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Oral Story: A pedagogical tool encouraging children's mathematical thinking.

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ORAL STORY: A PEDAGOGICAL TOOL ENCOURAGING CHILDREN'S MATHEMATICAL THINKING.

by

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Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

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McGrath, C. (2015) 'Mathematical Storyteller Kings and Queens: an alternative pedagogical choice to facilitate mathematical thinking and understand children's mathematical capabilities', in Chinn, S. (ED.) The International Handbook for Mathematical Difficulties and Dyscalculia. Oxon: Routledge.

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Oral Story: A pedagogical tool encouraging children's
mathematical thinking.

Abstract

This thesis is an exploration of how oral story can be used as a pedagogical tool by educators in a state infant school, to encourage children's mathematical thinking. Two research questions are framed as follows: *In using oral story as a pedagogical approach for mathematical thinking, what characterises the nature of the interaction between teachers and children and the role of children as mathematical storytellers? How can such narratives be documented?* It starts by identifying the Vygotskian principles of instruction that are of importance to the practice of teaching young children. Data are generated by means of interviews, discussions, classroom observations and written reflections, which progressively focus the study. In particular, the way in which oral story allows playful conjecturing about mathematical possibilities using the question 'what if?' is examined. The practice of two reception class teachers is analysed and differences are shown between their mathematical epistemologies and implementation of the early years curriculum, using oral story as a teaching strategy. The contribution to knowledge made by the thesis is represented by several features. First, it lies in the detail of the exploration of the interaction between teachers and children, illuminating innovative ideas about the nature of such interaction in the context of using oral story as a pedagogical tool with whole classes and smaller groups of young children. Though oral story has been examined in previous studies, these tend to have relied on retelling a story with mathematical themes rather than constructing a story with children which allows new connections to be made. Second, the study's findings relate specifically to children taking the role as mathematical storytellers and again, though complementing other studies, it extends our understanding of the way in which storytelling allows children to experience mathematical thinking. Third, in addition to new knowledge in the field of early years mathematics, it develops a novel way of documenting children's mathematical narrative, making use of video of children's storytelling to stimulate reflection on this by children, teachers and parents.

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Second, I thank students and colleagues who I have worked alongside over the past years, and the children, parents and staff at the school where the research was conducted, who helped me to create this imaginative project.

Finally, all those completing a PhD rely on the kindness and support from families and friends. Thanks therefore to my family and friends, who all supported me in their own ways.

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Chapter One Introduction

This chapter provides a rationale as to why I have chosen to carry out research in this area and in doing so offers a justification for the overarching research theme: how oral mathematical story as a pedagogical tool encourages children's mathematical thinking. There are two research questions which are framed as follows. *In using oral story as a pedagogical approach for mathematical thinking, what characterises the nature of the interaction between teachers and children and the role of children as mathematical storytellers? How can such narratives be documented?* The theoretical ideas informing the background to this work and the types of evidence I will use to answer the research question are outlined. Further, I provide an overview of the study and highlight the complexities of the constructs which support this empirical work.

The research evidence which supports this work involves observations of children participating as listeners and tellers of mathematical stories and playing with story-related materials (see photographs, Appendix 1). All names are pseudonyms and the project was guided by an ethics protocol which was approved by the awarding university's ethics committee (Appendix 2). This research project takes an interpretive approach with constructionism as the epistemological stance. The methodology is that of ethnography, using constant comparison as an approach taken to analyse data. My outcomes are suggestive rather than conclusive; they are plausible but not definitive as there are potentially other ways of seeing what I found.

What I want to enquire into

This thesis is an exploratory study of oral story as a pedagogical tool used by educators in a British state infant school, to encourage children's mathematical thinking. It starts by defining mathematics and identifying Vygotskian principles of instruction that are of importance to the practice of teaching young children and details challenges that face educators in the classroom. Oral story is positioned as a way of teaching mathematics to young children which supports holistic principles of early learning (Gifford, 2005; 2004b; 2003). It represents a model of shared learning based on Vygotskian principles of instruction which as an interactive strategy accommodates both child-led and child-initiated activity.

Over the duration of an academic year spent at the school, data were collected each week by means of interviews, discussions, classroom observations and written reflections which progressively focused the study. The project started in year one classrooms before moving to reception classes and therefore included children between the ages of four and seven years. As a researcher with early years Qualified Teacher Status (QTS), I sometimes took the storyteller role, which was valuable as educators could observe and document how children responded to this pedagogical approach.

The original contribution to knowledge made by the thesis is represented by three features. First, it lies in the detail of the exploration of the interaction between teachers and children, illuminating new ideas about the nature of such interaction in the context of using oral mathematical story as a pedagogical tool with whole classes and smaller groups of young children. Though oral story has been examined in previous studies, these tend to have relied on retelling a story with

mathematical themes rather than constructing a story with children through the oral medium. In particular, the way in which oral story allows playful conjecturing about mathematical possibilities using the question 'what if?' is examined. However, not every story experience results in children making imaginative mathematical connections and this work explores what it is that delineates mathematical story experiences by analysing the practice of two reception class teachers who show differences between their mathematical epistemologies and their implementation of the early years curriculum through the medium of oral story. One of the two teachers promotes mathematical learning that is based firmly on negotiation of mathematical meaning using higher order or skilful questioning, whereas the practice of her colleague is generally characterised by less skilled or lower order questioning.

Second, the study's findings relate specifically to children taking the role as mathematical storytellers and again, though complementing other studies, it reaches beyond previous theory to this particular possibility. Third, in addition to new knowledge in the field of early years mathematics, it develops a novel way of documenting children's mathematical narrative, combining mathematical and observation models with video of storytelling to stimulate reflection by children, teachers and parents.

What takes me to this research area

The education landscape has become increasingly politicised over the past 50 years in England driven by the intention of political parties to raise standards. The claim of successive governments has been that 'marketisation' is a necessary condition to ensure change to teachers' practice which is deemed essential for

pupils' success (Pratt, 2016; Keddie, 2016). This has resulted in an agenda with high-stake testing and accountability in a market environment, attempting to drive up standards of performance and raise pupils' outcomes. Keddie (2016) describes how the focus is clearly on targets such as Statutory Assessment Tests (SATs) which, she argues, are ineffective measures of 'success' in education, partly because they have become disassociated from educative goals.

What was previously a largely traditional vision of education has been replaced by a neo-conservative pressure where on the one hand there is devolution of power, and on the other the state retains a strong hold (Pratt, 2016). Market-orientated education policy drives planning, teaching and assessment practices and has implications for the interactions between teacher and pupils at classroom level; its effect on educational practice is well documented (Pratt, 2016; Keddie, 2016; Maguire et al. 2014; Ball, 2013a; Ball and Bowe, 1992). Thus, education in England operates within an increasingly market-driven and competitive context (Pratt, 2016).

Within education, the early childhood sector has been a site of intense policy intervention over the last decade (Bradbury, 2014). One outcome of policy intervention was the introduction of mathematical objectives, resisted by traditional early childhood education views, which Gifford (2005, p.9) argues has the advantage of positioning mathematics at the fore. Although it is important to have objectives to drive learning opportunities (Gifford, 2005), these need to be coupled with playful teaching, made relevant in ways that allow children to connect mathematics with other learning (Pound, 2006, p.128), and to understand mathematical ideas in relational ways (Skemp, 1976).

