definition of creativity related to mathematics learning seemed to change during the data collection process. By interview three he was characterising creativity in two ways: firstly, as pupils using their creative skills to solve problems; and secondly that mathematics creativity is defined as using, reordering and connecting knowledge already learnt (*you're using what you've been taught, using what you know, but in a different way).* By interview three, Teacher K seemed to be conceptualising creativity in the way defined by many sources in the literature, as presented in Chapter Two (Skemp 1989; Leikin 2009; Levenson 2011; Schoevers et al. 2019). As Skemp (1989: 77) states: 'In the context of mathematics, creativity means mental creativity: using existing knowledge to create new knowledge'.

During interview two, Teacher L displayed some very strong views about mathematics and creativity by claiming, *'I think the whole thing of creativity in maths is alien. I just think whoever came up with the term 'creativity' and stuck it next to maths needs shooting. In fact you've got something that's a methodical subject, and then you're trying to plonk creativity with it'*. When asked if she thought creativity in mathematics was different from English or art she responded:

> *Yeah completely because if you…in English and art it's not right or wrong. In art today, so we're making sculptures. Each one of them will express themselves in a completely different way and end up with something different, and then that's their creativity, being engaged there because when you think of creativity you think of, you think of having the chance to express yourself, and how can you express yourself when you're working with a set of formulas or a defined area'.*

Teacher L seemed to perceive pupil creativity as freedom of expression to create something unique; she felt that this was not possible in mathematics because as a subject it is too formulaic, with solutions to problems always either right or wrong. Her views changed as the data collection progressed and she spent time reflecting on the focus of my research and on her own practice. During the final interview it was clear that Teacher L had reflected very thoughtfully on her views about mathematics and creativity:

> *I thought back on what I said last week, on the last session, that* creativity *is the wrong word for maths. Maybe it doesn't have to be that big whole singing, whole dancing, drama, theatrical should we go and hug trees kind of thing, and really it's just about building links and connections and relationships with maths. They build on things they've learnt before and apply it to new stuff as well ... so creativity … it's making links and seeing the links between two things. Also today's lesson … I think it brought out their investigating skills and their thinking skills … so I think the lesson, it allowed them to think, and it was creative in that sense too.*

Teacher L's perception of pupil creativity as the creating of something unique switched to the view that in mathematics learning creativity occurs through creative thinking, through building links to connect mathematical knowledge and through understanding mathematical relationships. As defined by Schoevers et al. (2019), Teacher L moved towards the view that creativity in mathematics learning concerns pupils making connections between previous learning and new learning, and the linking together of mathematical concepts.

Like teacher K, Teacher L revised her description of creativity as 'all singing all dancing'. It was interesting that initially both teachers used the same expression, 'all singing all dancing'*;* it suggested that they both conceptualised creativity as a special event that only occurs once in a while. This relates to the observation made by Claxton (2006: 352):

> In education, especially at primary level, despite protestations to the contrary, creativity is often treated as if it (a) is specially related to the arts; (b) involves a concentrated episode of colourful, rather manic, activity; (c) is something that everyone can engage in equally—provided only that (d) they are allowed or encouraged.

However, during the data collection process both Teacher K and Teacher L moved away from this characterisation of creativity as '*all singing all dancing'* towards a greater understanding of everyday creativity (Craft 2000).

Teacher R was also very reflective of her own practice throughout the project. This is what she said during interview three:

> *Well I was thinking about general creativity, going back to a question that you asked me, and I've kind of come full circle with it. Thinking about the new curriculum and whether that helps or not with creativity, I've thought myself round in a circle really. I think … because what I was thinking of is choice … schools have the same choice of how they design their calculation policy, but actually you can, you know, you can still teach in a really creative way and that's down to the teaching in a classroom and the teacher in a classroom, not necessarily the curriculum itself. You can present the maths in a very spoon-fed formulated way, or you could really make them think and work things out for themselves, rather than just giving them it, and that's down to good teaching, whatever the curriculum is, so I've kind of gone full circle with that.*

Teacher R's perceptions about pupils' creativity in mathematics learning seemed to change as she reflected on how to conceptualise such creativity. During interview three it seemed that she had thought quite deeply about how she could make mathematics more creative. She concluded that although the curriculum was prescribed, teachers have a choice about how to deliver the curriculum. Her comment, '… *you know, you can still teach in a really creative way and that's down to the teaching in a classroom and the teacher in a classroom, not necessarily the curriculum itself*' suggests a repositioning of herself in terms of the autonomy available to her to make decisions about her teaching. As argued by Ramos (2006: 198):

> Developing autonomy as a teacher goes beyond individual freedom from control by others ... Becoming autonomous teachers has to do with our commitment to explore, change and grow …

There are strong connections between teacher autonomy and learner agency. Teacher R reflected: '*You can present the maths in a very spoon-fed formulated way, or you could really make them think and work things out for themselves, rather than just giving them it, and that's down to good teaching, whatever the curriculum is.'* By acknowledging that she could find more space to make decisions about her pedagogy, Teacher R was also concluding that she could give the pupils more learner agency to make choices about their learning. As Ramos (2006: 194) asserts, when a teacher transforms their role in the classroom to take more control over their teaching, this change can be 'concomitant with the transformation' of the role of their pupils. Teacher R reflected that by changing her teaching to give her pupils more learner agency, it was possible to make mathematics more creative. She continued by saying that mathematics could be creative if pupils are given the freedom to decide how to solve problems:

> *I think in terms of the maths, the only way it can be creative is connected to problem solving and it's about the task and it's about the task connecting to their maths so that they can access it, but it's about their freedom, and it's about the teacher being the facilitator and scaffolding where necessary, but letting them go, finding their own way round.* (Teacher R)

By the end of the project, Teacher R seemed to be characterising creativity in mathematics as the process of pupils using creative skills to solve problems in their own way. She also recognised the importance of connecting new knowledge with old (Skemp 1989; Bell 1993).

From his responses to interview questions, Teacher V's perceptions of creativity in mathematics learning did not appear to change as much as the other four teachers. When asked about what creativity in mathematics looks like in practice, he responded*, 'It looks like children are actually enjoying themselves.'* During the second interview, he explained creativity in mathematics as giving pupils learner agency, *'letting them go where they want to'*. Teacher V also recognised that mathematics can be open-ended:

> *The point of creativity is it's meant to be open ended. So true creativity in maths is open ended, and that's where I think people fall down, because they think that maths is shut and closed, which too often it is, and that's why it gets compared so unfavourably with English, so 'oh, the children in English, they're so creative because you just let them go where they want to'. I think true creativity in maths should be that as well. So, that's why you shouldn't be saying*

> *to children all the time, 'Right, you'll just do this, you'll just do that, you've just got a page of sums.'*

Teacher V expressed his frustration about the constraints on his teaching that he felt prevented him from giving his pupils more open-ended tasks to develop their creative skills, stating:

> *A lot of the time you're just teaching a method and that's not going to harbour their creativity; it's not going to be as interesting for them as something like creating scale models of planes, or going out and accurately drawing the size of a dinosaur on the playground.*

Teacher V seemed to characterise creativity in mathematics learning as pupils enjoying themselves and having ownership of their learning to choose how to engage with open-ended tasks. He also thought that using outdoor spaces and different settings promoted pupil creativity.

Each teacher participant was keen to explore the idea of mathematics as a creative subject; they were also very willing to reflect on their own practice. During the second and third episode of teacher interviews, teacher reflection on creativity in mathematics learning was evident across all cases.

There were some significant differences in the teachers' perceptions of the skills pupils need to be creative when learning mathematics. For example, Teacher B thought that mathematical fluency helped pupils to be creative, while Teacher V spoke at length about the importance of logical reasoning and working systematically. There were also strong similarities in their responses. All teachers identified problem solving as being closely linked to mathematical creativity. They were also all in agreement about the importance of independent thinking and investigation. In addition they all seemed to associate creativity with more unusual, enjoyable tasks that promote 'fun'.

> Teacher B: *If you make anything fun, or you find it fun, the kids find it fun and it's creative.*

Teacher K: *I think that creative tasks are often more fun or more engaging …*

Teacher L: *I'd have more time, and more time to have fun with maths.*

Teacher R: *They're discovering it for themselves, which is what real mathematicians would do when they look … you know, for enjoyment.*

Teacher V: *It looks like children are actually enjoying themselves … There's evidence that creativity's going to make maths much more fun, much more engaging, much more memorable for them.*

This perception of creativity as 'fun' corresponds with the findings of Levenson (2013) in her study of mathematics tasks that promote creativity. Levenson (2013: 286) reports that rather than associating mathematical creativity with tasks that facilitate divergent thinking and the solving of problems, some teachers conceptualise it as something 'different or unusual', with many linking mathematical creativity with tasks that are 'fun'.

While resilience was specifically referred to by all teachers, and emphasised by all as a crucial creative skill, they also pointed out that it is a skill that many pupils struggle to develop.

Teacher B: *The problem solving is something that I personally found they might be slightly weaker on because you can give the kids a slightly different problem and they just stare blankly at you. They wouldn't know how to attack it. They can have a quite negative attitude.*

Teacher K: *From my experiences, they definitely struggle more with the open-endedness of a problem sometimes. Because it suddenly becomes 'Well what's the right answer?" Yeah, and they're always searching for that because they want that and they're used to doing that. They haven't got the perseverance and determination skills so instilling confidence is quite important.*

Teacher L: *Anything that's different, anything that's not how I might have demonstrated it in the lesson, can throw some children.*

Teacher R: *Well we have children who are very good at doing maths, they're very good at getting a page full of ticks, but they can't apply it, so give them in a different context and they fall down.*

> Teacher V: *For a lot of them, it just went completely over the top of their heads, because they'd never had really, and this is no disrespect to their other teachers, they've never had maths like that before. And a lot of them don't like that, because it's … and that's laziness, apart from anything else. It's lack of drive, and they're not used to it… they've just been spoon fed for six years, that's the problem.*

It is interesting that all teachers displayed concern over their pupils' lack of resilience to more open-ended problems when tasks were presented in a different way and were unfamiliar.

Two important questions arose from the analysis. Firstly why do pupils struggle to be resilient when tackling unfamiliar mathematical tasks? Secondly, how do teachers create a classroom environment where they feel confident about giving some of the ownership of the learning back to pupils to enable them to develop their creative skills, including their resilience? These questions will be returned to in the discussion in Chapter Six.

5.4.3 Teacher Creative Practice

The theme of teacher creative practice was identified from the following categories: the framing of tasks; pupil opportunity for creativity.

As explained in Chapter Four, three mathematics lessons were observed in each school. During the first two observations, the teachers were asked to follow their usual classroom norms and practices to provide data about the classroom environments and practices during day-to-day mathematics lessons. In each case, the first two observed lessons were largely instrumental, with some time-limited opportunities for pupils to make connections with mathematical ideas and to develop their fluency and mathematical thinking, particularly in Schools K, L and R. In Schools K and L there were more opportunities for peer collaboration and Teachers K and L also facilitated more in-depth teacher-pupil dialogue. However, across all cases, pupils were not given the time, space or learner agency to fully immerse themselves in the mathematics tasks and to engage with possibility thinking (Burnard et al. 2006).

A review of pupils' books containing work completed in mathematics since September showed many pages of exercises involving computation and standard algorithms, interspersed with rare examples of word problems. It is important to note that these workbooks did not contain all the pupils' mathematics work. During the observed lessons, initial efforts and early attempts at new procedures were written either on whiteboards or scrap paper that were later erased or discarded (Claxton 2006). Many jottings and attempts at calculations made by the pupils during the learning process did not remain 'visible' for very long (Claxton 2006: 252). The reasons for this were not asked.

The data from the teacher and pupil interviews and from the first two episodes of observed lessons evidence that the teachers were used to framing mathematics tasks in a way that was highly structured, with the aim of preparing pupils for the tests. For example:

> Teacher L: *Because of the tests there's a lot of pressure and we're already behind, so we end up cramming. I feel like I ... I want them to move on. I want them to move on (clapping her hands as she says this) ... right we haven't got time ... haven't got time ... haven't got time ...Yeah, and I feel pressured and I feel like I'm pushing them and not giving them enough time ...*

> Teacher V: *In your bog-standard lesson you're just trying to get them to show you that they can answer a question. We do lots of test-base questions, because that's going to help them pass the SATs. The tests require extremely solid and quick calculations skills.*

The third observed lessons were stand-alone and intended to give the teachers the opportunity to explore mathematical tasks that promote pupil creativity. The following paragraphs provide more detail about the third observed lessons, in particular the ways in which the teachers framed their chosen tasks. I have also presented the pupils reactions to these lessons here because I think it is important to read these directly after each lesson has been described and analysed; to record their views later in the thesis would make it more difficult to follow the thread.

School B had recently adopted the Mastery Approach to mathematics learning (Drury 2018). As Teacher B explained in interview one, this approach was interpreted by School B as one in which the whole class were given the same task, with all pupils working at the same pace, covering the same content in each lesson; he said that occasionally the task was *‘tweaked slightly’* but most of the time differentiation occurred through different types of questioning. There was little evidence of differentiation in the mathematics tasks provided during the three observed lessons. For the third lesson, Teacher B chose a task that followed on from the work the pupils had been doing in the previous two lessons; he asked the pupils to solve problems involving mixed number and vulgar fractions, using the bar model (NCETM n.d.). Teacher B was particularly enthusiastic about the use of the bar model to support mathematical fluency and it featured strongly in all of his observed lessons. In the first interview Teacher B told me that he uses the bar model in most lessons to help develop conceptual understanding. He said that in his eyes the bar model particularly supports learning among *‘the lower ability pupils’*: *‘That’s the thing, that traditional lower ability find it easier to use the Bar Method and then to be able to explain why something’s happening more than they would in the abstract world of just numbers themselves.’*

In School B, the pupils were given strips of paper (bars) to help them solve problems that required them to add and subtract a combination of mixed number and vulgar fractions. The resources were pre-prepared, with the pupils given some explanations about how to solve the problems. This task did offer some affordances for creativity but unfortunately the task required prior knowledge and understanding of some specific mathematical concepts that pupils BA, BJ, BS and BZ did not have. The gaps in their knowledge and understanding were too wide for any dialogue or open questioning to be of any support. Without the necessary mathematical knowledge and skills, the pupils were unable to act on the affordances available.

During the second pupil interview, the pupils in School B displayed a very negative attitude to this third lesson. They talked about *‘hating fractions’*, not understanding the bar method and being moved on to new concepts '*too quickly'* before they had enough time to practice previous learning. BS said, '*I felt like crying. I'm not good at fractions and I'm worried about them.'* BA then contributed, '*I just wanted the lesson to finish*' to which BJ added, *'I tried but it was so hard'.*

These data, highlighting the negative attitudes of the pupils in School B, are closely linked to the discussion in the literature review about mathematics affect and pupils' self-efficacy. The data were not the result of any pre-planned questioning or probing and were not anticipated; it just happened that Teacher B selected four pupils to take part in the study who had developed a negative affective attitude to mathematics. As Beltrán-Pellicer and Godino (2019: 14) explain, the negative affective attitude displayed by pupils BA, BJ, BS and BZ is likely to be the result of 'a sequence of negative affective experiences in relation to mathematical learning'. Anxiety, frustration and fear of failure are all part of the affective domain that have a considerable impact both on the ways pupils engage with mathematics and on their achievement (Hannula 2012; Carey et al. 2019; Hannula 2020).

In School L, the data from third lesson revealed some significant contrasts to the other cases. The pupils in School L were asked to explore the relationship between the diameter and circumference of a circle, using string and rulers. All of the resources had been prepared for the pupils in advance and then laid out on the tables ready for the lesson. While the pupils were clearly engaged in the task, the teacher guided the process throughout. Step-by-step instructions were given for each stage of the lesson. Although there were regular opportunities for pupil participation and for pupils to work on the task independently, the creativity that may have emerged if the pupils had been left to fully immerse themselves in the task was constrained because Teacher L stepped in frequently to intervene. However, Teacher L did provide some opportunities for creative thinking by asking open questions and by encouraging the pupils to share their ideas; she demonstrated respect for the pupils' contributions through her follow-up comments and by asking further questions (Schoevers et al. 2019).

In addition, the way the pupils were organised in School L differed from the other cases. Through a Kagan cooperative approach to learning (Kagan 1990), the pupils were grouped in teams of four, with pupils LC, LD, LN and LT working together as one team; the pupils in each team were mixed-attainment levels. From the classroom observations, it was clear that the Kagan approach facilitated peer collaboration and pupil-to-pupil dialogue. As discussed in Chapter Two, when effectively managed and established as part of the classroom ethos, peer collaboration can support both creativity and learning in general (Dennen and Burner 2008; Warwick et al. 2010; Williams and Sheridan 2010; Craft et al. 2013). Another aspect of collaboration identified from the School L data was cognitive apprenticeship (Dennen and Burner 2008). With pupils organised in teams, peer coaching was encouraged, with one child acting as an apprentice and a more capable peer acting as a coach. Cognitive apprenticeships occurred during all observed lessons in School L, with pupils working together cooperatively.

An interesting finding was that even though the task chosen by Teacher L for the third observed lesson was heavily teacher directed, the way in which pupils LC, LD, LN and LT were grouped promoted collaboration and some creative thinking; there were time-limited opportunities for conjecture and for posing and answering questions. The data suggest that the Kagan approach to learning had enabled Teacher L to establish a classroom ethos in which pupils understood the rules of effective collaboration (Warwick et al. 2010) and had learnt to respect the knowledge, opinions and actions of others in their group (Williams and Sheridan 2010).

In the interview following the third lesson, Teacher L told me that she had spent the whole of Sunday preparing the lesson and making the resources. I asked her, ‘*Was that because I was coming into the lesson? Would you have spent that much time on it anyway?’* She replied:

> *No, I reckon I probably wouldn’t have done it like that. You wanted me to do something creative and so I tried something different. Normally, I just probably would have shown them the basics and gone … this is how you calculate it. Because at the end of the day, in the test, and*

> *this is really bad, I'm not going to get a piece of string out for them and show it. They need to know the formula for pi for the diameter and radius. All they'll be doing now is Pi calculations, and I'll be teaching them that is how you do it … but I do I think by doing it that way today they will have made stronger links and understand it more.*

While acknowledging that the lesson helped developed the pupils' conceptual understanding, there was a conflict for Teacher L between appreciating the importance of developing pupils' creative skills and preparing them for the tests; she was open and honest about this conflict, highlighted by her comment, *'this is really bad'*.

The Pupils in School L were very positive about the third observed lesson. LD thought that the lesson had made him think more *'to figure out puzzles'*, while LT thought she had '*to think about loads of different things at the same time'*. LN commented, '*You had to use your brain more today and you really had to think hard about it and how you were going to use the string to measure.'* LC, LD, LN and LT also approved of being grouped into teams of four and felt supported knowing that there was always someone in their group they could choose to ask for help if they needed it; their attitudes emphasised the value of cognitive apprenticeship (Dennen and Burner 2008). LN explained, *'If somebody doesn't know something, the other person will and they can explain how they know it'.* Then LT added*, 'I think it really helps when you've got all these different parts of the group and somebody might be really good at this and another person might be really good at this and then when you all work together you build like a picture'.*

In School R the pupils in Year 6 were set, with Teacher R teaching the top set. During the third lesson, Teacher R chose a problem-solving task, involving all four operations. This was a challenging task and a good choice for promoting creative skills. Like Teachers B and L, Teacher R introduced the task, went through examples with the pupils and talked a great deal about the necessary problem-solving skills the pupils would need to solve the problem. As in Schools B and L, the introduction to the task was heavily teacher directed with explanations given on how the problem could be solved. The pupils were told they would need ‘resilience’ to complete the task and were asked what this meant; one child put up his hand and offered a definition as *‘don’t give up’*. After ten minutes of talk and explanation, the pupils were given the opportunity to tackle the problem. After nearly seven minutes, the teacher offered further support and explanation; the children were then given another three minutes to work independently. The longest episode of independent problem solving before any teacher intervention was just under ten minutes. During the times the teacher provided support, she regularly asked the pupils if they had used efficient strategies to solve the problems, suggesting a tension between creativity and efficiency. Teacher R also talked about learning hurdles that required resilience to overcome. The pupils had the opportunity to pose questions, to conjecture and to be self-determined; there were no observed opportunities for risk taking, imagination and immersion because learner agency was so restricted.

The pupils in School R all expressed confidence in their mathematics learning. I asked if they often did tasks like the ones in the third lesson. Pupil RZ responded with, *‘No, never that I can remember’,* with RF adding, *‘We do lots of working out like addition and subtraction’*, to which RD replied, *‘Yes, lots of that.’* They said they preferred their *‘usual lessons’* (RN) because they were *‘good at sums’* (RD) and today’s lesson *‘was harder’* (RZ).

In School V the pupils were usually grouped by attainment and the tasks were differentiated accordingly. The third observed lesson was very different from usual classroom practice. During this lesson pupils were presented with a mathematics task that lasted for most of the school day, focussing on exponential growth of infection during an epidemic; this task required pupils to explore how quickly a virus could infect a community, and eventually how people could become immune and resistant. At the start, the teacher informed one pupil that they were infected; the identity of this child was kept secret from the class. The children were asked to walk around the classroom while the infected child whispered in the ear of another child, ‘You’re infected’. This continued for several rounds, with an infected child infecting another child each time; after three rounds the infected children became immune. The task continued for most of the morning. In the afternoon, two more Year 6 classes joined Class V and the task was repeated in the playground. The pupils were able to see from the tally charts how quickly the infected numbers grew and were given a sound introduction to exponential growth (oddly foreshadowing the current Covid-19 epidemic, preparing them to understand the exponential growth of Coronavirus). For the remainder of the afternoon, Teacher V discussed the data with the pupils and then they recorded it on their own graph. The presentation of these graphs was heavily teacher directed; however the pupils were able to choose the scale of the graph and the colour scheme.

While there was certainly some evidence of playfulness, collaboration, questioning, imagining, and mathematical thinking taking place with pupil participants VA, VB, VF and VS, the opportunities for pupil creativity were constrained by the way the task was framed. Although interesting and memorable, the task facilitated more teacher creativity than it promoted pupil creativity. Teacher V seemed to conceptualise creativity in mathematics lessons as a combination of teacher creativity and pupil enjoyment, rather than pupils using and developing their creative skills by engaging with complex, unfamiliar problems.

The NACCCE (1999) highlights the distinction between teacher and pupil creativity. Teacher creativity is defined as ‘using imaginative approaches to make learning interesting and effective’ (NACCCE 1999; cited in Jeffrey and Craft 2004: 4). ‘Teachers can be highly creative in developing materials and approaches that fire children’s interests and motivate their learning’ (NACCCE 1999: 89). Levenson (2013: 270) reports that many teachers associate mathematical creativity with teacher-directed creativity that ‘relate to teachers’ acts that reflect back on the teachers being creative’. Professional development opportunities to explore mathematical tasks that explicitly promote pupil-directed creativity can support teachers in distinguishing between teacher-directed and pupil-directed creativity (Levenson 2013). For creative teaching to achieve creativity in learning, the teachers should pass some of the control of the learning back to the learners (Jeffrey and Craft 2004). Teacher creativity is a key aspect of creative pedagogies and it is important that teachers model creative behaviour and experiment with their own practices. However, my data indicate that teacher creativity does not automatically lead to pupil creativity; children also have to be given tasks that afford creativity together with the time, space and learner agency to engage creatively with these tasks.

It is also important to distinguish between learner agency and learner participation. The pupils in School V did participate fully in the lesson; however because the teacher had control of the lesson with very little of the ownership of the learning passed to the pupils, there was clear evidence of learner participation but no observed evidence of learner agency. While pupils VA, VB, VF and VS reacted very positively to their statistics task, enjoying the drama, with the opportunity to be active in an outdoor setting, they were not given the learner agency necessary to enable them to fully use and develop their creative skills. After the lesson, Teacher V reflected:

> *I mean it's just a nice way to get them to really think about what the graphs actually showing. Yeah, and it gets them a little bit more engaged than they would be otherwise. If I just gave them a bunch of graphs and a bunch of questions, they would have been really bored, is the truth, you know, which I could have done for two days but … doing it this way was more creative.*

During the second pupil interview the pupils (VA, VB, VF and VS) all said that they had really enjoyed this mathematics lesson but had been scared by how quickly the disease spread. They liked the drama and seeing how quickly the numbers increased and it was something different from their usual mathematics lesson. When asked if they had this kind of lesson often VF replied, *'No we've never done this kind of thing before in Year 6'.* They were very enthusiastic about lessons from the past that they had enjoyed. VB said, *'If you do something really fun you remember it',* with which they all agreed enthusiastically. VS then added, *'Not just fun, something different like a challenge'*, with VF replying, *'Yes something new like a challenge'*, to which VA replied, *'Yes, not the same thing all the time, something new'*.

The most striking example of a mathematics lesson that offered affordances for pupil creativity that were acted on and realised was the third lesson observed in School K. School K had recently adopted the Mastery Approach but was in the early stage of implementation. As part of regular classroom practice, pupils were given differentiated tasks, but during the third lesson all pupils worked on the same tasks. Teacher K's third lesson focussed on the mode, median and mean. The pupils were asked to work in pairs on tables of four, with all four pupils on each table allowed to collaborate and discuss their strategies and solutions together; each pair was told to show their workings on large pieces of paper. Teacher K gave the pupils the time and space to grapple with these problems and to work independently. KC, KJ, KT and KW worked in pairs and also worked collaboratively in a team of four, engaging in possibility thinking and collectively using creative skills through interaction and cooperation (Craft et al. 2013).

Similar to Teacher L but to a greater extent, Teacher K asked open questions and encouraged the pupils to share their ideas and strategies (Schoevers et al. 2019). At one point, a few pupils (including pupils KJ and KW) were struggling to identify the median of a set of numbers:

12 8 15 18 9 5 1

Teacher K asked one pupil who had calculated the median to explain what he had done. The pupil explained, '*You have to put the numbers in order and then the median is the one in the middle',* at which point another pupil interrupted with, *'Or you can just half the largest number.'* There was a pause and then a girl put up her hand and said, *'I think that could be a coincidence.'* Teacher K asked the children to look at the numbers:

1 5 8 9 12 15 18

He then asked them why some pupils thought that to find the median you could just halve the largest number. There was some discussion about this and then he asked all pupils to test the theory by choosing another set of 7 numbers and seeing if halving the largest number still worked. Two of the four pupils (KT and KC) chose the following numbers:

20 12 9 46 16 8 27

They rearranged these in order and identified the median as 16:

8 9 12 16 20 27 46

KT and KC had clearly understood what they had been asked to investigate because they were able to say that 16 was not half of 46 and therefore that finding the median by halving the largest number in the set was an incorrect mathematical procedure and a misconception. Teacher K asked the pupils to report back on their findings and some shared their examples. He then asked them to do a final check with another set of 7 numbers. The pupils concluded that it was just a coincidence that the median was half of the largest number in the first set of numbers.

By asking them to test the misconception, Teacher K had aroused the pupils' curiosity and they were keen to resolve the issue. Having corrected the misconception, Teacher K stood back to allow the pupils to continue working on the problems independently. Teacher K positioned himself as a 'meddler-in-the-middle' (McWilliam 2009), providing as much support as necessary without actually giving the answers. Through stepping in with open questions to engage the pupils in creative thinking, and by standing back to give the pupils the time and space they needed for learner agency, Teacher K framed the tasks so that affordances for creativity were made available to pupils KC, KJ, KT and KW that they were able to act on and to realise. During the second interview, pupils KT, KC, KJ and KW expressed their enjoyment of this third lesson and wished they could have more lessons like this because, *'it made me think harder'* (KT), and *'it wasn't boring'* (KW).

Within this theme of creative practice, there were a few striking similarities and differences between the cases. School K was different to the other cases because of the way Teacher K framed the task, allowing the pupils the time and space to immerse themselves in the task; this meant that pupils KT, KC, KJ and KW were able to act on affordances for creativity and to realise them. While Teacher B chose a task that afforded some pupil creativity, unlike in the other cases the task required prior knowledge that the pupils did not have, meaning that they were unable to connect new knowledge with old (Bell 1993); any affordances for creativity could not be acted on and realised. The tasks chosen by Teachers L and R had the potential to offer affordances for creativity but were heavily teacher directed, thus constraining pupil creativity. However, Teacher L did provide some affordances for creative thinking by allowing the pupils to work collaboratively in groups for short periods (Sawyer 2003; Craft et al. 2013). While Teacher V chose an enjoyable, memorable task that allowed him to be ‘creative in developing materials and approaches that fire children’s interests and motivate their learning’ (NACCCE 1999: 89), this task did not do much to promote the pupils’ creative skills as they were not given enough control of their learning (Jeffrey and Craft 2004).

To support my analysis of opportunities for pupil creativity during the third lessons, I referred to the revised model of Burnard et al. (2006: 257), as presented on page 46. I looked at the data for evidence of pupils using the creative skills and features of possibility thinking included on this model.

Playfulness featured in all cases, made possible by humour, dialogue, positive teacher and pupil relationships, and good levels of pupil participation. Some opportunities for conjecture and posing questions were also observed in all lessons. Resilience, which all teachers referred to in the interviews as an important creative skill, was observed but not consistently in all of the lessons. Some opportunities for resilience were observed in Schools L and R but these were limited as these lessons were heavily teacher directed, putting restrictions on learner agency. In School V the only resilience required of the pupils was in terms of the stamina needed to continue with the same task for much of the school day; there were no opportunities for resilience as a creative skill. There were opportunities for resilience afforded by the task chosen by Teacher B but the pupils were not able to act on these affordances because the task was too difficult. Teacher B insisted that all pupils used the bar method to calculate the problem. In spite of the difficulties they faced, three of the pupils (BJ, BS and BZ) persevered for most of the lesson. However, this did not result in any realisation of affordances for creativity because they did not have the necessary knowledge or skills.

Opportunities for resilience were closely linked to opportunities for many of the other creative skills. Lack of opportunity for resilience meant that pupils in Schools B and V were not required to be flexible and adaptable; neither were they required to take risks, be innovative or immerse themselves in the tasks. In Schools L and R the tasks afforded some opportunity for flexibility, intentionality, adaptability and extrapolation, all of which were acted on by pupils; however, the way the teachers modelled and directed each stage of the lessons meant these opportunities were limited as pupils could not fully immerse themselves in the task.

Teacher K’s third lesson was different from the other cases because in Case K pupils were able to be creative. The tasks chosen by Teachers R and L were very similar to the task chosen by Teacher K in that they offered possibilities for affordances for creativity. However, while Teachers L and R demonstrated how the problems could be solved before the pupils had a chance to investigate them, and then stepped in to intervene frequently throughout the lesson, Teacher K stood back for longer periods, giving the pupils the time and space to explore the problems (Burnard et al. 2006; Craft et al. 2013). The pupils in School K had time to think at the edge (Claxton 2006) and to be innovative; in doing so they needed to be resilient, take risks and immerse themselves in the tasks.

There were significant constraints on risk taking, immersion, and innovation in four out of five of the third observed lessons (B, L, R, and V), caused by lack of time and space and the way the teachers controlled the lessons. Classroom culture and practices were so ingrained in Cases B, L, R and V that there were few opportunities for learner agency; as a consequence pupil creativity was significantly restricted. The pupils were not given the space they needed to work independently on the problems because teachers were concerned about time and loss of control. As Galton found in his 2008 study:

> When creative practitioners initially set up situations designed primarily to engineer 'cognitive conflict' so that the pupils are forced to think 'out of the box' teachers are often concerned about the lack of structure which they fear will result in an unacceptable performance.
>
> (Galton 2008: 34).

The first two lesson observations suggested that the usual classroom practice of all teachers was to carefully direct and model each stage of the learning. For the purpose of teaching pupils new mathematical knowledge and skills, modelling mathematical structures and procedures is very helpful; however to promote pupil creativity, a different type of modelling is needed. By modelling creative behaviours (Cremin and Chappell 2019), teachers encourage children to adopt these behaviours in their learning. For example, if teachers take risks with their own practices and 'break conventions', trying new ideas and investing time in discussion and critical reflection (Cremin and Chappell 2019: 19), pupils will be encouraged to experiment and to take risks themselves. It is also important that teachers pose questions such as 'What can I do with this?' and model 'what if' thinking (Burnard et al. 2006: 245). Teacher creativity, including the modelling of creative behaviours, supports pupil creativity (Jeffrey and Craft 2004). However, when a teacher models how a problem should be solved, giving instructions on the methods and strategies pupils should use, creativity is constrained. Only Teacher K changed his practice to reposition himself as a meddler-in-the-middle (McWilliam 2009). He managed the difficult balancing act of stepping in to provide necessary support, while standing back to give the pupils some ownership of their learning to make decisions and to be creative (Craft et al. 2012).

Because of the perceived pressures of time and high-stakes tests, all teachers struggled to see how creativity could be part of their everyday mathematics lessons. However, when given autonomy to design a lesson with the central aim of promoting pupil creativity, four out of the five were either unsure how to construct such a lesson or lacked the confidence to do so. In four of the cases one of the biggest constraints to pupil creativity was the way teacher-directed learning dominated pupil-directed learning.