Efforts to enhance children's mathematical performance led by a focus on the instrumental aspects of mathematics such as counting rather than on the remarkable capability of young children to pose and solve problems and think about mathematics in relational ways, is an outcome of the political drive to raise standards (Ball, 2013a). Downward pressures and demands to meet learning goals can undermine children's alternative representations of ideas and experiences (Pound, 2006, p.31), resulting in a narrow view of their mathematical capability. Instrumental teaching of mathematics is characterised by an over-reliance on worksheets as a pedagogical approach to teaching mathematics (Carruthers and Worthington, 2011, 2006). Worksheets fail to tap into the remarkable capacities of children to think playfully (Gifford, 2005; Pound, 2006; Carruthers and Worthington, 2011, 2009, 2006) and to give an accurate view of what children can do; careful observation of what children do and say can give that insight (Fisher, 2013). In their early years, children are most imaginative, most adept at playing and receptive to story as a medium to facilitate thinking; and yet the practice of using worksheets in reception and more notably year one classrooms persists (Carruthers and Worthington, 2011, 2009, 2006). Children's representations of mathematical ideas depend on their experiences and they need to build a bank of 'physical, visual and auditory images' (Gifford, 2005, p.19), which, this work proposes, can be facilitated through the medium of oral story.

Another possible response to downward pressure is the style of questioning employed by educators, which can broadly be categorised as lower or higher order; higher order questioning as an intervention strategy works best in

promoting mathematical thought with the use of open questions to which an adult is not the key holder and does not hold the answer, motivating children's thinking in a spirit of enquiry (Pound 2006, p.134; Gifford, 2005, p.55). Teaching as an interactive process draws on dialogue which can facilitate reflective thinking through skilful questioning and the aim of mathematical instruction should be for children to be looking for new patterns, to follow up their hunches and to find out more, in ways that position educators as seekers rather than as holders of knowledge (Pratt, 2006).

Further, in a climate of accountability there is a danger of misinterpretation of policy texts by educators as they seek to teach what will be tested (Keddie, 2016; Maguire et al., 2014; Ball, 2013a; Ball and Bowe, 1992). An emphasis on numeracy may have more to do with educators' 'perceptions of what is meant by the curriculum texts' than with what is actually documented in them (Edgington et al., 1998, cited in Pound, 2006, p.31). This presents potential misalignment between what children might experience in the classroom and that which is set out as intended curriculum policy (Ball and Bowe, 1992): the mathematical activity of educators becomes driven by instrumental aspects of mathematics which are more readily assessed (Skemp, 1976, p.23) at the expense of features such as problem posing or the process aspects of mathematics.

Thus, consequences of a culture of accountability are the influence exerted on the behaviour of educators with instrumental curriculum goals implicit in their activity (Pratt, 2016; Keddie, 2016). A goal-driven curriculum affects educator activity with children, and the nature of resulting interactional patterns (Maguire et al., 2014) between teachers and children, if not carefully managed, can impact

negatively on professionals (Pratt, 2016) and on learners (Keddie, 2016; Bradbury 2014, 2013).

Merrick (2016) cautions that it is crucial for practitioners to have a knowledge base that allows a critical approach to practice and that this requires the development of a skilled and knowledgeable workforce. Wood (2016) argues that in order to achieve standards and aspirations set by government, a reform to the workforce is necessary. As part of a 'professionalisation' of the early years workforce, both the 'why' and 'what' of pedagogy and practice should be part of professionals' learning experiences (Merrick, 2016; Waters, 2016). This thesis asserts that oral mathematical experiences can include both the 'what' and the 'why' of mathematics pedagogy. The work proposes an innovative way of teaching which aligns favourably with Vygotskian principles of instruction (Eun, 2010), offering meaningful teaching and learning experiences.

What takes me to this research is the drive to explore something different, which both satisfies a goal-oriented education market and supports the learning and development needs of young children. Oral story with mathematical themes is proposed as a pedagogical tool for teaching mathematics, offering divergent thinking to a subject which is often miscategorised as convergent (Pound and Lee, 2011; Pound, 2008; Craft, 2001, p.112; Hughes et al., 2000). Further, I believe that the natural tendencies of young children to develop networks of mathematical connections (Haylock and Cockburn, 2013; Pound and Lee, 2011; Pound, 2006), to use symbolic representations and meanings in ways which extend their power of conjecturing, and thereby provide a broader mathematical

experience, can be exploited and impact positively on how children develop and see themselves as mathematicians.

Positionality

My epistemological view is that young children should come to understand mathematics instrumentally and relationally (Skemp, 1976) and that, for relational understanding children need to be encouraged to see mathematics as a network of interconnected ideas (Haylock and Cockburn, 2013; Suggate et al. 2006, 2010) which oral story as a learning experience can provide. The sociocultural theoretical perspective through which this research is analysed is based on the work of Vygotsky (1978) which aligns with the mathematical ideas of: Casey (2011, 1999); Skemp (1976); Tall and Gray (1994); and Hughes (1986). Vygotsky's work presents the idea of mediators of learning with the source of mediators encompassing material tools, including spoken language, and the behaviour of another human being (Eun, 2010; Kozulin, 1990). Data gathered are viewed from a Vygotskian perspective and as such the language which supports this view is used to describe the constructs and outcomes of this empirical research. Interpretation of data is based on Vygotsky's (1978) idea of mediators with speech central to the social aspect of his theory. . .

The interpretative power of spoken and written stories

For young children, the literary experiences of conversing, listening to a story, and reading a written text, differ and yet share the characteristic of being interpretative experiences. This empirical research concerns the telling of oral mathematical stories prompted by picture books, other written texts, and the 'personal biographies' (Wells, 1986, p.216) of educators. Wells (ibid., p.200) considers the 'interpretative power of stories' in a number of situations including

stories told and read aloud and how these experiences allow children to discover the power of language in shaping thoughts borne from experience. The thesis now turns to a synthesis of ideas proposed by Wells (1986), Wood (1998) and Shotter (1993) which draw out the interpretative nature of the spoken and written word.

The nature of conversation and the spoken word

The nature of conversation is important to consider because in many of the oral mathematical stories it was as if there was a conversation between the storyteller and the listeners, either during or following the storytelling. Of words, Shotter (1993, p.79) skilfully uses the analogy between words as tools and tools in a tool box: 'For, like tools in a tool-box, the significance of our words remains open, vague, ambiguous, until they are used in different particular ways in different particular circumstances'. Thus words have a meaning which is dependent on the circumstances in which they are used (ibid.). Shotter identifies that both Vygotsky and Wittgenstein held the view that words have a meaning as defined by a dictionary and that words used in a context have a sense; in different contexts a word changes its sense (ibid., p.226).

Fluidity of the spoken and written word

Wood (ibid., p.118) points out how 'The same idea can be expressed in many different ways' and the same set of words can express several very different meanings depending on how these words are interpreted by the listener. Thus, there is a fluidity which needs to be navigated as part of verbal and written communications. He considers how a simple scene can be described in many different ways providing the example: 'A cat sat on a mat by the bed' and 'By the bed was a mat that a cat was sitting on' (ibid., p.118). He (ibid., p.118, italics in

original) explains 'The fact that *paraphrase* is a central and general feature of language demonstrates that the relationship between an *intended* meaning and the *sounds* used to *express* it are too complex to be explained in terms of learned connections between words and things'. Indeed, the same sequence of words can convey many meanings depending on how the words are interpreted or depending on how the listener 'parses' (ibid., p.118) the expression of words. He provides the example 'They were flying kites' (ibid.) and how the word 'They' might refer to people involved in the activity of kite-flying or to the kites in flight (ibid.): 'Thus, the same sound, "Flying" may be understood as a verb or adjective respectively, depending upon the overall meaning put upon the utterance' (ibid(ibid., p.118). Thus, 'Paraphrase and ambiguity are two pervasive and universal features of speech…' (ibid., p.118) considered by Wood as central to any theory about language.