The next sections contain an analysis of the data collected from the pupils.

5.4.4 Pupil Perceptions of Mathematics

This theme was identified from the categories pupil perceptions of mathematics learning and pupil perceptions of mathematics as a subject. While the theme does not relate directly to the RSQs, the conversations I had with the pupils about their views on mathematics provide an important background to help understand how the pupils perceived and engaged with different types of mathematical tasks. I decided to include the data from this theme, as they provide important insights into the quintain: affordances for creativity during mathematics learning.

During the interviews, I wanted to find out which mathematical skills the pupils perceived to be the most beneficial to their learning. I asked them:

> *Can you think in your head of somebody that you know that you think is really good at maths, and it could be yourself, ... and then think about what it is that you think those people do that makes them really good at maths. You've got this person in your class and you think wow they're fantastic at maths. What are they able to do?*

Across all cases they considered being quick to give a correct answer of great importance. For example: In School B, pupil BZ said *'They're really fast and I'm slow'*; In School K, pupil KW said, *'They're able to be fast ... I'm quite good at maths but quite like slow at maths like ... I won't get all the things done but with Sam umm ... he like ... he knows his times tables well and he can like say them you know quickly ... yeah, really fast';* In School L, pupil LC said, *'Like they're just a genius. They're so fast and they just say it straight away and get the right answer;* In School R, pupil RF said, *'If you are good at maths you would be really quick at umm ... finding answers to questions';* in School V, pupil VB said, *'You have to be quick with your brain'.*

When these responses were given, other participants in each case agreed by uttering words and sounds of affirmation. It seems that their experiences of mathematics learning had led the pupils to believe that being the fastest to the correct answer was the most important factor for being good at mathematics. Maybe the only way to change this perception is to give pupils greater learner agency to engage with the process of possibility thinking in tackling challenging problems. Perhaps if teachers gave a higher profile to the creative skills needed for possibility thinking, pupils would begin to see that rather than speed, skills like conjecture, extrapolation, innovation and flexibility are far more important. However, as Teacher L pointed out:

> *We're being asked to teach one method and one method only so they can be efficient … and then that's your straightjacket so how are you supposed to be creative with that? We've got to prepare them for this arithmetic paper and they've only got thirty minutes to answer all those questions. It's ridiculous how quick they need to be. We can't just let them sit around choosing how to do things their own way.*

Although it was not one of the questions I asked, some pupils expressed apprehension about the impending SATs, with others nodding and making sounds of affirmation as these thoughts were revealed:

> Pupil BS: *I'm worried about the tests.*
>
> Pupil KT: *My teacher always compares things. He says like 'Oh yeah, if you want to get a level 4 - I know we don't do levels anymore - but you'll have to get this and you'll have to get that. And if you want to be level 5 or level 6 you need to get into deeper understanding' - he speaks like that sometimes. I feel it's a bit near and I'm a bit scared.*
>
> Pupil LN: *If I can't do a test question I start panicking.*

During the interviews, I explored pupils' perceptions of the differences and similarities between mathematics and other subjects in terms of creativity. I asked them which subjects they felt they could be most creative in and whether maths can be a creative subject. All pupils gave interesting responses. In School B they felt they could be more creative in art because the teacher left them to their own devices more *'and no one marks our work'* (BJ) *'and we don't get tested on it'* (BA) *'and it's not just right or wrong'* (BS).

The pupils in School K thought that mathematics was often about right and wrong answers. They felt they had more chance to be creative in English and art, especially art. However, they did think they needed to be creative in mathematics when they had to think carefully about a problem and try different ways to solve it:

> *I think art, but that's just because ... that's what I think of when I think of creativity … I think you do have to be creative in maths but … I don't think it's the same type of creativity, but I think you still need to be creative. Because like if you're not creative in maths, you'll just think oh that must be that or, oh it must be this. But if you're creative you think oh it might be this, it might be this, it might be this ... you try that and then try something else* (KT).
>
> *I think it would be art because … I just think it is. You're not very creative in maths because it's mostly right or wrong …* (KC). (I interrupted at this point and asked: *Is there always a right and wrong answer in mathematics?*) KC replied: *Not all the time … but it's like what's 1 + 1 … and it's always 2 … although you do need to be more open-minded sometimes … with problems.*
>
> *I think it's either art or English because in art you can let your hair down ... you can just do what you like really and you can put your own spin on it and in English you can write really imaginative things and that can be creative. In maths much less so but I think you do need to be creative* (KJ).
>
> *I think ... umm ... when I think of all the like lessons and subjects ... art is a good example of being creative because when you do a picture like none of our pictures will be the same because we've either added something or not put something in and it can be like that in English as well; and also like drama ... it's like your own spin on it. In maths ... sometimes it can be creative but it's mostly a right or wrong answer or there's like ... so many right answers and so many wrong answers* (KW).

The pupils in School K thought that being open-minded, adaptable and flexible during mathematics learning was creative (‘*it could be very dull and boring to like not be like open minded’* – KC), with KT considering possibility thinking (‘*it might be this, it might be this ... you try that and then try something else’* – KT). However, they felt they were more likely to create something novel or unique in art, English or drama (‘*it's like your own spin* *on it'* – KJ and KW), (*'you can let your hair down … you can write really imaginative things'* – KJ).

In School L, pupils LC, LD, LN and LT discussed having to make more decisions and be more creative when the mathematics task was harder. LC said*, ' When it's hard I just start to think it through and sometimes I just ask people on my team when I'm very stuck and I can't work it out after a while'.* After some reflection, LT explained, *'I think in maths when it's more trickier you put more effort into it and when you've finished it you can look at it and you're like wow … and you compare it to an English story and you can see that it's much more better because it was hard and you feel good you did it.'*

Like the pupils in School K, the pupils in School L demonstrated an understanding of the need for creative skills when working on challenging mathematical tasks.

In School R, they also felt that they could be more creative in English or art than in mathematics. Pupil RF said, *'like in English when you're being creative you're thinking of lots of different ideas and there's no wrong answers and in maths there's always a right answer to everything'.* They explained that in English they could write about adventures and choose what to write but in mathematics calculations they had no choice. RD said, *'... for calculations you just need to like think hard and it's not really easy to be creative.* RZ replied, *'Not even thinking that hard.'* Imagination also featured in their conceptualisation of creativity in mathematics. They had a discussion about a word problem involving a cookie. *'Like you might like to think of ... imagine ... if it says like how big a cookie is or something, you're going to have to imagine how big it will be* (RF).

The responses from the pupils in School V were similar to those in School R. VA, VB, VF and VS all felt they had more opportunity to be creative in English (Literacy) than in mathematics. VF said, *'In Literacy there's more than one right or wrong answer but in maths there's one right answer',* to which VA added*, 'Only one right answer',* and VF followed with *'And many,*

many wrong answers'. VS then said, *'In Literacy you get to decide more what you do.'*

There were some differences in pupil perceptions of mathematics across the cases. The pupils in Schools B, R and V viewed mathematics as a subject characterised by speed and right or wrong answers. To a large extent the pupils in Schools K and L shared this perception but they also displayed awareness of the need for creativity during some problem-solving tasks.

5.4.5 Learner Agency

Learner agency is a theme identified from the following categories: time and space to develop and use creative skills; pupil choice and decision-making.

The concept of learner agency is explored in Chapter Two and defined as an individual's capability and opportunity to act, combined with their willingness and motivation to do so (Manyukhina and Wyse 2019). For pupils to experience learner agency it is important that mathematics tasks are not rigidly structured, giving pupils opportunities to chose their own path in tackling the problem, and to make choices about resources (Dyson: 2020).

Self-efficacy beliefs and affect also play a large role in how pupils choose to use learner agency. Tasks that are both too difficult and too easy can result in negative affect such as anxiety or boredom (Hannula 2020), preventing pupils from benefiting from the learner agency available to them. It is critical that teachers effectively assess the learning situation so that the challenge of the task can be adjusted to keep it at a suitable level for all pupils (Bell 1993). As Breen and O'Shea (2010: 44) argue, 'important points of contact between the actions of the teacher and those of the learner' during the lesson are essential in supporting pupils in completing challenging mathematics tasks; teachers must be proactive in providing support (Henningsen and Stein 1997). As evidenced in School B, pupils BA, BJ, BS and BZ were not able to access the task provided during the third observed lesson because it was too difficult; consequently, they could not connect and reuse existing knowledge to help them reach successful outcomes (Skemp 1989). During the lesson there were no 'important points of contact' (Breen and O'Shea 2010) to enable Teacher B to be able to adjust the task to a suitable level of challenge for these pupils (Bell 1993). Teacher B instructed the pupils to use the bar model to work out problems involving addition of mixed number fractions and vulgar fractions. Three of the four children stayed on task for much of the lessons, while the other gave up quite quickly; none of them were able to use the bar model to help them with the tasks and all of their solutions to the problems were incorrect.

During the second interview, I asked the pupils for their perceptions of the third lesson and the aspects they had enjoyed and those they had found more difficult. I did not specifically mention the bar method, but BJ told me, *'The bar method's a nightmare',* with BZ quickly responding*, 'It's a literal nightmare. I don't know how many lines we have to shade in and we have to use them all the time.'* As explained in Chapter Four, the pupil interviews were loosely constructed. In addition to the questions and tasks I had planned, these interviews were partly directed by what had been observed during the lessons, and partly directed by the pupils themselves. BS seemed very despondent about mathematics in Year 6 and the lack of opportunity she had to make decisions about her learning, claiming '*Maths is so hard in Year 6'*. Following a lesson that had left her feeling discouraged and defeated, without any prompting BS spoke openly about her negative perceptions of mathematics learning. I asked her what would help to make things better. She said, *'It would help if I could choose a different method and practice more. I'm not good at fractions and I'm worried about them. I wish I was allowed to practice them more so I get how to do them.'* BS expressed the need for more time to practice new mathematical knowledge and skills before moving on, and she wanted to be able to choose a method other than the bar method when trying to calculate a mathematics problem.

The pupils in School B were unhappy about having no choice about which method to use. The bar method was imposed on them, not only did they resent having to use it but from observing their struggles and incorrect answers, it appeared to be incomprehensible to them. These pupils wanted more choice in which methods to use and in which approaches to take when engaging with a mathematical task. They also wanted the time to practice, to enable them to become secure in new concepts before moving on to something more difficult. Perhaps if these pupils in School B had been given greater ownership of their mathematics learning, they would have been able to relay to their teacher their perceived needs and wishes as part of their learning process.

In School K, the pupils KC, KJ, KT and KW explained during the interviews that they would like more lessons like the mode, median, mean lesson as they were jaded by repetitive calculations that they already knew how to do. They spoke of their frustration that new, more challenging tasks were not given very often. They all strongly agreed with KJ when she said, *'I find maths boring sometimes when we've done something loads of times and go over it, and we all understand it already'.* KW added, '*We know how to do it but we still have to listen to the explanations',* with KJ then saying*, 'And even if we like do it with bigger numbers, like with adding and subtracting, it doesn't really make a difference. We do like adding two digit numbers together and that's really, really easy because we know how to do it. But even if it's with like a really long, long number, it's still the same knowledge and we know how to do it'.* KW complained, '*When we go over it, it's like there might only be two people that still can't do it ... what's the point of giving all of us it. I think it would be better if everyone would like move on to something else, but like the two people who still need to work on it might just instead like go to the art room'.* When I asked if repetition happened often, KT responded with, *'About a billion times*. *I agree you need to go over it a few times but sometimes I think we have gone over it a lot too much. I wish we could do more challenging things'.* KC said she liked learning *'something new'* in mathematics, to which KW added*: 'Yeah, new and intriguing'.*

While there was an acknowledgement that it was important to learn arithmetic computations, the pupils expressed frustration at having to revisit them repeatedly, even after they understood how to use them.

These examples of pupils feeling that their learning needs were not being fully met highlight an important aspect of learner agency. In School B, the pupils were disheartened because they did not have the necessary understanding or prior knowledge to productively engage with the tasks (Gresalfi et al. 2012; Kraft 2019). In School K, the pupils were frustrated because they wanted less repetitive, more challenging tasks. As part of a process of self-assessment, if pupils are able to signal both when they need support and intervention from the teacher to fill gaps in their knowledge, and when they are ready for something new and more challenging, then they have more learner agency. This aspect of learner agency is an important element of an ‘enabling context’ (Burnard et al. 2006: 258) in which pupils are involved in the assessment of their own learning and their own creativity.

During the three episodes of lesson observations, opportunities for pupil choice were limited. The pupils were told which task to do, sometimes differentiated depending on the pupils’ attainment levels; they were told which methods to use to solve the problems; and they were told which resources they needed to use in order to do this. The resources had been pre-prepared and were either distributed by the teacher at various points during the lessons or arranged on the tables before the start of the lesson. The one exception was in School K during the third lesson observation, when the pupils were allowed to choose how to proceed with no teacher intervention until it was clear it was needed.

When they reflected on the third observed lesson, the pupils in School K expressed a desire for more choice in their mathematics lesson:

> KW stated: *If I had a choice I wouldn't like do the same thing over and over. I think what we should do is like umm ... have different sheets for all things so we can choose what we need. Personally I find it difficult to like times a fraction by a fraction and so I'd probably want like a fraction sheet before SATs, just to help. But if someone is good at multiplying fractions they don't need that sheet; they need a different one.*
>
> KJ then added: *I think, umm ... it's good to for the teacher to ask why and how we know things, but sometimes I find it easier by like ... figuring it out for myself. I like ... I know how I got there, rather than saying, oh the teacher told me ... it's like finding out my own numbers and my patterns ... sometimes I find it hard like when teachers says*

> *this is a very good way to do it, ... but to be honest sometimes I want to do it a different way.*

These pupils were very articulate in expressing their views; they explained that they wanted more learner agency to direct their mathematics learning.

5.4.6 Possibility Thinking

Craft's concept of possibility thinking is defined in the introduction to my thesis and returned to in Chapters Two and Three (Craft et al. 2013). Possibility thinking is central to Craft's theory of 'little-c' creativity, and enables all pupils, operating in an 'enabling context', to engage positively and creatively in problem-solving activities, using a range of skills including imagination, questioning, risk-taking and self-determination (Burnard et al. 2006: 257).

The theme of possibility thinking was identified from two categories in the data: pupil engagement in the tasks; and pupil creative skills. The data from which this theme was identified were collected during the first and second episodes of pupil interviews; these interviews provided important data in answering the research sub-questions (RSQs) numbers two and four:

- What are the distinctive features of mathematical tasks that promote creativity?
- How do pupils perceive and engage with different types of mathematical tasks?

In this section, when discussing pupil engagement with tasks, the tasks refer specifically to the mathematics tasks from the NRICH website (NRICH n.d.-a) that I gave to the pupils during the first and second interviews. (Links to the selected NRICH tasks are provided in appendix 2.) NRICH offers a wealth of mathematics tasks designed by experts from the Faculties of Mathematics and Education at the University of Cambridge; they focus on problem solving activities that enable pupils to learn mathematics through exploration and discussion.

> Our rich 'mathematical tasks build students' perseverance, mathematical reasoning, ability to apply knowledge creatively in

> unfamiliar contexts, and confidence in tackling new challenges, enabling teachers to embed engaging, creative, rich mathematics in the reality of the classroom.
>
> (NRICH n.d.-a: para 4)

The pupils in Schools K, L, R and V were given the same tasks during the interviews. As explained in Chapter Four, I had already selected two tasks (‘Two and Two’ and ‘Presenting the Project) prior to meeting the pupils. However, during the data collection process I had to make an adjustment and find a different task for the pupils in School B. Pupils BA, BJ, BS and BZ had expressed negative views about their mathematics learning and lacked the prior knowledge needed for the tasks chosen for the other pupils. Also, the interviews in School B took place just before lunch and immediately after mathematics lessons that had left them feeling demoralised. BA, BJ, BS and BZ wanted to talk about the difficulties they were experiencing with mathematics before starting to engage with another task. Therefore, I only gave one mathematics task to the pupils in School B; this took place during the second interview. I selected one that I felt they would be able to both access and enjoy; the task chosen was ‘Tricky Track’:

> This activity gives children the opportunity to grapple with experimental vs theoretical probability, in an accessible and appealing context. It will be essential for learners to discuss their ideas with others as they work on the problem.
>
> (NRICH n.d-b: para 1)

To introduce the task, I explained that the pupils needed to work in pairs to throw two dice, taking it in turns, with one throwing the dice and one recording the score; the number they recorded the most often would be their winning number and they needed to find out which number that was. This was the only information I gave them and they were curious to find out more. After each pair had all thrown the dice six times I asked them if they noticed anything. BJ replied, *‘Twelve’s not got one’*. I asked if it was possible to make 12 and BJ replied, *‘Yes, 6+6’*. Then I asked, *‘How many ways are there of making 12?’* and BA said, *‘You could have 5+7’,* to which BJ responded, ‘*There’s no 7 on the dice’*. There was a pause and then pupil BS commented, *'You can only make 12 with two 6s.'* They continued with the task and then BZ exclaimed, '*Nobody's got a 1. It's not possible 'cos 1+1 is 2'*. BA replied, *'What?'* and BZ explained, '*You can't score 1 because 1+1=2.'* BS added, *'You can only score 1 with one dice'*. They carried on with the activity; then I asked them if they had noticed anything about the scores. BJ replied, *'I've got more 9s'*; BZ said, *'I've got more 6s'*; and BA and BS reported that they had more 7s.

The pupils were fully engaged, with lots of shouts of *'6, 7 and 8'*, with other numbers occurring occasionally. BA then exclaimed, *'7s the winner'*. After a pause, BJ said, *'It's because it's an odd number and there are more ways of making seven*.' BS asked, *'How many ways are there of making 7?'* Even though the lunch bell rang, they all began to explore how many ways they could make 7. BS then reported*, 'When you roll the dice ... more numbers can add to make 7, like 5+2, 6+1, 1+ 6, 5+ 2.*' BZ added *'and 4+3 and 3+4'.*

That was all we had time for, but before they left I asked them if they had enjoyed the task. They all said enthusiastically that they had. I asked them if they thought the task was maths and they all nodded. BS said, *'Yes because it's about numbers and there was lots of adding.'* BJ finished the conversation by remarking, *'It was maths because you were learning something but in a different way.'* The time available for the pupils to fully explore their task (Tricky Track) was limited; however, during the time that we had, all pupils immersed themselves in this task in a positive, playful way. They posed questions, conjectured and collaborated with each other.

Although, BA, BJ, BS and BZ had been disheartened by the mathematics lesson they had experienced immediately prior to this second interview, in the short period of time available, all pupils were able to use their creative skills and engage in possibility thinking as they worked together positively and collaboratively. The data indicate that during the 'Tricky Track' task the pupils were self-motivated to participate out of both curiosity and enjoyment. They made the following comments: *'I want to do this'* (pointing to Tricky Track) (BA); *'Are we using dice?'* (BZ); *'What do we have to do?'* (BS); *'Miss,* *can we start?'* (BA); *'This is fun.'* (BJ); *'I like this.'* (BZ); *''What's the winning number?'* (BA); *'Miss, I like this game.'* (BS).

As explained, the pupils in the other four cases, K, L, R and V were not given the task 'Tricky Track' because I wanted them to engage with something more challenging. The pupils in these four cases were all given the same two tasks. During the first group interview they were presented with the task 'Two and Two' (T&T):

> This problem offers an opportunity to practise addition in a more interesting and challenging context than is usual. It requires students to work systematically, record their progress efficiently and apply their understanding of place value.
>
> (NRICH n.d.-c: para 1)

'T&T' facilitates abstract, divergent and systematic thinking; it is much more challenging than it appears at first glance. In order to complete the task the pupils needed to understand column addition and to be able to add two 3-digit numbers together; they also needed a good grasp of place value. From talking to their teachers, observing in the classrooms and looking in their mathematics books, I felt that all pupils from Schools K, L, R and V would have the prior knowledge to enable them to access this problem.

When first presented with 'T&T' the pupils reacted with a mixture of curiosity and frustration; all groups were very curious about this unfamiliar task and wanted to make sense of it. The pupils began by discussing what the problem meant. Initially thoroughly confused, they offered many random suggestions as solutions. The reactions from all groups were almost identical, expressed by comments like, '*I'm confused'* (KW), '*It's doing my head in'* (LC), *'My brain's exploding'* (RD), *'This is so complicated',* (VS). However they all continued, demonstrating resilience. They also had to be adaptable because at first they did not understand what they had to do and some of the paths they went down were dead ends. Because of the abstract nature of the task, the first challenge was to understand that the letters TWO represented numbers. With some questioning from me they began to realise that both of the two three-digit numbers were the same and that each letter in the calculation represented a different number. I did need to step in to ask questions that guided their progress; however, they all had to engage in possibility thinking and really grapple with the problem for a period of time before they began to see how they could work more systematically to come up with solutions. Across all cases (K, L, R and V) the pupils displayed self-motivation, curiosity and perseverance.

The pupils in School K were missing half an ICT lesson to join me for this group task, typically a very popular lesson in Year 6; all pupils were very reluctant to leave the mathematics task to go to ICT, expressing the wish to complete the problem. A breakthrough came when KT announced '*F is 1 because if you add 999+999 it would equal a 1 in the thousands*'. This discovery spurred the group on, with all four determined to find a solution.

In School L, LD announced at the beginning of the task that he was only staying for half the session because he did not want to miss the class silent reading session, *'I've got 100 pages left of Harry Potter Four.'* At which point LC decided that he would leave half way through too. As part of the ethical process, it was agreed with the children and their parents that should a pupil wish to withdraw from the research project at any point they would be able to do so. Therefore, if pupils LD and LC had wanted to return to their classroom for their reading session they would have been able to. However when it came to the time to leave for reading, LD was so engaged in the task that he announced, '*I'm going to stay. I'm not going.'* LC then agreed that he wanted to stay too. After that the conversation continued like this:

> LD: *No! Them two numbers are the same. Maybe it's 5, 6*
> LC: *No, 928 ... 928*
> LN: *I've got 1856*
> LC: *928*
> LC: *Oh, can we carry on?*

To begin with, the pupils in School R were baffled by the task 'T&T'. RD said she was *'frustrated'*; RN said, '*It's kind of confusing'*; and RZ said he was *'stuck'*. They repeatedly asked for the answer, so I explained that there were lots of correct answers and that I was unsure if I had found them all. They needed encouragement to persevere and to become immersed in the task.

The pupils in School V reacted in a similar way to the pupils in Schools K and L. They found the task very challenging at first but they persevered and after a while they began to make progress with VF pointing out, '*It's got a thousand column'* and VA pointing to the numbers in the hundreds column and saying, '*So these two numbers have to add up to a thousand'.*

We did not have time to finish the task 'T&T' during the first group interview and so I left it with them to puzzle over and to come back and discuss in the second session. At the beginning of the second interview, we returned to the task and compared results. All pupils had made impressive progress and each one had at least three solutions. In School L, LN had found one solution that I had missed (846+846) which she was very pleased about. In School K, KT had worked out that W ≥ 5 because there has to be 1 carried to the hundreds column; he also pointed out that none of the other letters could equal 1 because F had to be 1. VF worked out that neither W nor O could be 0 because then U or R would also have to be 0 and that was not possible. They were proud of their solutions and discoveries and were keen to share them. It was an excellent task for provoking dialogue.

After reviewing their solutions to 'T&T', we spent the second interviews exploring a completely different problem — 'Presenting the Project' (PtP):

> This problem requires learners to use the different forms of data to answer questions. It is made harder by the fact that they will need to look at more than one chart/table/graph in order to answer a single question.
>
> (NRICH n.d.-d: para 1)

Like 'T&T', this task stimulated discussion; it was also very effective in promoting peer collaboration. When first presented with 'PtP', the pupils in Cases K, L, R and V reacted in a similar way to the first task (T&T), with curiosity and confusion, but this time with less frustration. While there was not enough time to fully complete 'PtP', all groups achieved positive outcomes. They were intrigued with the pie chart that offered no meaningful information, being quite imaginative in considering what the chart might represent. As the task was explored, the discussion followed similar paths:

School K: KJ, suddenly making a discovery, announced, '*Wait ... it can't be Saturday or Sunday because you're not in school.*' (Followed by cries of *'oh yeah'* from the other three). KT then said, *'so it can't be the ... ohhh, it's the 21st. I know it was a girl because ... it says on this chart (points to gender bar graph),'* after which KJ asked, *'who are the boys and the girls'*. KT pointed to one of the graphs and said to KW and KC, *'These are all the boys, on this chart here.'*

School L: LC informed the others, *'It's quite obvious which day it is because it's June. Only 21st works because the 21st is on a Wednesday and the rest are on Saturday and Sunday'* to which LN replied, *'So? What do you mean?'* LC explained, *'You don't go to school at the weekend.'*

School R: All pupils were puzzling over the graphs and the clues to the questions. RF commented, '*So on the day it has to be a birthday'*, to which RZ replied '*Oh right, so it's someone's birthday, look birthday lists by gender. Listen, look, there's the 10th. The 10th is on a Saturday so cross out the 10$^{th'}$*. RF then says, *'The 25th is on …'* and RZ interrupts with, *'Sunday'*. RZ then tells the others, *'So cross that one out then … and it's going to be 21st … Wednesday'*.

At the end of the second episode of pupil interviews, I asked the pupils to compare the two tasks I had given them. The pupils in School K agreed that while they had enjoyed both tasks, they preferred 'PtP'. KJ tried to explain her thoughts by saying that 'PtP' allowed her to choose which order to work things it out in, *'When you do that one (pointing to T&T) you have to work it out a certain way but when you do this one (pointing to PtP) you can work it out like …',* at which point KT interrupted with, *'… in many ways. It's a bit like that game Guess Who, when you have to ask questions and knock the people off and then right at the end when you only have a few people you can start to make better choices'*; they all agreed. Then I asked them if they thought 'PtP' was maths. KT replied, *'It's sort of maths. It involves maths but I don't think it's completely maths. That one's more maths'* (pointing to T&T). There was a pause and then KJ said, *'It's got maths in it but it's more of a puzzle'*. The KC added, *'I think this one (PtP) is more a maths problem and this one (T&T) is just more regular thinking.'* All four expressed a wish for more tasks like T&T and PtP during everyday mathematics lessons. Pupil KC also added that it was also important that they learnt arithmetical computations. She explained that she would not have been able to access the NRICH task (T&T) if she had never been taught how to understand and use column addition:

> KC: *We wouldn't have been able to do it because we wouldn't have known how to do the method. And you need to think about that quite a lot - about the carrying, in this puzzle.*

In School L there was lack of consensus about which of the tasks they preferred, although they agreed that they had enjoyed them both. LN said, '*This one* (PtP) *… you've got the information there and you've got to find it. The other one you have to work it out for yourself.'* LT added, *'This one* (PtP) … *is more problem solving because you've got to keep going back to look at the information you've got'*, to which LC added, *'Yes, and the other one is more just trying things out and seeing if it works because it's kind of like ... umm this and this and this … umm no that's not right … so this and this and this … til you figure it out.'*

In School R, pupil RN preferred 'T&T' because he liked addition; RD and RF preferred 'PtP' because they liked reading information and solving puzzles; while pupil RZ had no preference as he liked, *'problem solving and every type of addition.'* RZ also thought that 'T&T' *'was more direct maths because of all the addition'*. All four agreed that they had enjoyed both tasks.

In School V the pupils thought that 'PtP' was more difficult than 'T&T' and that because 'T&T' was set out in column addition it was more like the maths they were used to. They also said that they enjoyed doing 'PtP' because while it was *'hard'*, it was also *'a challenge'*. They also liked 'PtP' because it was a mixture of maths and English and they found challenges easier in English because they were more used to them.

When engaging with the NRICH tasks, the pupils in Schools K, L, R and V conjectured and used their imagination; they posed and responded to questions and were innovative in their thinking; they were also self-determined and resilient. All pupils took risks in trying to find solutions, displaying adaptability and flexibility when the first attempts they made were fruitless; playfulness also occurred regularly when they joked with each other or with me about the tasks. Both humour and playfulness helped to ensure that the pupil interviews were enjoyable for all. With varying degrees of support from me, the pupils were all immersed in the tasks.

Across all cases, the pupils collaborated well when engaging with the NRICH tasks, supporting the finding of Craft et al. (2013) that peer collaboration is an important feature of possibility thinking. On some occasions the pupils worked in pairs, acting in competition with the other pair; this collaborative competition was constructive, acting as a motivator to persevere (Williams and Sheridan 2010). There was also evidence of ‘cognitive apprenticeship’ (Dennen and Burner 2008: 426), with different pupils adopting the role of coach and apprentice. These roles were fluid; sometimes the coach became the apprentice and vice versa. The pupils engaged in effective collaboration, assuming different roles and responsibilities as the learning progressed (Warwick et al. 2010).

Two additional features of possibility thinking not included on the Burnard et al. model (2006: 257) were identified — curiosity and noticing. All three tasks (Tricky Track, T&T and PtP) were unfamiliar to the pupils, causing some ambiguity at first. However, the pupils were very curious to find out more about the tasks and how to find solutions. Their curiosity seemed to counterbalance their confusion and to spur them on; they were motivated to find out what the tasks were about. The pupils also used their learner agency to notice important mathematical ideas and relationships when solving the problems; they then made decisions about what they noticed to help them reach positive outcomes. Noticing is important in supporting pupils' creative reasoning and the development of their cognitive skills.

> … what students notice mathematically becomes a basis from which they generalize their learning experiences to reasoning in subsequent situations. A variety of different ways of reasoning in a later situation may be possible, but each is grounded in what was noticed.
>
> Lobato et al. (2013: 844-845)

Noticing supports creative thinking because the mathematics that pupils notice in one situation can be used to help solve an unfamiliar problem in a different situation (Lobato et al. 2013). It is possible that noticing is a feature of possibility thinking specific to mathematics.

In all cases, it was impressive to see how the pupils engaged with the NRICH tasks and how keen they were to find solutions, collaborating with each other in a process of possibility thinking (Craft et al. 2013). However, there were differences across the cases. When working with the pupils in Schools B, R and V, particularly B and R, I had to step in more frequently with prompts, questions and encouragement to help them to stay on task and persevere. In Schools L and K the pupils worked together more collaboratively, supporting each other and engaging in productive pupil-to-pupil dialogue; when working with the pupils in these two schools I was able to stand back for longer periods and let them work independently. On reflection, these differences were not surprising. During the first two observed lessons in Schools K and L, the organisation of pupils together with teacher-pupil dialogue and peer collaboration provided small pockets of opportunity for creative thinking; the pupils were encouraged to collaborate. In School B, the pupils had demonstrated negative affect related to their mathematics learning, which could explain why they needed more support when engaging with 'Tricky Track'. One interesting difference was that when first presented with 'T&T', the pupils in School R demonstrated the least resilience. These pupils were in the top set and had expressed confidence in their mathematics learning; yet when presented with an unfamiliar task, they were frustrated that an answer did not immediately come to mind. RD, RF, RN and RZ did persevere, take risks and immerse themselves in the task, but at first they needed more encouragement and support to do so. Through reflexive thinking, I was able to see from these data that it is a false to assume that the highest attaining pupils are always the most resilient when facing new challenges.

While there were differences between the cases, with varying degrees of support from me clear evidence emerged from the data of all pupils acting on and realising the affordances for creativity made available to them by the NRICH tasks. Linking this back to Gresalfi et al.'s concept of the 'dynamic intention', 'between affordances, effectivities and intentions' (2012: 252), the pupils were able to access the tasks though previously mastered mathematical skills and experiences (their effectivities); they were also motivated to engage with the tasks. The expectation was that if the pupils persevered they would eventually succeed in finding positive outcomes.

I had the luxury of working with small groups of pupils, interacting with them as they engaged with unfamiliar problems and observing how they responded to opportunities for creativity. It is clearly much easier to manage open-ended, unfamiliar tasks and to judge when to stand back and when to step in when working with a small group of pupils than it is with a class of thirty. There was also the novelty factor; they all felt proud of being selected for this research project. I had their support from the outset. Even LD and LC, who were the least keen to start with, changed their minds and stayed for the whole session when they became so immersed in 'T&T'. Across the cases, pupils willingly missed playtime, ICT, and silent reading, and even delayed their lunch, in order to continue with the tasks. Working with these children was a privilege that resulted in rich, interesting data.

In this chapter, I have both presented the methods of data analysis and compared the five case-study primary schools to look for themes, commonalties and differences (Stake 2006). I understand that some authors advocate the more traditional approach of including the methods and procedures of analysis in the methodology chapter to keep methods and interpretation separate, for example Wolcott (2001). However, there are others who promote a more creative approach by breaking with tradition (Barad 2007). When making decisions about my research design and thesis structure (Murray 2017) I took an onto-epistemological stance, with the view that knowing and being cannot be separated. As Barad (2007: 185) argues, ‘[p]ractices of knowing and being are not isolable, they are mutually implicated’. The phenomena that we seek to research cannot be separated from the way in which we research it; there is ‘an ontological inseparability between research-objects and research-apparatuses’ (Sauzet 2015: 43). Therefore in this chapter, I have broken with tradition and taken a more creative onto-epistomological approach (Barad 2007; Sauzet 2015); I have done this by fusing the methods of data analysis with the analysis, interpretation and presentation of the participants’ stories. Within this chapter there is also a nexus of policy and practice, showing both the interplay between teachers and pupils and the pupils and teachers reflections over time. My decision to structure the thesis in this way makes a research contribution to knowledge.