Wood (ibid., p.122) states, 'Meaning involves much more than simply stringing words together: it is *not* simply the sum of word parts. Rather, the meaning of words themselves is constrained by the overall structure of the utterance in which they are embedded. Thus meaning is 'structure dependent' (ibid.). The ambiguous and paraphrasing features of speech combined with the dependency of meaning on structure contribute to the interpretative nature of the spoken word. Shotter (1993, p.78) states how '…there are an indefinite number of ways in which the connection between an utterance and its circumstances is, or can be, literally, "made" and – if the utterance is a claim to knowledge –- justified'. There are countless kinds of uses for our utterances; countless kinds of use of symbols, words and sentences (ibid.). Though we may think that words are stable with previously determined meaning, this is not so: 'But in the openness of ordinary

life, in comparison with the closed world of logic, this is precisely *not* the case' (ibid., p.79, italic in original).

The relationship between English as it is written and spoken is far from simple (ibid.). When learning to read '…children are not just uncovering a simple code for translating speech into print' (ibid., p.203). Remarkably, the same printed word can vary so much depending on the context within which it is uttered and yet can correspond with a written version. Wood (ibid., p.203, italics in original) states 'The "same" word in the context of different utterances, even when spoken by the same person, may *sound* quite different, yet it looks the same in print'. When conversing and listening to stories, children are constructing meaning, implicit in this is the point that meaning is not fixed by the spoken or written words. As 'active meaning makers' (Wells 1986),) children will construct meaning in different ways as they experience conversation and listen to stories.

Wells (ibid.) dispels what he considers to be a misplaced optimism of believing that one will be understood if one says things clearly enough. Teachers setting about telling a story with mathematical intent need to be aware of this possible misplaced optimism as not all children will necessarily pick up on the intended message. The problematic nature of this belief is captured by Wells (ibid., p.216) as follows: 'Nobody else has exactly the same mental model of the world, since nobody else has had exactly the same experience. It follows, therefore, that nobody can have exactly the same ideas as I have'. Thus communication between a teacher and pupils relies on more than clarity of expression. Indeed communication requires use of syntax and vocabulary and that the listener re-encodes the message, as Wells (ibid., p.217) explains:

Interpreting another person's message, therefore, requires that one also have expectations, based on prior knowledge or information derived from the situational context. Comprehension is the result of an act of meaning construction by the receiver. It occurs only when the meaning derived from a decoding of the linguistic message fits with the meaning that the receiver predicts from an interpretation of the context in the light of the relevant aspects of his or her mental model of the world.

Thus, the process of conversing requires taking cues from the communication context, the personal experiences of participants, and on picking up linguistic signals or clues (ibid.). The process of conversing allows participants to calibrate interpretations against what is intended, by checking in with each other as part of the exchange which happens in conversations (ibid.). As part of constructing meaning, a range of cues are drawn on and 'the meaning that is finally constructed is the outcome of a collaborative and negotiated interaction, which owes as much to other sources of information as it does to the actual words spoken' (ibid., p.155).

The context of the moment is key to constructing meaning in the process of conversing (ibid.):

In ordinary conversation, which is every child's first and most frequent experience of language in use, the meanings that are communicated arise for the most part out of the context of ongoing activity or out of past or future events about which the participants have shared knowledge or expectations. To understand what is meant, therefore, they can use the context to help them interpret what is said.

In conversation, the child and adult are face to face which means that immediate feedback can be provided as both parties are attending to the other (Wells, ibid.; Wood, 1998). What matters is the difference the word makes to people in the context in which it is uttered and how the word 'moves' people (Shotter, 1993, p.198). Indeed, when conversing, participants never know for sure what is

intended by the other, it is the opportunities for each to 'calibrate his or her interpretation of what is meant against that of the other for a consensus to be reached that is usually adequate for most of the purposes for which people communicate with each other' (Wells,1986; ibid., p.217). Thus, the meaning of conversations are constructed by participants and involve collaboration and negotiation as each participant calibrates against the other (ibid.). Meaning has the potential to converge or diverge depending on how these variables play out. This conceptual framework identifies the potential for variation as what is constructed by one individual may differ to that of another; there will potentially be 'a wide variation in the interpretations that are put upon the teacher's words' (ibid., p.219). Wells (ibid.) argues that participants in conversation rely on informed guessing and piecing together of intended meaning; and that consequently there is potential for the construction of multiple meanings. Thus the interpretative nature of speech will characterise oral story experiences which rely on the spoken word.

The sense of story: storying

The concept of storying is described by Wells (ibid., p.194) as 'constructing stories in the mind', which he positions as one of 'the most fundamental ways of making meaning'. By storying, children construct meaning and if they are given the opportunity to vocalise these stories as oral narrative, they can make their personal interpretations accessible to whoever is listening (ibid.). It is the outward expression of constructed meaning which makes this accessible to others and allows children to check alignment of their mental models with those of others (ibid.). Through the exchange of stories, children and teachers can share their understandings about a mathematical idea and align their mental models of the concept (ibid.). In the empirical research there are examples of children

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articulating their ideas and aligning these with those of their teachers; these articulations serve as validations of their mathematical thinking. Examples of children doing this include Freya and Jake who articulate their mathematical thinking by themselves and other children who converse with their teacher during stories such as 'Penguin' or 'The Greedy Triangle'.

From oral to written language

Wells (ibid., p.191) acknowledges limitations of speech citing 'its transience, for example, and the consequent difficulty of reflecting on the verbal formulations of ideas that are produced'. Through experience, children come to understand that spoken language is a resource for the exchange of meanings and that written language conveys meaning in different ways to that of spoken language (ibid.).

When listening to stories 'children are already beginning to gain experience of the sustained meaning-building organisation of written language and its characteristic rhythms and structures. So, when they come to read books for themselves, they will find the language familiar' (ibid., p.151, p.152). This connection between listening to stories being read and learning to read is noted by Wells (ibid.) who argues that it is this experience which has implications for attainment at school. Through the process of listening to stories, children are brought beyond their experience (ibid.): 'In the process they develop a much richer mental model of the world and a vocabulary with which to talk about it' (ibid., p.152). Wells (ibid.) argues that this puts children at an advantage when they are faced with curriculum concepts. Through the act of reading the story and the related conversations, the adult supports the child: 'Such talk and the stories that give rise to it also provide a validation for the child's own inner storying – -

that internal mode of meaning making which is probably as deeply rooted in human nature as is language itself' (ibid., p.152).

Reading the written word of stories

When reading the written word, the situation is different between writer and reader as they are not face to face and there is no monitoring of the interpersonal relationship (Wells ibid.). Wells (1986) acknowledges that the reader brings personal experience to the business of interpreting the text and to the construction of meaning; he highlights the need for a greater focus on the linguistic message of the text. What is notable is 'there is no context to support the writer's meaning other than that created by the text itself and the form in which it is presented' (Wood, 1998, p.155). Wood (ibid., p.203) considers that reading and writing are less 'context-sensitive' than speaking and listening. When reading and writing, children need to take on more responsibility as they are less assisted by 'a shared context' (ibid., p.204). Written text has less in the way of spoken language such as intonation and other signals which play a role in verbal communication (ibid.). Interpretation is read into texts by the reader: 'Reading demands *interpretation*' (ibid., p.206). A range of possible meanings can arise depending on which words are emphasised. When reading one sentence, the surrounding sentences provide a context for the sentence being considered, which more experienced readers tend to take in as they read (ibid.). Indeed, as Wood points out (ibid., p.207),) 'As expert readers, we are able to construct or imagine a variety of spoken versions of what, in print, is an identical piece of text'. Thus the interpretative nature of written text is an outcome of experience the individual brings, the context provided by the surrounding sentences, and how the reader imagines this text.

Difference between spoken and written language

The most important difference between spoken and written language Wells identifies is as follows: 'In conversation, and particularly in casual conversation around the home, what is said arises out of shared activity and only takes on its full meaning when considered in relation to that non-linguistic context'. Wells explains, 'the context aim in conversational speech, therefore, is to make the *words fit the world'* (Wells, 1986, p.156, italics in original). The literacy experience of reading or writing contrasts with that of conversing as 'In most writing, on the other hand, there is no context in the external world to determine the interpretation of the text. The aim must therefore be to use *words* to *create a world* of meaning, which then provides the context in terms of which the text itself can be fully understood' (ibid(ibid., italics in original). Therefore to understand a story or any written text the child has to rely on the linguistic message so that they can build a structure of meaning (ibid.).