The next two chapters present a discussion of the data findings and also relate the participants’ perceptions and experiences to the wider culture of education policy and practice (Kvale 2007).

CHAPTER SIX
Discussion of the Findings

6.1 Overview

The discussion is organised into two chapters. This chapter explores new insights that my study reveals about creativity in mathematics learning, linking findings from my data to the literature. The next chapter presents the new contributions my research brings to the field, specifically related to the primary research question.

6.2 Constraints on Affordances for Creativity

This section considers what the data reveal about the constraints acting to hinder affordances for creativity during mathematics learning.

6.2.1 The Environment, Pedagogy and Policy

In order to establish a classroom environment that affords pupil creativity during mathematics learning, teachers need both the autonomy and the training to enable them to do so; they also need freedom from policies that severely constrain possibilities of developing creative pedagogies.

The evidence from my data draws attention to a conflict between the teachers' recognition of the importance of open-ended tasks that allow pupils to take risks, become more resilient and to develop confidence in themselves as mathematicians (Craft 2000) and the ways the teachers felt external policy limited what they saw as possible to do. A culture of performativity (Ball 2003) featured prominently as a constraint on creativity during mathematics learning. While the current demands of performativity and accountability continue, school leadership teams are unlikely to give teachers the autonomy to make significant changes to their pedagogy (Olgier 2019); however, if headteachers do decide to undertake such reform, in the current climate the accountability regime will likely present many obstacles (Solomon and Lewin 2016).

All teachers in my study voiced concerns about what would happen if they changed their established classroom norms and practices to provide tasks that offer affordances for creativity during mathematics lessons. They all expressed anxiety about the impact such changes would have on pupil outcomes in tests, with two (Teacher B and Teacher V) also raising concerns about the impact these changes could have on pupil behaviour. All were apprehensive about the implications of giving pupils more ownership of their learning, with Teacher L asserting: '*We can't just let them sit around choosing how to do things their own way'.* My data suggest that these teacher concerns acted as constraints on pupil creativity. As argued by Harris and de Bruin (2018), a common feature of creative pedagogies is the way teachers balance learner agency with structured classroom practices. To promote creativity, teachers allow pupils to be 'co-participants in creative acts' and ensure there is 'appropriate time and space to experiment' (Harris and de Bruin 2018: 217). Dyson (2020: 119) emphasises the importance of pupils having 'the power to act on their interests and intentions, and on their own inclinations'. Children need frequent opportunities to explore, to take risks and to make decisions about their learning; they also need to be able to collaborate with each other so that ideas can be shared and creativity can be distributed (Glăveanu 2014). Allowing pupils some time and space to choose how to do things their own way is part of the creative process.

Affordances for creativity in mathematics learning are also impeded when pupils operate in an environment in which speed to find a correct answer is given great importance. During mathematics lessons, pupils should be encouraged to view challenges and mistakes as part of their learning and become familiar with resolving cognitive conflict (Dweck 2006, 2015; Kraft 2019). In a discussion about fixed and growth mindsets, Dweck (2015 para. 5) argues that pupils can 'thrive on challenges and setbacks on their way to learning.' 'Getting 'stuck' is an important part of the learning journey and when pupils get stuck 'teachers can appreciate their work so far, but add:

“Let’s talk about what you’ve tried, and what you can try next” ’. As detailed in the literature review, an environment in which growth mindsets are nurtured (Dweck 2006) is one in which pupils can develop the resilience necessary to persevere to realise the affordances for creativity made available to them. All teachers in my research felt that their pupils lacked resilience when presented with more open-ended, unfamiliar mathematics tasks. The comment by Teacher V that his pupils had been *‘spoon fed for six years’* was a striking disclosure. If they operate in an environment where resilience is not fostered as part of classroom norms, then it is not surprising that when faced with a task that requires resilience, children lack the necessary mindset to persevere.

Craft et al. (2013) found that the characteristic of possibility thinking least evidenced was risk-taking. In my study, during the observed lessons, risk-taking was also the least evidenced. During the pupil interviews, because of the nature of the task, ‘Tricky Track’ did not require the pupils in School B to take risks. However, in Schools K, L, R and V all pupils were able to be resilient and to take risks when engaging with ‘T&T’ and ‘PtP’; if an idea or strategy was not working, they were prepared to try something else, even if the new path also led nowhere. As Craft et al. (2013: 257) found, ‘… children took risks as part of the process of moving their thinking forwards …’.

The reason for these differences between the observed lessons and the pupil interviews in terms of both pupil resilience and risk taking could be because during the interviews the pupils were working in small groups of four with the view that they were participating in the project to help me with my university work. There was more of a playful atmosphere and the children seemed more relaxed than during the observed lessons; the only expectations placed on them during the interviews was that they should participate and do their best. When they became immersed in the tasks, solving the problems became more of a personal challenge. In spite of the learning hurdles, the pupils became increasingly eager to find solutions. Across all cases, the pupils talked about mathematics as a subject characterised by speed and right or wrong answers. It is likely that during the interviews, in a more relaxed atmosphere without the pressure to be quick to find the right answers, the pupils felt able to engage in possibility thinking. Risk-taking became more appealing because making mistakes and arriving at a wrong answer was not as daunting in a low-stakes situation (Cizek and Burg 2006).

Through reflexivity, I became aware that I had overlooked an important question during the interviews; I did not ask the pupils for their perceptions of how working in a group of four and engaging with the NRICH tasks differed from the way they felt when learning mathematics in the classroom. This question might have provided some important data about how the pupils perceived the two environments and whether they recognised any differences. With the exception of the third lesson in School K, there was no evidence of risk taking in any of the observed lessons, and yet the pupils in Schools K, L, R and V were prepared to take risks when engaging with the NRICH tasks. While the reasons for this were not probed in the interviews, the novelty factor of participating in my research should be taken into account, together with the fact that pupils were working in groups of four with one adult's full attention.

During the first two lesson observations, all teachers mentioned the statutory tests to the pupils at least once and placed emphasis on speed and time restrictions. While test anxiety is not the focus of this study, it was clear that all teachers experienced test anxiety in the sense that they were worried about the consequences of their pupils performing badly in the SATs tests. Their main goal was to deliver the curriculum in a way that they perceived best-prepared pupils for the tests. During the interviews, some pupils also shared feelings of anxiety about the tests. As Cizek and Burg (2006:1) argue, '[w]ithout question, testing is expanding at every level of education. … With that expansion has come a proliferation of test anxiety'. An important aspect of a classroom environment conducive to creativity is one that is free from test anxiety on the part of both the teachers and the pupils (Cizek and Burg 2006; Plank and Condliffe 2013) and one in which pupils are able to take risks, makes mistakes, and share their ideas and strategies with no fear of giving a wrong answer (Dweck 2006; Schoevers et al. 2009). The data from my study evidence test anxiety in both the pupils and their teachers, resulting in some negative affectivity (Carey et al. 2019; Hannula 2020).

As well as the high-stakes tests and the accountability regime, another external policy influencing mathematics pedagogy at the time of the data collection was the Mastery Approach (Drury 2018). As explained in Chapter Five, this approach had already been implemented in two of the schools (B and K), and was being considered by two others (R and V). The Mastery Approach, shaped by practices in Shanghai, was intended to drive forward school improvement in mathematics both by improving pupil performance and by raising England's position in international league tables. As explained by Blausten et al. (2020), the Mastery Approach, although optional, has gained widespread support, including from Ofsted, and plays a major part in education policy. Boylan et al. (2019) conducted a longitudinal study from 2015 to 2017, involving 47 cohort schools, all of which took part in the Shanghai Mathematics Teacher Exchange Programme (MTE). Several methods of data collection were used to assess the impact of the MTE and the Mastery Approach on pupil learning outcomes (Boylan et al. 2019). Data were collected through interviews and surveys of a wide range of stakeholders; this included teachers and pupils, lead teachers from Maths Hubs and those with responsibility for the Mastery Approach at the NCETM. To examine the impact of the MTE and the Mastery Approach on pupil attainment, Boylan et al. (2019) also completed an analysis of Year 2 and Year 6 SATs results from 2013 to 2017. Based on the findings from this study, Boylan (2019) reports that the Mastery Approach has not yet led to any significant improvements in Year 6 SATs results; he also claims, 'at this point it does not look like the mastery policy is going to lead to the big gains that politicians hoped for that would push England up the international league tables' (Boylan 2019: para 5). However, Blausten et al. (2020) argue that evidence of the impact of the Mastery Approach is inconclusive as the quantitative data available to assess the impact is sparse.

In their small-scale qualitative study of a single class of Year 4 children, Bonnet et al. (2017) explore the link between a mastery-orientated approach and creativity; they conclude that it is possible for a Mastery Approach to improve pupil metacognition, and motivation. However, they also acknowledge that enabling pupils to work creatively presents many challenges to schools, given the constraints of time, space and resources (Bonnet et al. 2017). Unfortunately, policies introduced to improve pupil performance in high-stakes tests tend to constrain possibilities for creative pedagogies (Lucas et al. 2013; Craft et al. 2014; Ogier 2019).

My findings show that external policies acted as significant constraints on affordances for creativity across all cases. However, the data suggest that simply removing these constraints and giving teachers the autonomy to teach mathematics in a way that affords pupil creativity is not always sufficient. With the approval of their headteachers, during the third observed lesson the five teachers were given the autonomy to choose any task they thought would promote pupil creativity. They had the opportunity to make professional decisions about how to frame the task, how to organise the pupils and which resources to make available. Yet, only one of the teachers delivered a task that provided affordances for pupil creativity. Three adhered closely to their established, teacher-directed classroom practices; another designed a lesson that was enjoyable, memorable and informative, but promoted teacher rather than pupil creativity.

Ogier and Eaude (2019) argue that the practices of performativity, testing and league tables have been common policy in England for so long that many teachers do not have the training or the experience of anything other than the formulaic versions of mathematics they are familiar with. As seen in the case of Teacher K, there are exceptions to this. The data from the first two lessons, together with a review of pupil workbooks, indicate that as regular classroom practice Teacher K tended towards an instrumental approach; however, during the third lesson he was able to move towards a more relational approach that afforded pupil creativity. It is possible that changes to the accountability system would result in Teacher K taking a more relational approach to pedagogy as part of regular practice, without any further training. My research indicates that there are some teachers who find it easier than others to move from an instrumental to a relational approach when external constraints are removed; the reasons for this are unclear and more research into teachers' backgrounds, previous training and past experience is needed to understand this finding.

The data from Schools B, L, R and V suggest that changes to professional development are required to support teachers in making changes to mathematics pedagogy. To promote pupil creativity, teachers need to move away from practices such as heavily teacher-directed, tightly structured lessons to a more relational approach (Skemp 1989). Without these changes, affordances for creativity will continue to be constrained.

6.2.2 Teacher Perceptions

My data reveal that another constraint on creativity during mathematics learning is the perception that 'mathematics' and 'creativity' are incompatible, this was manifested by Teacher L when she said, '*I just think whoever came up with the term creativity and stuck it next to maths needs shooting'.* Based on the findings from several studies, Levenson (2015) reports that while there is a need to develop teachers' awareness of mathematical creativity and of the types of tasks that support pupil creativity in mathematics learning, there is also a need for further research to understand how this awareness can be best achieved. If teachers do not consider mathematics to be a creative subject and/or have little awareness of creative pedagogies that promote creativity, then unless perhaps unintentionally, teachers are unlikely to make affordances for creativity available to pupils while learning mathematics. As shown in the cases of Teachers K and L, classroom organisation, pupil collaboration and teacher-pupil dialogue can create small pockets of opportunity for creative thinking during mathematics lessons, even when creativity is not a learning intention.

Four out of five teachers (B, K, L and R) displayed some scepticism about linking creativity with mathematics; in varying degrees, this scepticism had faded by the end of the data collection, particularly in Teachers K, L and R. From the outset, Teacher V spoke of the potential for mathematics to be a creative subject; however during the third lesson, he confused pupil creativity with teacher creativity and pupil enjoyment.

During the research, the perceptions of three teachers (K, L and R) shifted to the extent that they were beginning to conceptualise creativity in mathematics learning as pupils connecting and reusing mathematics knowledge already gained in new and unfamiliar ways; however, all but one (Teacher R) felt that time constraints would prevent them offering these opportunities to pupils as part of regular classroom practice.

6.2.3 Mathematics as a Creative Subject

In Chapter Five it is argued that there are two very good reasons why pupils should experience mathematics as a creative subject and why they should be given the opportunities to develop their creative skills. Firstly, they have rights as children in the here-and-now to become confident mathematicians, positively disposed to the discipline. Secondly, they will need these creative skills in the future both for any employment related to STEM and for dealing positively with challenges and changes in their daily lives. A creative approach to mathematics, through which all pupils are perceived as capable both of being creative and of achieving successful outcomes, is more equitable, democratic and inclusive (Craft 2000; Boaler 2008; Craft 2014; Adams and Owens 2015).

Regrettably my data reveal that while mathematics as a discipline is regarded as a creative subject, many pupils in school are experiencing mathematics learning that is disappointingly uncreative. This is an important finding supported by other studies from the literature, for example: Claxton (2008); Boaler (2009); NCETM (2016b); and Ogier and Eaude (2019). The statement at the beginning of the National Curriculum for Mathematics, claiming that '[m]athematics is a creative and highly inter-connected discipline' (DfE 2013a: 99) is in the context of a standards regime where pupil outcomes are considered of utmost importance, judged on tests that teachers perceive as requiring efficient methods and speed. It seems that the current policies of performativity and accountability have narrowed a teacher's choice of pedagogy to the extent that a heavily teacher-directed, instrumental approach has often become the norm (Ogier 2019).

An NCETM review (2016b) of Year 6 pupils' responses to the 2016 SATs questions (the first statutory tests based on the new curriculum) provides an interesting perspective on mathematics pedagogy. Using Skemp's (1989) theory of instrumental and relational learning, the NCETM review emphasises the importance of a relational approach to learning, contradicting the idea that an instrumental approach has to be taken in order to prepare pupils to do well in the tests. The review (NCETM 2016b) suggests that if pupils experience a more relational approach to mathematics learning, they will do better in the tests. It also recommends that when given a mathematical task, pupils should be encouraged to take the time to notice things; they need the time to consider a question and see what they notice, before attempting to answer (NCETM 2016b). The review also advises giving pupils opportunities for decision-making in mathematics learning; by taking the time to notice things and then making decisions based on what they notice, pupils will develop a better understanding of mathematics: 'The result will be children who understand mathematics and demonstrate this understanding in a test situation' (NCETM 2016b: 6).

The relational approach recommended by the NCETM (2016b) to improve pupils' performance in the SATs is also the approach needed for pupils to experience mathematics as a creative subject (Skemp 1989). It makes sense that a relational approach that allows pupils to explore, conjecture, look for relationships and make connections with previous learning will improve performance in tests; however, that largely depends on how pupils are tested and what they are tested on. As the teachers in my study claimed, success in the current tests requires efficient methods and speed. Teacher V stated emphatically: *'If you can find me one question on that test that requires creativity to answer it I'd eat my hat'.*

While the NCETM (2016b) recommends taking a relational approach to improve pupils' understanding of mathematics and their ability to notice, the SATs are timed and so they require a certain amount of speed. Also, as Kraft (2019: 5) points out, while statutory tests typically assess more than just recall and computation, they rarely expect pupils to 'solve extended unstructured problems'; yet it is these extended, unstructured mathematics problems that require 'cognitively demanding processes' (Kraft 2019: 5) and creative skills. As the teachers in my study made clear, their mathematics teaching was largely directed by the requirements of the Year 6 tests. Volante (2004: 1) states:

> Some teachers have begun to employ test preparation practices that are clearly not in the best interest of children. These activities may include relentless drilling on test content, eliminating important curricular content not covered by the test …

Based on his conversations with secondary school teachers, Teacher V told me, '*the biggest problems that secondary schools have is children go up to secondary schools and they hate maths.'* He perceived this negativity to be a consequence of the Year 6 testing regime. However, as presented in Chapter Two, other factors contribute to a negative view of mathematics. Affective features such as anxiety, boredom and fear of failure can make pupils ill-disposed to mathematics (Bandura 2001; Mercer 2011; Hannula 2020). As Bandura (1994) affirms, low self-efficacy beliefs about one's capability to achieve and perform can have a negative affect on how one behaves. Following a series of negative affective mathematical learning experiences, the pupils in School B demonstrated low self-efficacy. These negative experiences acted as constraints on their creativity, with pupil BA declaring, *'I just wanted the lesson to finish'*. The pupils expressed frustration and anxiety about being moved on too quickly, with insufficient time to practice new concepts and procedures. It seems that an unintended consequence of time constraints, speed and curriculum overload is the negative affective attitude that some pupils develop towards mathematics (Boaler 2009, Beltrán-Pellicer; Godino 2019; Hannula 2020). As Carey et al. (2019: 6) report, maths anxiety has been identified in children as young as six years old. Anxiety often leads to a negative affective attitude that can result in pupils 'not studying maths beyond the minimum expected level'. 'Maths anxiety has many different manifestations, including … feelings of apprehension, dislike, tension, worry, frustration or fear' (Carey et al. 2019: 6). It is important that maths anxiety is addressed, with interventions put in place to help children overcome their anxiety (Carey et al. 2019).