Intuitive sense of language

Wells (1986, p.156) identifies that the most important outcome of listening to stories is the experience the child gets as they imagine the story and discover the 'symbolic potential of language'. Wood (1998, p.111) confirms that generations of families repeat the pattern of their predecessors as they move in cycles through time. He (ibid.) recognises that 'social classes tend to perpetuate themselves by means of differences in language and child-rearing practices'. Wells (1986) investigates the differences in home-based language as part of these child-rearing practices and experiences and finds that it was the practice of reading stories which contributed to rate of progress children made at school. Wells (ibid.) noted that the literary experience of being read to was the practice of well-off

families. Wood (1998) refers to Bernstein's thesis and an 'elaborated code' which is associated with children from homes whose parents have had 'extensive education'; working class children are associated with a 'restricted code'.

The story experiences noted by Wells (1986) support the child in paying attention to linguistic messages much the same way as they need to when listening to teacher talk, or when handling abstract ideas where they cannot rely on personal experience to make out the meaning. These children, Wells (1986) argues, are at an advantage as they have developed a sense of how to use the power of storying in other learning situations. Wood (ibid., p.113) explains as follows: 'Since school teaching confronts children with speech that is often, even usually, independent of the immediate physical context, children who are fluent in elaborated code language will find communication and learning relatively easy in comparison to those whose major experiences of language are confined to a restricted code'. Wells (1986) finds that children who have been read to are best positioned to decode language communicated by their teacher because they access what Wood (1998) refers to as the 'elaborated code'.

The importance of children being read to in their formative years is what contributes towards what Wood (ibid., p.213) refers to as 'intuitive sense of the nature of language'. Wood (ibid.) explains how, 'Children's intuitive sense of the nature of language, though no doubt influenced and made more explicit by learning to read, probably comes about by quite different development routes, such as nursery rhymes, stories, word play and language games'. This 'intuitive sense of the nature of language' (ibid.) which develops through experiences such as listening to stories, helps children in the context of school. Wood (ibid., p.145) highlights that language at school is different from that experienced at home and

involves 'unique features with which young children (and their teachers) have to come to terms'.

Wood (ibid., p.141) considers the 'child learner as an active, constructive and generative architect of her own language and her own understanding'. He identifies that as part of the communication between teacher and child, non-verbal exchanges are important: 'intonation, gesture, and a shared situation' (ibid., p.142) each contribute to the achievement of mutual understanding. Some children do not succeed with reading because they struggle to 'interact' with text and find it difficult to attempt to interpret the content (Wells 1996). Wood (1998, p.223) states 'The fact that children are able to draw "inferences" from spoken narrative (to go "beyond the information given") also enables them to construct models of the situations depicted in stories in which what is said is elaborated to make connections not explicitly mentioned'. Wells (1996) expresses the view that it is the experience of listening to stories which affords children understanding of less familiar narrative of school, the talk of teachers.

Both story books and oral stories are interpretative literary experiences, with meaning which is not fixed but fluid, and which can be playful as they allow the elaboration of story and mathematical ideas. The interpretative nature of conversation, of storytelling and reading, highlights the power of language in shaping children's mathematical thinking and has particular relevance to the findings of this empirical research.

The major concepts and constructs

The major concepts and constructs which support this investigation are as follows: mathematical learning; oral story; the role of story-related materials. The relationship between constructs – story and play, and story and mathematics – are highlighted. These constructs and the relationships between them facilitate an exploration of the possibilities for oral mathematical story in an early years context.

Mathematical learning

The term 'mathematics' needs to be clarified as the term 'numeracy' is often the focus, which is restricted to functional aspects of the subject. Though the functional aspect of mathematics is important, a broader view of mathematics should be part of the early years and primary curricula (DfE, 2014; DfE, 2013). However problem solving tends to be marginalised possibly because of adult lack of confidence; problem finding is not referred to in the early years curriculum (Pound, 2006) despite being a characteristic which contributes to a positive disposition to mathematics. Thus early years curricula fail to include important aspects of mathematical thinking and development. The Early Years Foundation Stage curriculum (EYFS) (DfE, 2014) focuses mainly on counting to twenty rather than about how children might think mathematically, for example by conjecturing. This notable misalignment between the natural mathematical disposition of young children (Pound, 2006) and the early years curriculum (DfE, 2014) implemented by educators is central to this research; the young child is capable of mathematical activity beyond that taken into account in the curriculum. I am interested in exploring this capability by observing how children respond to mathematical ideas constructed through the medium of oral story and in related

play activity. I propose that oral mathematical story presents an opportunity for young children to develop relational mathematical schemas (Skemp, 1986) and my experience over a span of twenty years participating in and observing classroom practice suggests as a pedagogical tool it has the potential to fit a sociocultural view on mathematics education more so than other approaches such as worksheets. Hence, I am setting out to explore how oral story as a pedagogical tool will provide insight into children's mathematical capabilities, which could be overlooked by reliance on other pedagogical approaches such as worksheets.

For this research, children's mathematical learning is based on three tenets (Eun, 2010; Pound, 2006; Vygotsky, 1978): first, learning is driven by experience, social interactions and associated language that children experience in their early years, all of which influences their future ability to think mathematically; second, mathematical learning is a complex interconnected process and is not about learning in an instrumental or linear way; third, the activity, aptitude and attitude of educators, parents and others towards mathematics influence a child's mathematical disposition. Mathematical education is more than being numerate and is based on interconnectivity and understanding conceptual connections (Haylock and Cockburn, 2013; Suggate et al., 2010). Skemp (1976) describes how an instrumental schema concerns learning by habit, for example to count number names, whereas relational schemas are about reflecting on and thinking about learning. Pound (2006, p.50) cautions that 'if educators only give weight to instrumental approaches, children will lose confidence in their ability to operate at a more reflective level and recognition of the need to do so'.

Oral story

That oral story is a work of art is acknowledged by several authors (Kuyvenhoven, 2009; Ong, 2002; Allison, 1987; Bryant, 1947). Though for the most part in the Western world we are literate, we are born first to orality: children's early learning relies on orality which is infiltrated with literacy (Ong, 2002). As adults operating in a literate way, we still engage in orality; orality is never completely eradicable as for example reading a text 'oralises' it, (Ong, 2002, p.172), which, as educators we do when teaching and learning. Hence, there is a dynamics between orality and literacy even within a literate society. Ong (2002) considers that the orality of our forefathers was different, as it was without text and, in its pure state, had certain qualities which are lost on becoming literate. He proposes that, 'In an oral culture, restriction of words to sounds determines not only modes of expression but also thought processes' (2002, p.33), a point which he explains as '…in the total absence of any writing, there is nothing outside the thinker, no text, to enable him or her to produce the same line of thought again or even to verify whether he or she has done so or not' (Ong, 2002, p.34).

Further, story as an oral tradition is a powerful medium for thinking and one which is often neglected as part of young children's learning experiences (Booker, 2004; Egan, 1988; Allison, 1987; Walker, 1975; Bryant, 1947). Spoken language allows a child to move between different ways of knowing, 'to move between intuition and logic', to connect ideas learnt in different contexts (Mithen, 1996, cited in Pound 2006, p.26). Pound (2006, pp.2, 6) considers that talking, discussing, explaining, singing, chanting and reciting, each play a part in establishing children's knowledge and understanding and that children make symbolic representations through sounds, colours, models, images, movement, stories

and imaginative play (Pound, 2006, p.27); it is the possibility of symbolic representations through oral story which is central to this work. As an alternative pedagogical approach, oral story takes teaching and learning to a higher level as it 'transforms the abstract, objective, deductive mathematics' ordinarily delivered 'into a subject surrounded by imagination, subjective meanings and feelings', creating a different experience (Schiro, 2004, p.viii).

Oral communication unites people in groups, whereas writing and reading are solitary activities that throw the psyche back on itself (Ong, 2002, p.68). Group story-making activity allows remarks made by one child to stimulate imagery in another with these situations providing an opportunity for educators to listen to the voice of the child (Walker, 1975, p.2). Bruner proposes that not only are children equipped to 'calibrate the workings of their minds against one another, but to calibrate the worlds in which they live' through story as a means of reference (Bruner, 1986, p.64); oral story is proposed as a point of reference against which children can calibrate their mathematical thinking.

The role of story-related materials

Oral story offers many choices, can be told flexibly in ways that are relevant to children, offers a unique problem-posing/solving opportunity, moving across curriculum disciplines as language, manipulatives (props) and physical action are orchestrated (Carlsen, 2013). Through this traditional mode of expression children think in action, representing their mathematical understanding in play, talk, movement and sound as well as two- and three-dimensional images using story-related materials (Pound, 2006, p.117). The provision of associated play materials will be catalytic in bringing the external oral story and a child's internal

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thinking together; 'providing a play area such as a bears' cave or Grandma's cottage complete with dressing up clothes acts as a simple invitation to 'play at' the story' (Corbett, 2007, p.8) and playing at a mathematically themed story potentially gives us clues about a child's mathematical thinking. Schiro (2004) emphasises the importance of manipulatives, and Pound (2006, p.69) advises that story props support the development of 'mental images' and provide a 'physical dimension to memory'. Thus, it is anticipated that story-related props will allow children to retell mathematical stories using these concrete materials to represent abstract story-contextualised ideas.

The relationship between the major constructs
Play and story

Play and story as constructs relate to each other in that both are mediums through which children think and express their mathematical ideas, and differ in that play and story narratives are not one and the same: story is bound by a plot (Bruner, 1996) whereas play narrative is more fluid. For children, story and play are seamless narrative activities with Paley (1999, p.40) identifying how they '…have no problem following the simple transition to fantasy. They do it themselves continually when they play'. Paley (1999, 1981) observes the power of children's dramatisation of story as play narrative, noting that in the same natural way that they play, children tell stories.

This research exploits the natural drive of children to make mathematical connections through story and play narratives with story language and related materials supporting mathematical ideas, promoting children's understanding in a creative way. Story is explaining a sequence connected to a problem and a

fundamental ethos in mathematics is explaining thinking and reasoning (Naik, 2013). Where the story and mathematics connect, there is scope to think mathematically through the story context; Naik (2013) refers to a '…space between the known and the unknown where true creativity can thrive'. Schiro (2004, p.57) holds the view that discovering problems and solutions requires insight and intuition; insight is an outcome of combining imaginative and intuitive feelings of story with intellect; experiencing mathematics on the intuitive level can be achieved through story.

Mathematics and play

Playful situations enable children to operate at their most skilful; open-ended, problem-seeking play has an important role in supporting children mathematically (Pound, 2006; Vygotsky, 1978). Further, Gifford (2005, p.151) attributes enhancement of young children's self-esteem to successful problem solving. NACCCE (1999, p. 34) state: 'Familiarity with a wide range of problem-solving activities can lead to greater competence in seeing underlying patterns and analogies across learning domains'. Naik (2013) describes a creative classroom where a teacher constructs a scenario about rescuing bears in boats and comments on how children engage with the fiction the problem is contextualised in; indirect or circumspect use of a story places mathematical problem solving in context, and through the medium of story the teacher poses a problem which children solve using story-related materials. The facility to choose and use appropriate equipment or tools to solve the problem is similar to the choosing or selecting of symbolic resources in play scenarios (Naik, 2013). The provision of such play opportunities following oral mathematical stories is central to the project design.

Play activity provides first-hand experiences and allows the making of connections and abstract thinking, all of which support mathematical learning (Pound, 2006, p.33: Gifford, 2005, p.22). Play learning contexts allow children to reflect on previous experience and consolidate understanding (Pound, 2006, p.48). Thus play and mathematics merge as, 'The thinking processes that are part of play – deciding, imagining, reasoning, predicting, planning, trying new strategies and recording – turn out to be the very ones that are required for later mathematical thinking' (Lewis 1996, cited by Pound, 2006, p.65), or more explicitly, the thinking processes young children express in play correspond with the process aspects of mathematics. Imaginative or exploratory play can involve children in posing problems which draw on mathematical thinking skills (Gifford, 2005, p.22). However, it is worth noting here that children do not necessarily use number skills in their play, and that socially constructed knowledge like number requires adult-led activity (Gifford, 2005, p.2; Gifford, 2004a). Gifford's view that adult involvement is needed to support certain aspects of mathematical learning is upheld in this research (Gifford, 2005, p.3); oral mathematical stories in this project are adult-led followed by child-initiated play and storytelling activities.

Efforts made in the past to connect children's literature to mathematics in the search for an alternative pedagogical approach

A positive outcome of Corbett's work for literacy is that educators commit to the creative opportunity oral storytelling brings as they develop a personal pedagogic tool (Corbett, 2006; 2007; Palmer and Corbett, 2003). The three stages of imitation, innovation and invention of oral story equip children with prerequisite story-writing skills, in terms of structure and pattern which can be used as part of

oral mathematical activity. Corbett's (2007) innovation stage is particularly valuable for our purposes concerning mathematical possibility thinking as children will be encouraged to think playfully. Corbett's (2007) strategies for story-making transpose to this project as he is advocating fluency, and freedom or playfulness as children create stories. Further he is teaching the educator how to do this so that they can model, scaffold and stand back, as children become confident storytellers allowing educators to swap roles from that of storyteller to listener. The Talk for Writing (2008) strategy, though intended for literacy, creates an opportunity for educators to utilise these pedagogical skills with mathematical intent.

Research studies recommend the use of children's picture books to support mathematical learning proposing that children's literature positively influences children's dispositions to pursue mathematics learning (Keat and Wilburne, 2009; Marja van den Heuvel-Panhuizen and Sylvia van den Boogaard, 2008; Hong, 1996). Mathematical ideas are often contextualised in a meaningful way in story contexts to which children respond favourably (Hong, 1996; Schiro, 2004; Welchman-TischlerTischler, 1992; Marja van den Heuvel-Panhuizen and Sylvia van den Boogaard, 2008). Van den Heuvel-Panhuizen and Elia (2012) tease out supportive mathematical learning characteristics which picture books can have. Keat and Wilburne (2009) research into how story books influence achievement and positive approaches to learning mathematics and suggest that construction of mathematical knowledge comes about because the characters of story allow for playful learning opportunities. Further, Hong (1996) finds that children's disposition to voluntarily pursue mathematics learning increases using children's literature. These research findings support the use of children's story books to

support children's positive disposition towards mathematics, with the emphasis on looking for mathematical opportunity in published literature.

The work of Schiro (2004) and Carlsen (2013) concentrates on mathematical ideas in stories being articulated by children through the medium of oral story. This empirical research explores the possibilities of mathematical themes being played with through the medium of oral story to construct new connections and to observe how children might create original mathematical stories themselves by using the question 'what if?' across two domains: mathematics and story. What happens to the mathematical idea if we change the story? Or what happens to the story if we change the mathematical idea? This principle of playing with a story plot is utilised so that children think mathematically, to innovate and invent new stories through 'possibility thinking' (Craft, 2001, p. 111). For example, the story plot of 'Goldilocks and The Three Bears' can be played with to prompt possibilities for mathematical thinking using the conjectural question 'what if?' What if there were four bears instead of three? What if there were two similarly aged small bears (twins)? What if Goldilocks was out that morning with a friend from her village, how would they share the porridge?