Creative approaches to pedagogy are required if pupils are to experience mathematics as a creative subject. Based on their own experiences of teaching and learning, the teachers and pupils in my study perceived creativity to be more closely related to English and the arts than to mathematics. As Morrison and Bartlett (2009) argue, reform is needed to the way STEM subjects are taught. STEM has become a buzzword in education to describe the science subjects (Science, Technology, Engineering and Mathematics). This has led to an educational debate about why the arts have been left out, resulting in another buzzword – STEAM. Those who advocate STEAM argue that the arts should be included to help reform STEM pedagogy. Thinking about STEAM instead of STEM is also more inclusive; more inclusive thinking about pedagogy is important to prevent 'art and design education being relegated to the margins of curriculum' (McAuliffe 2016: 1) and 'the narrowing of cultural education in schools' (Neelands et al. 2015: 34). The Warwick Commission Report (2015) states:

> …policymakers are obsessed with a siloed subject-based curriculum and early specialisation in Arts or Science disciplines that ignores and obscures discussion around the future need for all children to enjoy an education that encourages creativity, making and enterprise across the curriculum. We need creative scientists as much as we need artists who understand the property of materials and the affordances of new technology.
>
> (Neelands et al. 2015: 23)

Therefore STEAM holds many benefits for both the arts and the sciences, with arts pedagogies offering insights into how mathematics can become more creative. By including the arts in STEM, STEAM provides possibilities for stimulating debate about educational reform and ways of increasing pupil engagement in STEM subjects (Colucci-Gray et al. 2017). Conradty and Bogner (2020) suggest a possible link between integrating arts pedagogies into STEM teaching and between higher levels of pupil self-efficacy and motivation. Moving away from STEM towards STEAM offers a more holistic approach to learning, better preparing pupils to engage with critical thinking, to navigate complex systems and to 'explore possible futures' (Boy 2013: 1).

Evidence from both my findings and from the literature indicates that for pupils to experience mathematics as a creative subject as part of regular classroom practice, changes are needed to both pedagogy and to the assessment system.

6.3 Insights into Pupil Creativity during Mathematics Learning

This section presents some new insights into pupil creativity, gained from links made between my findings and the literature.

6.3.1 Features of Possibility Thinking

Craft et al. (2013) identified peer collaboration as an emergent feature of possibility thinking; my research supports this, highlighting collaboration as an important aspect of possibility thinking during mathematics learning. My data analysis also revealed two additional features of possibility thinking that support pupils in acting on and realising affordances for creativity while learning mathematics – noticing and curiosity. Noticing is a new a feature of possibility thinking particularly relevant to mathematics learning. As Mason et al. (2009:11) explain, giving pupils time to observe and explore mathematical structures and relationships is 'crucial to mathematical creativity'. Interventions from teachers acting as meddlers-in-the-middle (McWilliam 2009) are sometimes necessary to support pupils in noticing mathematical relationships and structures; pupils can then use what they notice to solve unfamiliar problems (Yao and Manouchehri 2020). Noticing is not encouraged or fostered in an environment that prioritises speed to the right answer, or one in which teacher-directed learning dominates child-directed learning (Craft et al. 2007). Having the time to notice things when engaging with the NRICH tasks during the pupil interviews helped the pupils in my study to think creatively and to achieve positive outcomes.

Craft (2000) and Burnard et al. (2006) all perceive curiosity as important for possibility thinking, with Craft (2000: 6) stating '[a] characteristic of possibility thinkers is their curiosity'. However, curiosity is not included on the models of pedagogy and possibility thinking (Chappell et al. 2015: 61-71). While, posing questions is one aspect of curiosity, I suggest that curiosity should also be added, as it is an important feature of possibility thinking during mathematics learning. Because affordances for creativity are largely made available to pupils through unfamiliar tasks that can be ambiguous and cause confusion, it is important that rather than being anxious about the unfamiliar, pupils are curious and keen to explore. Pupils benefit from curiosity when encountering unfamiliar mathematics tasks because curiosity about the unfamiliar can counterbalance the confusion caused by the ambiguities. This was certainly the case when the pupils first engaged with the NRICH tasks during the interviews. It was curiosity about the unfamiliar that helped motivate the pupils to persevere with the tasks in spite of their initial confusion and frustration. The work of Vygotsky (1978) demonstrates that stimulating children's curiosity through activities that require exploration can also develop their cognitive capabilities. Pluck and Johnson (2011: 24) assert: 'Curiosity is an aspect of intrinsic motivation that has great potential to enhance student learning'. My findings suggest that curiosity encourages pupils to act on affordances for creativity during mathematics learning.

6.3.2 Standing Back and Stepping In

The data from my study provide further insights into an important aspect of pedagogy conducive to promoting pupil creativity during mathematics learning. As identified by McWilliam (2009), Craft et al. (2012), Chappell et al. (2015) and Yao and Manouchehri (2020), it is not just the standing back to give pupils time and space and learner agency that is important, but what teachers do when they step in to intervene. Teachers need to maintain a difficult balancing act of standing back and stepping in (Craft et al. 2012), giving all the support necessary to enable pupils to persevere without actually providing the answer (McWilliam 2009). Schoevers et al. (2019) found that together with choice of mathematical tasks, teacher dialogue and teacher questioning were critical in supporting pupil creativity. Finding a balance between adult-directed learning and child-directed learning (Craft et al. 2007) is central to successful mathematical problem solving. Too much adult-directed learning will constrain creativity and pupil decision-making, while 'total freedom may confuse, and may not enable a child to reach beyond themselves as far as they might' (Craft et al. 2007: 9). It is important that teachers stand back to give pupils the time and space to engage in the process of TATE (Claxton 2006); this process helps children to develop the complex cognitive processes from which creativity emerges (Claxton 2006; McWilliam 2009; Van Harpen and Sriraman 2013; Clay 2014; Schoevers et al. 2019). Finding the right balance between standing back and stepping in will differ from situation to situation and is a key aspect of pedagogies that support pupil creativity during mathematics learning.

Across all cases, with the exception of the third lesson in School K, teacher-directed learning dominated child-directed learning (Craft et al. 2007). Creativity was significantly constrained because the pupils were not given agency to make decisions and choices about their own learning.

6.3.3 Pupil Competencies

As presented in Chapter Five, questions arose from the data concerning pupils' lack of resilience when presented with unfamiliar mathematics tasks. As part of the process of reflexivity, I returned to the literature to explore some answers; in doing so I identified an interesting relationship between pupil creativity in mathematics learning and pupil competencies, both their 'complex cognitive skills' and their 'social-emotional competencies' (Kraft 2019:1). As Duckworth and Yeager (2015: 238) point out, many terms have been devised to try and encapsulate all the factors that contribute to a pupil's 'cognitive ability'; no term is perfect and none are easy to measure. However, the term 'competencies', as used by Kraft (2019: 1) to include both complex cognitive skills and social-emotional competencies, seems to relate well to pupil creativity during mathematics learning. I prefer 'competencies' to the term 'effectivities' coined by Gresalfi et al. (2012: 252) because 'competencies' includes cognitive skills, personal attributes and mindsets. I also prefer 'competencies' to 'ability'; the term 'ability' suggests that 'mathematical apptitude' is fixed (Swanson et al. 2017: 172), while competencies can be nurtured and developed.

Complex cognitive competencies are fundamental to the ways in which pupils act on affordances for creativity while learning mathematics; they enable pupils to reuse and apply mathematical knowledge already gained in new ways, and to extrapolate and to make connections between different mathematical concepts and domains (Bell 1993; Claxton 2006; Schoevers et al. 2019). Individual cognitive competencies depend on the 'conceptual structure (schema) from which its possessor can (in principle) produce an unlimited number of plans for getting from any starting point within his schema to any finishing point' (Skemp 1989: 14-15). Pupils require complex cognitive competencies to enable them 'to classify new problems into cognitive schema and then to transfer content and procedural knowledge from familiar schema to new challenges' (Kraft 2019: 5).

Together with cognitive competencies, social-emotional competencies also support the creative process. Social-emotional competencies help foster a growth mindset (Dweck 2006; Dweck 2015; Kraft 2019) and are critical when engaging with challenging, ambiguous tasks that afford mathematical creativity. In some respects possibility thinking, conceptualised as being 'at the core of creativity in learning' (Craft 2000: 7), is closely linked to pupils' social-emotional competencies. Some aspects of possibility thinking, in particular self-determination, resilience, adaptability, collaboration with peers, risk-taking and immersion in a task, require the social-emotional competencies of a growth mindset; these include effort, perseverance and a consistency of interest (Kraft 2019). Jukes at al. (2018) also identify a number of social-emotional competencies, some of which are particularly important in enabling pupils to act on and realise affordances for creativity while learning mathematics: respect — important for peer collaboration; curiosity — important as a motivating factor; and daring — important for risk-taking. The social-emotional competencies of respect, curiosity, daring, perseverance, effort and consistency of interest identified by Jukes et al. (2018) and Kraft (2019) support pupils when working on challenging, open-ended mathematics problems that afford creativity; they are also indicators of a growth mindset (Dweck 2006; Kraft 2019).

These hard to measure cognitive and social-emotional competencies are not fixed (Duckworth and Yeager 2015); their growth and development is largely dependent on the learning experiences pupils are provided with and on the environment pupils operate in. The development of these competencies in mathematics learning requires regular exposure to the type of ill-defined, unfamiliar mathematics tasks that promote creativity. There is an interdependent relationship between the mathematics tasks, pupil creativity and pupil competencies. Unfortunately, as Kraft (2019: 36) argues:

> Current accountability and evaluation systems in education provide limited incentives for teachers to focus on helping students develop complex problem-solving skills and social-emotional competencies.

My identification of the close relationship between mathematical creativity and pupils' cognitive and social-emotional competencies brings new insights to the field. It also has implications for education policy, pedagogy and teacher training. Pupils are most likely to experience mathematics as a creative subject if taught using an approach that values and nurtures their complex cognitive skills together with their social-emotional competencies.

The next chapter presents the new contributions my study makes to research, specifically related to the primary research question.

CHAPTER SEVEN
New Contributions and Conclusions

7.1 Overview

By highlighting the interdependent conditions that operate together to make affordances for creativity available to pupils while learning mathematics, this chapter presents the new contributions my research brings to the field. Within this chapter, the limitations of my study are also discussed and suggestions are made for future research.

7.2 Conditions under which Affordances for Creativity are Made Available to Pupils while Learning Mathematics

As detailed in Chapter Three, I used two theoretical models as a starting point for my study: firstly the Gresalfi et al. (2012: 252) model of 'the dynamic relations between affordances, effectivities, and intentions' to show that learning occurs through interaction between pupils and their environment; secondly my modified version of the Burnard et al. (2006: 257) model, capturing 'the integration of the creative teaching and learning which appears to foster possibility thinking'. While these models were useful in informing my research, neither focuses specifically on creativity in mathematics learning.

Based on my findings, I propose a new theoretical model to demonstrate the conditions under which affordances for creativity made are made available to pupils while learning mathematics. This model combines my findings and those from the literature, including aspects from both the Gresalfi et al. model (2012) and the Burnard et al. model (2006).

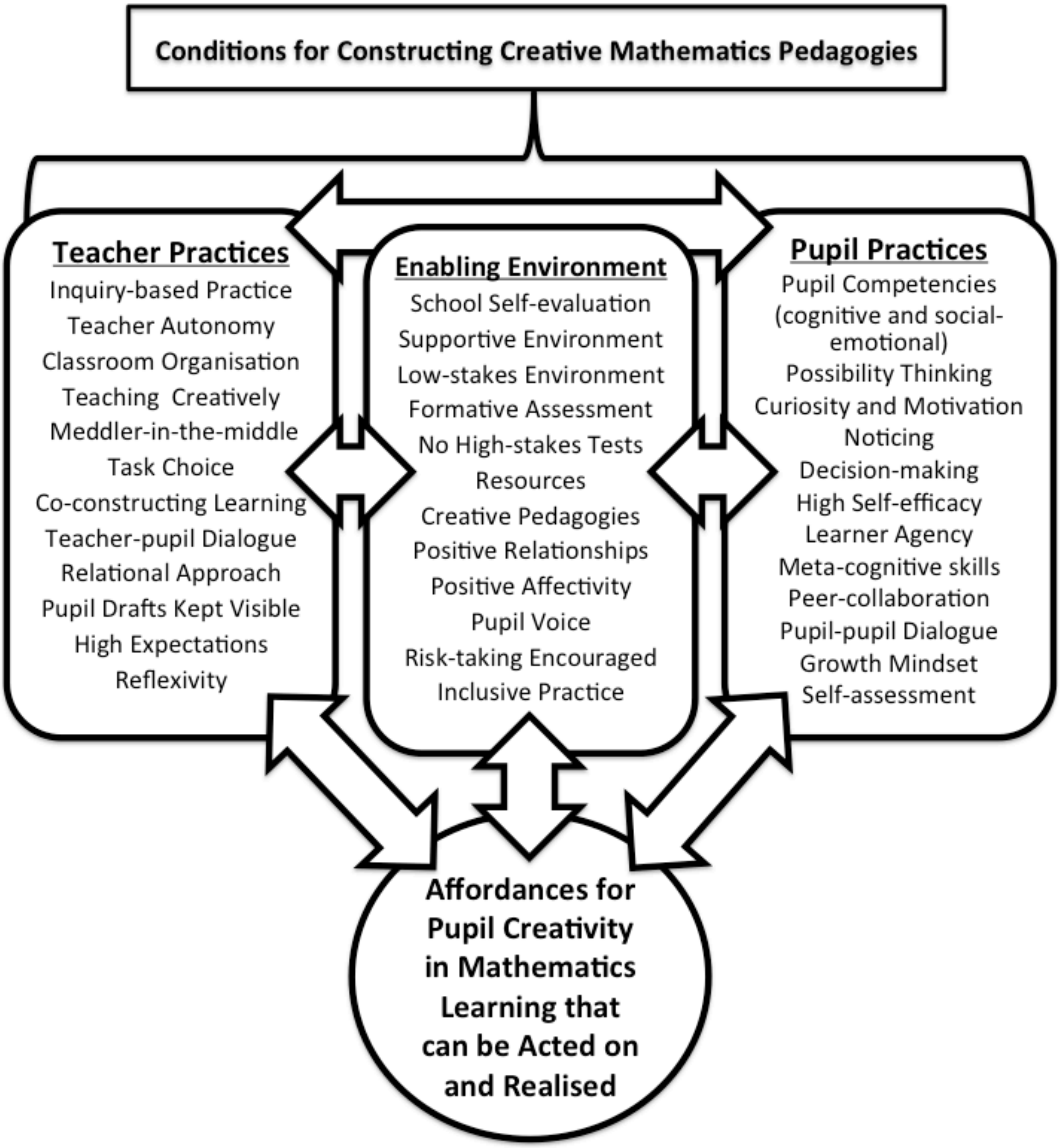


Figure 5: Model demonstrating the conditions under which affordances for creativity can be made available to pupils while learning mathematics

In the new model, three factors operate together to construct the conditions under which affordances for creativity are made available to pupils while learning mathematics: the environment, which includes the classroom environment and the wider school context; the practices of the teacher; and the practices of the pupils. Through the use of arrows, the model illustrates how all three factors are interrelated and interdependent; the environment needs to be conducive to creativity; teacher practices generate affordances for creativity and support pupils in perceiving, acting on and realising these affordances; and pupil practices enable pupils to act on the affordances, to use their creative skills, to persevere when tasks are ambiguous and challenging and to realise affordances by reaching positive outcomes. The arrows also show that while the environment maybe conducive to pupil creativity and while teachers may create affordances for creativity, the pupils need the competencies, curiosity and motivation to act on these affordances.