Barriers which stand in the way of implementing a story approach

The barriers which stand in the way of this research are the persistence of a culture of accountability which drives the more instrumental goal-orientated practice of educators in the classroom. The idea of implementing an alternative pedagogical practice as part of the interpretation of curricula may be met with resistance by some educators (Naik, 2013). Pressures from the Primary and Early Years curricula (DfE 2013; DfE 2014) and from parents whose expectations

of mathematical learning are set by how they were taught the subject make the prospect of taking a different approach for educators challenging (Pound, 2006, p.24). However, the problem of finding a different pedagogical tool for mathematics remains viable as the pressure of accountability persists and continues to constrain the practice of educators (Pratt, 2016; Keddie, 2016; Bradbury, 2014). Within early education the need for change in how educators respond to policy intervention is recognised and documented by educators, some of whom include Merrick (2016) and Wood (2016).

Outline of subsequent chapters: an overview of the study

The study begins, in this chapter and the next, with a review of what it means to teach and learn mathematics in the early years attempting to define how knowing can be understood and what mathematical knowing might mean. Literature relating to this aspect of the investigation is reviewed in Chapters Two and Three. After these introductory sections, Chapter Four details the methodology and methods used in the empirical work, alongside a methodological justification for their use relating to the epistemological basis of the study as a whole. Chapter Five is an exploration of teachers' mathematical epistemologies followed by Chapter Six which documents children as oral mathematical storytellers. Through this exploration, a number of areas of interest for further study are delineated, of which one, the use of oral mathematical story as a pedagogical approach, is proposed. The implementation of this approach is documented in Chapters Six and Seven.

Thus, the research centres on the possibility of exploring an alternative way to encourage children's mathematical thinking by exploiting three opportunities:

first, recognising that children's play can be mathematical as they pose and solve problems; second, recognising that stories are often rich in mathematical opportunities; third, recognising that oral story could be utilised as a medium for mathematical ideas to be thought about in a flexible way. Bruner (1986) outlines how individuals negotiate meanings with and through discourse with each other and this work is based on the premise that there are many possible worlds of meaning which can be created through discourse. Oral mathematical story will be employed with intention: as a creative pedagogic tool to encourage mathematical thinking.

In carrying out this work, the study moves from a broad view of some potential challenges for teachers to a progressively more focused analysis of the moment-by-moment implementation of oral mathematical story with children in the classroom and educator reflections on their experiences. From these analyses, the thesis concludes by relating the findings back to the theoretical base in the literature, particularly in relation to the way in which oral story might be used in smaller group reception class situations to make learning mathematics imaginative, and meaningful, for children and their teachers.

Chapter Two   Mathematics and policy: possibilities for oral story

Introduction

This chapter starts with the complex challenge of defining mathematics, and then offers a framework through which mathematics can be conceptualised, before considering the constraints and possibilities that policy process brings for early years educators. The purpose of a mathematical education from both a philosophical and a policy point of view is considered. The tensions between a creative approach to teaching and learning mathematics and the demands of government policy are acknowledged. The contextualisation of these complexities serves to support a response to the research theme about how oral story as a pedagogical tool can encourage children's mathematical thinking.

This chapter considers a social-historical-cultural perspective on mathematics alongside education policy for children up to seven years of age in England. A model based on the work of Casey (2011; 1999) is adapted to frame the interpretation of research outcomes as children listen to stories; play with story-related materials; and take the role of mathematical storytellers. Included in this framework is the idea that conjecture can be viewed as part of a child's mathematical disposition and as a way of thinking about mathematics creatively, with the question 'what if?' positioned as central to connecting mathematics and story in a playful way.

The Organisation for Economic Co-operation and Development (OECD, 2012) encourages quality early childhood education and care and makes international comparisons, promoting policies that improve the economic and social wellbeing of individuals. In England, policy reform with a drive to raise educational standards equates to test results, which are presented as a measure of success

(Boaler, 2009; 2002). Schools under the pressure of policy with an overbearing focus on raising standards become places where educators act in ways that aim for children to perform 'well' in tests (Marks, 2014; Boaler, 2002). Thus school performance is driven by Government policy concerned with international competitiveness (Marks, 2014; Boaler, 2002; Ball and Bowe, 1992).

Mathematics education is a construct shaped by policy, and a three-stage model for policy, proposed by Ball and Bowe (1992, p.100), is referred to in this chapter in order that this construct can be conceptualised. Ball and Bowe (1992) propose that policy analysis requires distinctions between: intended policy; actual policy; and 'policy-in-use' or 'policy enactments' (Maguire et al., 2014, p.2). Ball and Bowe (1992) characterise the policy process as a cycle which involves intended and unintended consequences, and identify two different responses to intended or actual policy: a 'professional response' and a 'technician response', each influencing different approaches to teaching and learning. Educator perspectives about mathematics and their response to pressure of policy will influence how they teach this subject and have consequences in terms of how it is presented to children (Hersh, 1998, p.41).

The policy texts for early childhood mathematics are aligned with the framework which conceptualises mathematics (Casey, 2011) in order to identify 'silences' or 'gaps' and contradictions in these curricula texts. Tensions within and between the early years and primary curricula are identified with each promoting different pedagogical possibilities for mathematics. School readiness as an educational theme brings constraint and challenge for early years educators and is discussed as part of policy concerning early years practice. The appropriateness of the early years assessment model is challenged (Bradbury, 2013) and the need to

document moments of mathematical thinking in a meaningful way is identified here and returned to later in the thesis in Chapter Seven. This chapter creates a backdrop of constraints and possibilities against which oral story as a pedagogical approach to facilitating mathematical activity is positioned.

Conceptualising mathematics

Part of the difficulty defining mathematics is due to its complexity, involving knowledge, skills, processes and emotional dispositions towards the subject. Casey proposes a model to assist with the conceptualisation of aspects of mathematics (2011) and represents his model as inner and outer five-sided pentagonal shapes (Figure 1). The five inner pentagon points are acquisition of facts and skills, fluency, curiosity, and creativity, selected by Casey (2011), who proposes a balance between the discipline and practice of mathematics. Children need to acquire facts and skills and develop fluency, as well as freedom to follow ideas about which they are curious, and a balance between these components develops a capacity for creativity (Koshy, 2001). Koshy (2001) acknowledges that fluency with facts is required to operate well with mathematics. The outer pentagon concerns key mathematical processes: *algorithm, conjecture, generalisation, isomorphism and proof* (Casey, 2011, italics in original). Algorithms or procedures or mathematical calculations are essential for mathematics, some of which include addition, subtraction, multiplication and division.
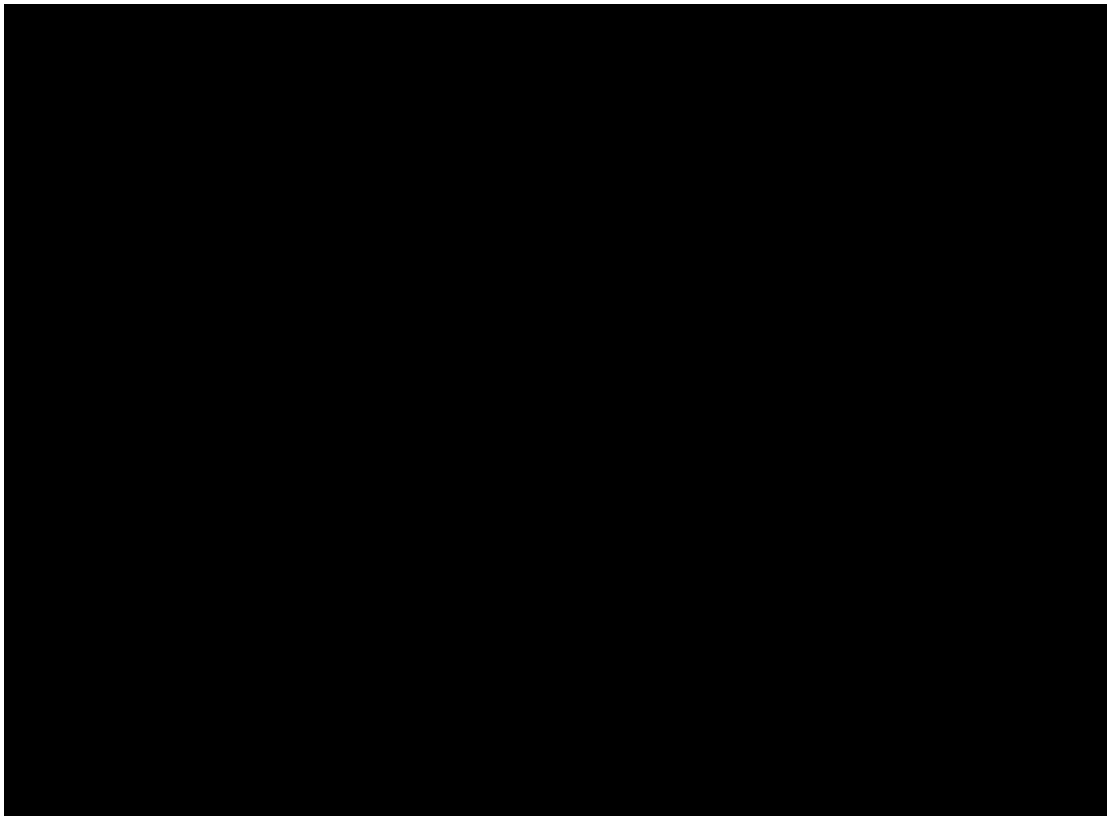
Figure 1: Inner and outer pentagons. Taken from Koshy, V. (2001) *Teaching mathematics to able children.*