The classroom environment is determined partly by external policy, partly by whole-school policy and partly by individual teacher perspectives and pedagogical approaches. The group dynamics and the relationships between teachers and pupils and between pupils themselves will also shape the environment, making each classroom context unique. For the environment to be conducive to pupil creativity during mathematics lessons, a supportive and respectful atmosphere is required, with a culture as free as possible of negative affect. Positive relationships and a good rapport between teachers and pupils, with pupils feeling understood, listened to and cared for are also of great importance (Cremin and Chappell 2019).

One aspect of an enabling environment included in my model is a low-stakes environment; this has implications for wider education policy and requires the end of high-stakes tests in primary schools. A low-stakes environment where assessment is used formatively to support and inform learning is more conducive to creativity. When too much importance is placed on the outcomes of summative tests, a high-stakes environment can develop, causing anxiety and negative affect in both teachers and pupils (Cizek and Burg 2006; Carey et al. 2019); such an environment constrains pupil creativity. By ‘low-stakes’, I do not mean an environment where there is no ambition to learn; challenging tasks together with self-determination and self-motivation are all of great importance. I define a low-stakes environment as one that is as free as possible of maths anxiety and negative affect; it is also an environment in which mistakes and difficulties are regarded as part of the learning process. These learning hurdles need to be tackled with effort, perseverance and a growth mindset (Dweck 2015; Kraft 2019). A low-stakes environment needs to be combined with high teacher expectations of all pupils (Craft et al. 2014). As Carey et al. (2019: 54) argue, '[r]ather than holding the belief that mathematical abilities are fixed, or perhaps even innate' it is important to believe 'that every individual has the capacity to improve and exceed their past performance', including those with a mathematics learning disability such as dyscalculia (Carey et al. 2019). In a low-stakes environment pupils are encouraged to become self-motivated, self-regulated learners, developing meta-cognitive skills that support creativity (Mercer 2011; Warwick and Mercer 2011).

Teacher practice is the second key factor shown on my new model. Teachers need the autonomy, the training and the confidence to establish classroom norms and practices that facilitate creative pedagogies. It is important that teachers model creative behaviours in their own practices. My data indicate that creative teaching does not automatically lead to creative learning (as shown in the third lesson in Case V). However, as argued by Jeffrey and Craft (2004: 84), through 'a learner inclusive pedagogy' learners can 'model themselves on their teacher's approach' by using their learner agency to explore, to be imaginative and to be innovative. In School V, pupil creativity was constrained because the lesson was heavily teacher-directed, with no opportunities for pupils to exercise learner agency.

A teacher's choice of mathematical tasks is also critical. As part of regular classroom practice, pupils need tasks that are open-ended, ill-defined and allow for learner agency and possibility thinking. These tasks can be cross-curricular, for example linked to art and design, with children asked to design and build a scale model; they can be tasks that take place in different settings, such as an outdoor maths trail; or they can be problem-solving tasks similar to those provided by NRICH. Importantly, as discussed in Chapter Two, pupils need frequent opportunities to engage with tasks that require 'the cognitive act of combining known concepts in an adequate, but for the pupil new way, thereby increasing or extending the pupil's (correct) understanding of mathematics' (Schoevers et al. 2019: 324). By taking a relational approach to mathematics pedagogy, teachers enable pupils to engage with tasks that require them to use their existing knowledge to create new knowledge and new ideas (Skemp 1989). As Aharoni (2015) explains, children learn the beauty of mathematics through an investigational approach that is interactive, experimental and involves discussion; simple arithmetical computations are a boring hurdle that must be jumped on the way to real mathematics. 'The beauty of mathematics lies in creative activities' (Aharoni 2015: 196).

My data indicate that when learning mathematics at primary school level, creativity occurs during the process of engaging with a challenging, unfamiliar task. Observing the participating pupils engaging with the NRICH tasks (as presented in Chapter Five), it was evident that they felt a sense of achievement when they reached positive outcomes or generated new ideas; however, it was during the endeavour of unravelling, puzzling and noticing that the creativity emerged. Creative thinking was also evidenced through dialogue, posing questions and through peer collaboration (Craft et al. 2013). When framed in a way that makes expectations explicit and holds pupils to account for their mathematical decisions, creativity in mathematics learning can also occur through pupils posing their own problems (Silver 1997). There was no evidence of pupil creativity through problem posing in my data but it has been evidenced in previous studies (Silver 1997; Leikin 2009; Kontorovich et al. 2011).

My data also emphasise the importance of teachers selecting tasks that pupils can access through their previously acquired mathematical knowledge. If tasks are too difficult for pupils to access (as in the case of School B), over time pupils may develop maths anxiety (Carey et al. 2019: 31) and affordances for creativity will not be acted on and realised; if tasks are too easy or too repetitive (as the pupils in School K complained) then the pupils will not be given the opportunities to either think at the edge (Claxton 2006) or to develop complex cognitive skills (Kraft 2019).

As discussed in the previous chapter, standing back to provide sufficient time, space and learner agency for the pupils to immerse themselves in the task (Chappell et al. 2015), while judging when to step in to offer support through hints and open questions is also crucial. To support pupil creativity, teachers need to act as meddlers-in-the-middle (McWilliam 2009), making adjustments to the tasks when necessary, to keep them at a suitable level for all pupils (Bell 1993). There need to be ‘important points of contact’ between the teacher and pupils during the learning so that teachers can recognise when their support is needed (Breen and O’Shea 2010: 44). During these important points of contact, asking open questions, listening to and further probing pupils’ responses and being respectful of pupils’ contributions and ideas are all important (Schoevers et al. 2019). To develop creative pedagogies, rather than teachers adopting the position as ‘pedagogues in control’, teachers and pupils need to work together to ‘co-author’ learning in collaboration with each other (Cremin and Chappell 2019: 19). Giving children some ownership of their learning to make decisions about the paths they take in tackling a problem is of great importance; this includes allowing them to make choices about the resources they need to support their learning. Craft et al. (2014) emphasise the importance of teachers positioning themselves as facilitators of learning, co-constructing knowledge together with their pupils, valuing pupils’ agency and having high-expectations of pupils’ engagement in creative activity; teachers who take this approach are more likely to succeed in establishing creative pedagogies in their classrooms.

Following a lesson in which pupils have been exposed to an unfamiliar mathematics task that promotes creativity, a process of reflexivity will allow the teacher to consider the mathematics learning and the creativity that has taken place. As part of this assessment, reviewing the pupils’ cognitive and social-emotional competencies during their engagement with the task is of great importance (Kraft 2019). Fostering these competencies is fundamental in enabling pupils to act on and realise affordances for creativity during mathematics learning. In addition, maths anxiety needs to be identified with interventions put in place to help children address their anxiety (Carey et al.

2019). Teachers' engagement in a process of reflexivity is largely dependent on their perceptions of mathematics as a creative subject and also on their awareness of tasks that promote creativity. As discussed previously, further training is required to support teachers in developing creative mathematics pedagogies. It is also possible that a checklist of creative competencies would support teachers in assessing pupil creativity both during and after a mathematics lesson.

The third factor in the new model is the practices of pupils. My findings show that pupils require learning experiences that change their perceptions of mathematics as a subject largely characterised by speed to the right answers. It is important that skills and qualities such as curiosity, perseverance, noticing, question posing and risk-taking are valued more than how fast they are to reach a correct answer. If mathematics is to be experienced by children as a creative subject, it is crucial that they are given some learner agency and the time and space to possibility think, conjecture, and ask questions (Craft 2000); they also need the motivation to use the learner agency in a productive way that supports creativity (Bandura 1994; Mercer 2011; Manyukhina and Wyse 2019).

To confidently engage with unfamiliar mathematics tasks that promote creativity, pupils require the cognitive competencies to enable them to access the task and the social-emotional competencies to stay on task regardless of any confusion or ambiguities (Dweck 2006; Kraft 2019). Pupils also need to learn to collaborate constructively with each other, helping each other both to notice things and to make decisions about what they notice (Warwick et al. 2010; Williams and Sheridan 2010). By collaborating effectively, as detailed in Chapter Two, children are able to share and develop their thoughts and to support each other (Dennen and Burner 2008). Each child within a group may experience the creative process differently; however, through collaboration pupils can share ideas and solve problems together. Pupils need time for the intrapersonal moments of individual mental activity and time to share their thoughts and ideas with others in their social context (Askew 2004; Banaji and Burn 2007). Through collaboration, the creative thinking that occurs in individual minds can be shared, ideas can be built on, and creativity can be distributed (Glăveanu 2014).

Pupils will be more inclined to engage in peer collaboration and to co-construct learning with their teachers if they have a sense of belonging (Cremin and Chappell 2019). A sense of belonging increases a pupil's willingness to take risks and to make decisions. Self-identity and self-efficacy beliefs influence how pupils position themselves in relation to others and the actions they take in responding to the environment and to the learner agency available (Vaughn 2020). They also influence how pupils behave when operating in a group (Bandura 1994; Guan and So 2016). Low self-efficacy beliefs can have a negative impact on how pupils engage with mathematics and cause long-term negative affective attitudes (Hannula 2020). Therefore, avoiding experiences that damage pupils' self-confidence in their mathematics learning will help boost pupils' self-motivation and their willingness to participate (Mercer 2011). Prioritising the development of both social-emotional and cognitive competencies will support pupils in acquiring important cognitive tools and a strong sense of self-efficacy; as a result, pupils will become better equipped to tackle challenging, unfamiliar mathematics tasks constructively and creatively. To act like mathematicians, pupils need the opportunity to 'have imaginative ideas; ask questions; make mistakes and use them to learn new things' (Watson 2008: 3).

Pupils should also be given a voice and the opportunity to assess their own creativity. My study shows that pupils are capable of understanding, discussing and assessing their own learning; as part of inclusive practice, it is important that their voices are heard (Einarsdóttir 2007; Morrow 2008).

Of course, there is no single recipe for promoting affordances for creativity. The way all the different elements (listed under the three factors in my proposed model – Figure 5) operate together will vary depending on both the learning context, the learning needs and the previous experiences of each group of pupils. For example, some pupils may already have well developed social-emotional competencies and may be able to exercise learner agency with minimal teacher intervention; others may be at different starting points, with fixed mindsets and low levels of perseverance (Dweck 2006), requiring teachers to step in more frequently to offer support. With different amounts of teacher support, all pupils should be considered capable of everyday, little–c creativity during mathematics learning (Craft et al. 2013).

My findings emphasise the importance of all three factors, the environment, teacher practices and pupil practices, operating in harmony together. This was evidenced during the pupil interviews; with varying degrees of support, all pupils across all cases engaged creatively with the NRICH tasks, while working in a low-stakes environment that potentiated such creativity. The ways in which the three factors interrelate are key in creating the conditions under which affordances for creativity are made available to pupils while learning mathematics. This is clearly not an equitable triad, with the pupils dependent on teachers to provide both a suitable classroom environment and the necessary learning experiences, and with the teachers largely dependent on both school policy and national policy to allow them to do so.

The biggest constraints preventing pupils from experiencing mathematics as a creative subject are the high-stakes tests and the accountability system. Another significant constraint is teachers' lack of understanding that mathematics can be a creative subject and how this creativity is characterised. In addition, my study highlights the negative impact a predominantly instrumental approach to mathematics can have on a pupil's development of cognitive and social-emotional competencies. Without the resilience to persevere when a task creates confusion and causes cognitive conflict, pupils are unlikely to act on and to realise affordances for creativity.

Overall, the data collected from this quintain multiple case study make a new contribution to the field by highlighting both the conditions under which affordances for creativity are made available to pupils during mathematics lessons and the constraints that impede these conditions.

7.3 Limitations

This study has three clear limitations. Firstly, the focus was on teachers and pupils operating in Year 6 classes, the year group in which the high-stakes, end of KS2 tests take place. It could be that in other year groups the teachers and pupils feel under less pressure from the tests; therefore, pupils may experience a more relational approach to mathematics in which affordances for creativity are made more widely available to them.

Secondly, my data collection took place during a time of change. Schools were implementing a new curriculum, the Mastery Approach had recently been launched and new tests were introduced to assess pupils' knowledge of the new curriculum. When I collected my data, teachers were preparing their pupils for the new tests for the first time. It could be that five years later they feel less constrained and less pressurised by these tests and are able to offer pupils more opportunities for creativity in mathematics lessons. However, there are many recent sources in the literature that suggest the accountability system is still operating to restrict creative pedagogies. For example: Keddie (2017); Hodson (2018); Brill et al. (2018); Olgier (2019).

Thirdly, the scope of this study was limited because of its size. This was a small-scale multiple case study, with enough rich data to produce some interesting findings and to raise important issues for future studies; however, a larger more diverse sample could help to validate my new model and the theory generated from my study; it could also lead me to make alterations.

7.4 Conclusions

The statement at the beginning of the National Curriculum for Mathematics describes mathematics as 'a creative highly inter-connected discipline' (DfE 2013a: 99) and that is exactly what it should be. Pupils should be taught in ways that allow them to experience mathematics as a creative subject; not just a bit of occasional fun or a one-off enjoyable activity, creativity should be a central part of their mathematics learning. In an interview with Gold (2006:

para. 5), Marcus Du Sautoy, Professor of Mathematics at the University of Oxford, stresses:

> Mathematics is not just sums. … We don't say to children learning music: 'You're only allowed to play scales until you've got them all right' … 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.

While mathematics as a discipline is regarded as a creative subject to which the words ‘beauty’ and ‘curiosity’ can be ascribed (DfE 2013a: 99), my study indicates that many pupils are experiencing mathematics in ways that are far from creative. If pupils are to develop ‘an appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject’ (DfE 2013a: 99) some significant reform to mathematics pedagogy is urgently required, supported by radical changes to educational policy.

A new theoretical model based on the findings from this study represents the conditions under which affordances for creativity can be made available to pupils while learning mathematics (Figure 5 – p.147). The model illustrates the importance of both the environment and teacher practices in enabling pupils to engage in practices that allow them to experience mathematics as a creative subject; my research also highlights why this matters.

My journey as a doctoral researcher has been a complex mixture of challenges, surprises, dedication, resilience and intensive learning. My own conceptualisation of mathematics as a creative subject has evolved and developed during this journey. It has also become increasingly clear to me how important it is that pupils use and develop both their mathematical creativity and their cognitive and social-emotional competencies. The study has revealed how mathematical creativity holds potential for change, both in the here-and-now and in the future.

I began this doctoral journey as a teacher and teacher educator with an interest in researching creativity during mathematics learning; I completed it as a doctoral researcher whose research identity has evolved and been shaped by engaging in this study and by taking a reflexive approach. By immersing myself in this research, I have simultaneously provided new insights into creativity during mathematics learning and developed and strengthened my own research identity.

7.5 Recommendations

This section includes recommendations for future research, as well as recommendations for change arising from the data findings.

7.5.1 Future Research

A larger population sample, to reflect the diversity of schools in England, would help provide further insight into the conditions in which affordances for creativity are made available to pupils while learning mathematics. It would also be interesting to include teachers and pupils from Years 4 and 5, in addition to Year 6, to explore whether the high-stakes tests constrain creativity in mathematics learning in other year groups.

A longitudinal study, possibly comprised of a small team of researchers rather than a lone researcher, would allow for more time to be spent in schools and possibly provide the opportunity to explore whether participation in research into creativity in mathematics learning had and any longer term impact on teacher creative practices.

Actively involving practicing teachers in future research as co-participants could influence change. Enabling teachers to explore practices and pedagogy in their own contexts, in partnership with university researchers, could be a powerful way of initiating and sustaining reform (MacBeath 1999; Cochran-Smith and Lytle 2009; Kincheloe 2012; Chappell et al. 2015). Co-participatory research, as used by Burnard et al. (2006) to develop new understanding about pedagogy and possibility thinking, is more inclusive and allows teachers to engage with research 'in ways meaningful to the development of their respective practices' (Burnard et al. 2006: 248).

It would be useful to gain more understanding of how teachers' past experiences, including their previous training, shape their views on creativity in mathematics learning. Given the time and resources available, this was beyond the scope of this thesis; however, it is an important area for future research if insights are to be gained into how teacher training and continual professional development can advance a pedagogical approach that promotes creativity in mathematics learning.