Adapting Casey's (2011) model, 'conjecture' can be viewed as part of a child's mathematical disposition and the idea of thinking about mathematics in a creative way. A child's disposition towards learning mathematics is important: Pound and Lee (2011, p.9) propose that above all, and of great importance in mathematics, is the attribute of developing a 'what if?' learning disposition. The disposition to think 'what if?' is at the heart of problem solving and is referred to as conjectural or possibility thinking by Pound and Lee (2011) and Craft (2001), and lies at the heart of this work. 'What if?' is a question prompting problem posing and Sheffield (1999, cited by Casey, 2011) recommends asking: what if I change one or more parts of the problem? Watson and Mason (1998, cited by Casey, 2011) state that questions such as 'what if?' provoke children into becoming aware of

mathematical possibilities. Thus, possibility thinking is framed by the question 'what if?' and is central to creative work with mathematical story. 'What if?' as a question in a story context poses problems which need to be solved, as discussed in Chapter One. Hersh (1998, p.18) suggests that questions drive mathematics and that solving problems and making up new ones is what constitutes the essence of mathematical life. The question 'what if?' is central to playing with mathematical ideas and story, and allows the posing and solving of problems.

In mathematics it is important to see patterns, make general statements which articulate pattern, and explain why this is so. Generalising is about making general or broad statements (Fairclough, 2011; Koshy and Murray, 2011). Generalisations in mathematics come from seeing patterns and Frobisher et al. (1999, p.240) describe how establishing relationships and 'recording of general statements about numbers have their foundations in pattern'. Frobisher et al. (1999, p.266) highlight how 'children's growing grasp of addition, subtraction, multiplication and division may be supported by drawing attention to and building on patterns'. Seeing pattern in subtraction allows children to make predictions: if 10-2=8 what will 10-8 be? The patterns children find and study can lead to powerful ideas such as generalisations and later to algebraic formulae (ibid., p.244). Haylock and Cockburn (italics in original, 2013, p.297) describe how:

> …generalisations are statements in which there is reference to something that is *always* the case. As soon as children begin to put words such as *each, every, any, all, always, whenever* and *if …then* into their observations they are generalising — and, therefore, they are reasoning in a way that is characteristic of thinking mathematically.

In articulating a generalisation children are making one statement that is true about a number of specific cases (ibid., p.98).

Children should be encouraged to articulate patterns and there are two potential ways children do this: describing what changes; describing what stays the same (ibid.). Description about pattern enables children to predict, or generalise, about what will happen next and drawing out explanations about what happens every time is getting children to think like mathematicians: to generalise. Frobisher et al. (1999, p.136) advise that children not only describe the pattern in words as a generalisation but explain *why* this is so.

Mathematics also involves problem posing, problem solving and making connections between ideas. The subject is built up by individuals making connections (Haylock and Cockburn, 2013; Gifford, 2005; Askew et al., 1997) and linking old ideas with new. Suggate et al. (2010; 2006) describe mathematics as being about interconnections between facts or concepts. For example, they (ibid.) highlight that addition is not thoroughly understood until its relationship to subtraction is realised. Mathematics involves the construction of networks of interconnected ideas; it is about interconnectivity; it is about conceptual connections.

One of the challenges for educators is to encourage children to see patterns, make connections and generalisations about mathematical ideas (Haylock and Cockburn, 2013). In the context of oral story, questions which prompt describing or generalising about pattern include: What is the pattern in the story? Does that happen every time? What do you think will happen next? What pattern are you using or thinking about? How can you check that (possibly using story-related props)?

Mathematics does not hinge on proof, though one might think so. Acceptance as true and rejection as false are companions as mathematics evolves, and Hersh (1998, p.45) identifies that for two millennia, mathematicians and philosophers accepted reasoning that they later rejected, acknowledging that we would not be where we are unless this misplaced acceptance had happened. He (ibid. p.59) is cautious about proof and suggests that the role of proof in classrooms is different from its role in research: in the context of classrooms it serves to explain and in the context of research, to convince. Proving is about 'convincing sceptics that the generalisation is true in all cases' (Haylock and Cockburn, 2013, p.303). Though primary school children are not expected to prove, they can formulate simple explanations (ibid., 2013, p.303) and a story context can be used by children to explain how mathematical ideas work.

Isomorphism is about recognising that the same solution works for two different situations or contextualised problems. Casey (2011) attaches importance to isomorphism as a component of his model to conceptualise mathematics describing isomorphism as seeing that different situations share a common mathematical structure; different contexts require the same mathematical skills. For this research project, Casey's (ibid.) idea of isomorphism is related to children taking mathematical ideas heard in a story into play contexts where they author mathematical narratives, and vice versa. By providing a play opportunity with props following a mathematical oral narrative story, it is anticipated that children think about the mathematical ideas of the story in a different context. The term isomorphism (ibid.) captures children restructuring mathematical ideas in a play situation which were heard in an oral story, and is proposed as a possibility, in so far as story and play contexts can share a common mathematical structure. This

idea of isomorphism (ibid.) in the context of oral story is developed further by considering a horizontal and vertical model for mathematical thinking.

A horizontal and vertical model for mathematical thinking

Treffers and Beishuizen (1999) refer to Realistic Mathematics Education (RME), a model originating in the Netherlands and which encourages a two-pronged approach to mathematical thinking: to mathematise 'horizontally' by abstracting the situation (moving between abstract and concrete and back again); and to mathematise 'vertically' by extending the ideas. For children, mathematising horizontally and vertically could happen when mathematical ideas of a story are restructured in play situations, with play-related props representing abstract ideas of story in concrete ways and a play context allowing ideas to be played with or extended.