7.5.2 Recommendations for change

An improved accountability system that places school-based evaluation and school-based curriculum development at its centre is a much-needed change (MacBeath 1999; Ehren and MacBeath 2016). Such change would create the time and space for schools to develop creative pedagogies, including creativity in mathematics learning. Rather than an accountability system that relies excessively on quantifiable data and measurable pupil outcomes, schools could take a more holistic approach to pupil learning, pupil wellbeing and pupil attainment. This holistic approach could include the development of pupils' competencies and the development of pupils' creative skills when learning mathematics. As discussed previously, by competencies I am not referring to measurable outcomes, but to a broader definition of competencies, both cognitive and social-emotional. As Kraft (2019) argues, statutory tests provide narrow measures of pupil learning that do not include assessment of a range of important competencies.

A more holistic approach to teaching and learning, to include the prioritising of creative pedagogies, requires the termination of the current high-stakes tests at the end of Year 6. This raises questions about the nature of a new assessment system, and how creativity in mathematics learning can most appropriately be assessed. Blamires and Peterson (2014) highlight the importance of assessing pupil creativity in a test-free environment; they argue that this can be done by collecting a range of evidence gained through observations, teacher-pupil dialogue, and by exploring pupils' work, both during and after the learning process. It is important to consider how pupils' written work can best support and illustrate their mathematical creativity. As Claxton (2006) suggests, preliminary ideas should be valued and reflected on. Instead of early strategies and pictorials written on whiteboards or scrap paper and discarded, children could have work journals in which all writing is recorded, valued and 'made visible' through each stage of the creative process (Claxton 2006: 353). As well as valuing children's efforts, these work journals would make pupil creativity in mathematics easier to assess.

Blamires and Peterson (2014) recommend that when assessing pupil creativity teachers should concentrate on the following: the ways in which pupils see connections and make relationships; how pupils question and challenge; pupil consideration of different possibilities to 'envisage what might be'; the ways pupils explore and demonstrate flexibility; and the ways in which they reflect critically on 'the ideas, actions and outcomes' generated (Blamires and Peterson 2014: 159). The observing and assessing of pupil creativity should take place in context, over time, and not through summative tests. Whenever possible, assessment of creativity should involve both teachers and pupils, with pupils given some ownership to assess their own creativity (Blamires and Peterson 2014). As presented by Cremin and Chappell (2019), the co-constructing of learning by pupils and teachers is a key aspect of creative pedagogy; this should include involving pupils in the assessment of their learning.

Lucas et al. (2013: 26) acknowledge the difficulties both of establishing creative pedagogies and of assessing pupil creativity when operating in the context of 'a subject-dominated', 'over-tested' education system in which 'there is no clear understanding and consensus about what creativity means in different contexts'. However, they argue that with changes to education policy, it is possible to develop an assessment structure that enables teachers 'to become more precise and confident in their teaching of creativity'; it is also possible to develop a 'formative tool to enable learners to record and better develop their creativity' (Lucas et al. 2013: 26). The Lucas et al. (2013) creative assessment tool is aimed at pupils aged 5-14 and includes an assessment model of five creative dispositions: pupil inquisitiveness; pupil persistence; pupil imagination; pupil collaboration skills; and pupil discipline related to their ability for reflection, critical thinking and making improvements (Lucas et al. 2013: 16). This is a useful model that could support teachers and pupils in assessing creativity if schools moved towards a more creative approach to teaching and learning.

A reformed assessment system would include assessment of a wider range of competencies than those assessed by the current system (Kraft 2019). This would include assessing how pupils engage and progress with more complex mathematics problems, including their ability to connect and reuse two or more mathematical concepts already learnt (Skemp 1989; Claxton 2006; Schoevers et al. 2019). As well as cognitive skills, a pupil assessment record could include social-emotional competencies such as resilience, perseverance and risk-taking.

Assessment reform is beyond the remit of this thesis and requires input from a range of stakeholders, including practising teachers. However, having argued strongly for the termination of the current high-stakes tests, it seemed important to make some suggestions, supported by the literature, about how to create an assessment system that supports creative pedagogies, to replace the current system that constrains them.

Reforms to teacher training and to leadership training are also recommended. Teachers need some support in developing creative approaches to pedagogy. As Levenson (2015) argues, there is a need to raise teachers' awareness of mathematical creativity and of the types of tasks that afford this creativity. Through participation in my research, across all cases the teachers' perceptions of mathematics as a creative subject shifted; they spent time puzzling over how mathematics could be a creative subject and as they did, their views changed. One way to raise teachers' awareness of mathematical creativity could be to involve them in practitioner research to explore their own practices. Rather than involvement in research perceived as a drain on teacher time and resources (Hancock 1997), it is important that it is viewed as a valuable aid to developing pedagogy. Practitioner research holds potential for developing teachers' awareness and appreciation of creative pedagogies; it could also enable them to become more creative about the ways they view their own practices. An exploratory approach to teaching practice encourages teachers to engage in possibility thinking (Burnard et al. 2006) about their own pedagogy by asking 'how', 'why' and 'what if' questions (Hanks 2015: 630). Teachers need time to explore and evaluate their own practice. As Teacher L said during interview three, *'I'm enjoying having time to reflect on my own practice'.* The new model (Figure 5), illustrating the conditions under which affordances for creativity are made available to pupils while learning mathematics, highlights teacher practices as one of the three key factors. As Cochran-Smith and Lytle (2009: 1) argue, 'teachers and other practitioners are critical to the success of all efforts to improve education'. Empowering teachers to engage in practitioner inquiry is recommended as a way of integrating research and pedagogy to effect change (Cochran-Smith and Lytle 2009; Hanks 2015). Innovative research partnerships between university researchers and practising teachers could enable teachers to engage in research as co-participants and empower them to become catalysts for change.

In order to develop creative pedagogies, I also envision inquiry-based practice and research to be integrated into initial teacher education. My experience as a lecturer in primary mathematics education led me to understand that much of the mathematics training received by students in the university, focussing on mathematics as creative subject, was contradicted by many of the practices they observed and were expected to implement during placements in schools. There was a conflict between preparing trainee teachers to teach mathematics as a creative subject and preparing them to enter a profession dominated by the current accountability system. The narrative of pupil ability in mathematics, with pupils labelled as 'lowers' or 'uppers', was so strongly reinforced in many schools that it was difficult to shape trainee teacher perceptions of mathematics as both a creative and an inclusive subject. Swanson et al. (2017) highlight the inequalities caused in mathematics education by the social constructions of pupil abilities as hierarchical and fixed. Therefore, part of school reform needs to include eradicating the labelling of pupils by ‘ability’ and an end to the discourse of ‘uppers’ and ‘lowers’. The success of creative mathematics pedagogies depends on teachers having high expectations of the creative capabilities of all pupils (Craft et al. 2014). As articulated by Luria et al. (2017: 1033), tasks that require creativity can be made ‘accessible to learners of all levels’, including pupils with learning difficulties such as dyscalculia (Reisman and Severino 2021). Embedding creative practices in mathematics pedagogy can ‘increase classroom equity’ (Luria et al. 2017: 1033). As teachers are the key to educational change, research-led, evidenced-based teacher training is of utmost importance. Inquiry-based practice could help resolve the gap between research and practice (Puustinen et al. 2018).

School leadership teams also need support in implementing radical reform in their schools, including the development of curricula that cater more holistically for pupils’ needs both in the here-and-now and for the future; this includes prioritising a creative approach to pedagogy so that pupils can experience mathematics as a creative subject. It is possible that by introducing a reformed accountability system, one that no longer includes high-stakes tests and no longer names and shames through widely published league tables and Ofsted reports, a more creative approach to pedagogies would evolve naturally. Reform is long overdue. As Claxton (2008: 194) urged fifteen years ago:

> We need a new narrative for education that can engage and inspire children and their families. … Let us fire kids up with the deep satisfaction of discovery and exploration. They are born with learning zeal; let us recognise and protect it, but also stretch, strengthen and diversify it.

Recent research by Moss et al. (2020) analyses how primary school teachers have responded to the needs of pupils and their families during the Covid-19 pandemic. Through teacher surveys and online conversations, the research team explored teachers' priorities that emerged from the crisis. From their data analysis, Moss et al. (2020) highlight lessons learnt from the pandemic experience and make recommendations for ways forward for educational policy. As a result of the virus pandemic, no statutory KS2 SATs tests took place in 2020, with the tests also cancelled for 2021. Teachers have made it clear that they do not want a return to 'business as usual in testing and accountability' (Moss et al. 2020: 3). The draft report states:

> The assessment and accountability system is in urgent need of review – We need a fairer system that is more fit for purpose especially during these challenging times.
>
> (Moss et al. 2020: 4)

To enable schools to develop creative pedagogies so that pupils can experience mathematics as a creative subject, urgent reform to both education policy and to the current accountability system is strongly recommended.

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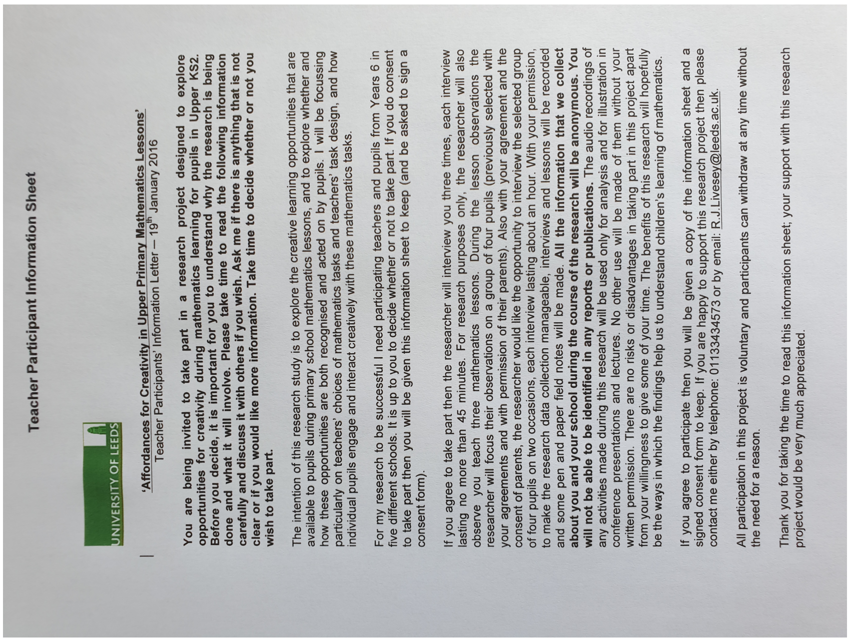
APPENDIX 1

Participant Information Letters

Information for Teachers



Teacher Participant Information Sheet

UNIVERSITY OF LEEDS

'Affordances for Creativity in Upper Primary Mathematics Lessons'
Teacher Participants' Information Letter – 19th January 2016

You are being invited to take part in a research project designed to explore opportunities for creativity during mathematics learning for pupils in Upper KS2. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

The intention of this research study is to explore the creative learning opportunities that are available to pupils during primary school mathematics lessons, and to explore whether and how these opportunities are both recognised and acted on by pupils. I will be focussing particularly on teachers' choices of mathematics tasks and teachers' task design, and how individual pupils engage and interact creatively with these mathematics tasks.

For my research to be successful I need participating teachers and pupils from Years 6 in five different schools. It is up to you to decide whether or not to take part. If you do consent to take part then you will be given this information sheet to keep (and be asked to sign a consent form).

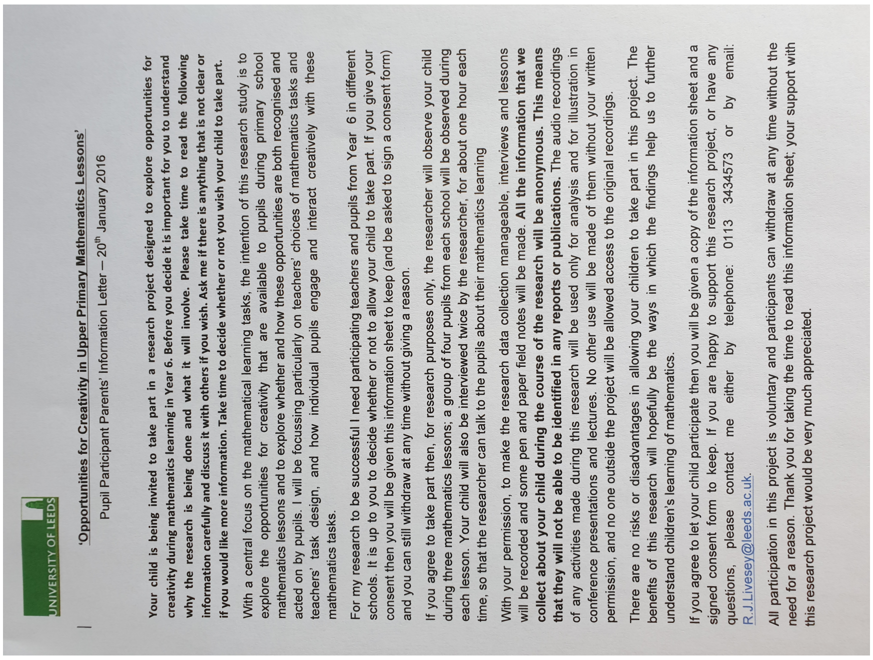
If you agree to take part then the researcher will interview you three times, each interview lasting no more than 45 minutes. For research purposes only, the researcher will also observe you teach three mathematics lessons. During the lesson observations the researcher will focus their observations on a group of four pupils (previously selected with your agreements and with permission of their parents). Also with your agreement and the consent of parents, the researcher would like the opportunity to interview the selected group of four pupils on two occasions, each interview lasting about an hour. With your permission, to make the research data collection manageable, interviews and lessons will be recorded and some pen and paper field notes will be made. **All the information that we collect about you and your school during the course of the research will be anonymous. You will not be able to be identified in any reports or publications.** The audio recordings of any activities made during this research will be used only for analysis and for illustration in conference presentations and lectures. No other use will be made of them without your written permission. There are no risks or disadvantages in taking part in this project apart from your willingness to give some of your time. The benefits of this research will hopefully be the ways in which the findings help us to understand children's learning of mathematics.

If you agree to participate then you will be given a copy of the information sheet and a signed consent form to keep. If you are happy to support this research project then please contact me either by telephone: 01133434573 or by email: R.J.Livesey@leeds.ac.uk.

All participation in this project is voluntary and participants can withdraw at any time without the need for a reason.

Thank you for taking the time to read this information sheet; your support with this research project would be very much appreciated.

Information for Parents



UNIVERSITY OF LEEDS

'Opportunities for Creativity in Upper Primary Mathematics Lessons'
Pupil Participant Parents' Information Letter – 20th January 2016

Your child is being invited to take part in a research project designed to explore opportunities for creativity during mathematics learning in Year 6. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish your child to take part.

With a central focus on the mathematical learning tasks, the intention of this research study is to explore the opportunities for creativity that are available to pupils during primary school mathematics lessons and to explore whether and how these opportunities are both recognised and acted on by pupils. I will be focussing particularly on teachers' choices of mathematics tasks and teachers' task design, and how individual pupils engage and interact creatively with these mathematics tasks.

For my research to be successful I need participating teachers and pupils from Year 6 in different schools. It is up to you to decide whether or not to allow your child to take part. If you give your consent then you will be given this information sheet to keep (and be asked to sign a consent form) and you can still withdraw at any time without giving a reason.

If you agree to take part then, for research purposes only, the researcher will observe your child during three mathematics lessons; a group of four pupils from each school will be observed during each lesson. Your child will also be interviewed twice by the researcher, for about one hour each time, so that the researcher can talk to the pupils about their mathematics learning

With your permission, to make the research data collection manageable, interviews and lessons will be recorded and some pen and paper field notes will be made. **All the information that we collect about your child during the course of the research will be anonymous. This means that they will not be able to be identified in any reports or publications.** The audio recordings of any activities made during this research will be used only for analysis and for illustration in conference presentations and lectures. No other use will be made of them without your written permission, and no one outside the project will be allowed access to the original recordings.

There are no risks or disadvantages in allowing your children to take part in this project. The benefits of this research will hopefully be the ways in which the findings help us to further understand children's learning of mathematics.

If you agree to let your child participate then you will be given a copy of the information sheet and a signed consent form to keep. If you are happy to support this research project, or have any questions, please contact me either by telephone: 0113 3434573 or by email: R.J.Livesey@leeds.ac.uk.

All participation in this project is voluntary and participants can withdraw at any time without the need for a reason. Thank you for taking the time to read this information sheet; your support with this research project would be very much appreciated.

As explained on page 52, the pupils also gave their verbal consent to participate before any data was collected; the pupils were also told that they could withdraw from the project any time they wanted to.

APPENDIX 2

The NRICH Tasks Explored with the Pupils

The Three Neighbours: https://nrich.maths.org/8108

Tricky Track: https://nrich.maths.org/2150

Two and Two: https://nrich.maths.org/twoandtwo/note

Presenting the Project: https://nrich.maths.org/4922