Educators can mathematise horizontally and vertically, as oral mathematical storytellers and as facilitators of play experiences. A story such as 'The Doorbell Rang' (Hutchins, 1986), which is about a plate of cookies being divided among more and more children as the doorbell rings repeatedly, provides an example. To mathematise 'horizontally' is to allow children to work with physical cookies and role play the outcome of each doorbell ring in terms of division of 12 cookies by an increasing number of unexpected visitors; to mathematise 'vertically' is to explore what happens if the number of cookies is changed, i.e. the numerator changes and the denominator stays the same, or the idea of division with an increasing denominator, beyond 12 cookies. The 'vertical' line is prompted by educators seeing possibilities beyond initial ideas of the picture book. This

research proposes that oral story can provide possibilities for horizontal mathematising (Treffers and Beishuizen, 1999), abstracting mathematical ideas from a story context to concrete representations and vice versa using story-related props, and vertical mathematising by allowing children to play with the mathematical ideas themselves.

Returning to the conceptualisation model, there are other mathematical processes, some of which are referred to by Casey (2011, p.135) outside of his model, and others observed as skills children demonstrate in play: communicating (listening, talking, showing); counting; corresponding (one-to-one correspondence); classifying and sorting; matching; symbolising (using symbols); estimating; reasoning; working systematically; justifying and checking; sequencing and patterning; reflecting and recording. Further, working with numbers and number relationships includes: number bonds; subtraction complements; multiples of; doubling. It is difficult to encompass all aspects of mathematics within a single framework. Rather than attempt to include everything in a tabulated format, these can be included as they occur. For the purpose of the research, additional features concerning young children's mathematical thinking, such as mathematical errors and utterances, are included in the observational framework which brings together Casey's (2011) mathematical model and Carr's (2001) learning story model and documents children's mathematical thinking as they partake in play and story narratives (Appendix 3). Mathematical errors and utterances are included in the adapted framework because it is fascinating to observe how: children correct errors and, as Gifford (2005, p.20) advises, 'spotting errors is important for revising misconceptions'; adults make and avoid correcting errors (sometimes these go unnoticed); errors

could present opportunities which can be returned to if missed (Carr, 2001). Mathematical utterances are included as a way of gaining insight into children's mathematical thinking and fit well with the oral story approach which is based on talk or speech.

Though Casey (2011) identifies and supports more able mathematicians, these ideas transpose to work with children more generally and are represented in a framework which essentially tabulates aspects of mathematics to assist with the challenge of capturing mathematical happenings. The framework is proposed for three purposes: first, to conceptualise mathematics; second, to capture children's mathematical behaviours (talking; acting; representing); and, third, to examine the quality of these mathematical expressions which can derive from: whole class oral story; small group oral story; children as storytellers or playing with story-related props. The conceptualisation of mathematics allows the second step concerning the observation of mathematical behaviour, by providing a frame of reference, against which narrative can be judged. This framework is developed further in Chapter Three, and supports the analysis of the research outcomes.

Two kinds of understanding

Though the framework described above provides a way of conceptualising mathematics there are different ways of understanding this complex subject. Skemp (1976,p.20) defines relational understanding as 'knowing what to do and why', and instrumental understanding as 'rules without reasons', which he indicates is a form of understanding satisfied by possession and application of a

rule, for example in the way that short multiplication can produce correct answers without the child necessarily understanding the significance of the technique. He (ibid.) is careful not to dismiss instrumental understanding and acknowledges associated advantages as follows: that it can be easier to understand; the results are immediate; and the answers are arrived at quickly and reliably. However, he (ibid.) identifies richer advantages of relational mathematical understanding as: it is adaptable to new tasks; easier to remember; that it can be effective as a goal in itself; and that relational schemas are organic in quality. Despite the advantages of relational understanding, he (ibid.) identifies a bias towards instrumental teaching and learning and attributes this to difficulty assessing whether a person understands relationally: 'From the marks he makes on paper, it is very hard to make valid inference about the mental processes by which a pupil has been led to make them; hence the difficulty of sound examining in mathematics'. This difficulty assessing relational understanding could be supported by assessing mathematics in a qualitative way, for example by recording oral mathematical story.

Skemp (1976) proposes that because instrumental and relational understandings are so different, potentially there are two kinds of mathematics. He describes his stay in a town and how he learnt a number of essential journey routes before forming 'a cognitive map of the town'. He identifies that no one would know by observing his action of walking whether he was merely going from A to B or whether he was constructing a map of the town, which highlights that: '…the most important thing about an activity is its goal' (ibid.), a point relevant to the activity-orientated goals of teaching which participants in the project pursue. Suggate et al. (2010; 2006) describe these two mathematical understandings proposed by

Skemp (1976, p.26), drawing an analogy with finding the way to a wedding with a map, compared with following a set of instructions. With the map there is a bigger frame to connect into, which provides support if needed (relational understanding), whereas with the set of directions if an error occurs this is difficult to correct as there is no bigger picture to connect to (instrumental understanding). Skemp (1976, p.25) elegantly differentiates between instrumental and relational understanding and the consequence of making an error. First, a reliance on instrumental understanding means that, '…if at any stage he makes a mistake, he will be lost; and he will stay lost if he is not able to retrace his steps and get back on the right path'; second, relational understanding allows for errors to be managed as, '…if he does take a wrong turn, he will still know where he is, and thereby be able to correct his mistake without getting lost; even perhaps to learn from it' (ibid.). Oral mathematical story is proposed as a way of allowing children to build conceptual structures or relational schemas for mathematical ideas as they think playfully about mathematics through a story context.

The power of flexible thinking: symbols

Gray and Tall (1994, p.4, italics in original) consider the duality between process and concept in mathematics and how the same symbolism can represent both a process and a product: for example, 'the symbols 5+4 represent both the process of adding through *counting all* or, *counting on* and the concept of *sum* (5+4 is 9). This ambiguity of notation, they identify, allows the successful thinker a flexibility of thought: to move between the process to carry out a mathematical task and the concept to be mentally manipulated as part of a wider mental schema. They argue that a successful mathematical thinker uses a mental structure which is a combination of process and concept which they term 'procept' (ibid., p.6) and that

this facility brings an ease to their thinking, placing those who think in this way at an advantage.

Though notation will not necessarily feature as part of the research, the symbolic representation of mathematical ideas using story-related materials will be of paramount importance in oral story work. By using notation or symbols ambiguously to represent either process or product, the mathematician manages to encompass both process and product; ambiguity in interpreting symbolism flexibly is at the heart of successful mathematical thinking (ibid.). Gray and Tall (1994) consider that an absence of ambiguity leads to stultifying uses of procedures that need to be remembered. In the same way that the more capable mathematician can understand mathematics in a relational way (Skemp, 1976), the 'good' mathematician thinks ambiguously about the symbolism for product and process (Gray and Tall, 1994). Rather than struggle with the complexity of 'process-concept duality', the 'good' mathematician accepts and works with the convenience of '*process-concept* ambiguity' (ibid., p.6, italics in original). The implication for this theoretical construct rests with the use of story-related materials which children will use to represent both the process and concept of mathematics.

That process and concept will be cognitively combined by children as they observe and use story-related materials to support oral mathematical stories is proposed as a central tenet to this work. The story-related props symbolise either process or concept, or indeed both – for example the cut-out fish for a story about Penguin – can evoke either the process of addition of two numbers such as 2 and 8 and/or the concept of sum or complements to make 10. Gray and Tall (1994)

characterise 'proceptual thinking' as the ability to manipulate the symbolism flexibly as process or concept. This notion of thinking flexibly about notation or symbolism is relevant to this research in that children might think 'proceptually' (Gray and Tall, 1994) about mathematical ideas in stories and use related materials or props to represent their thinking.

Top-down performance management

In order to explore oral mathematical story as a potential pedagogical tool to encourage children's mathematical thinking, the thesis needs to consider the education policy climate of England at the time the research was conducted. The chapter thus far considers the complexity of mathematics and now turns to the tensions that educators face when teaching children. An educator's conceptualisation and understanding of mathematics may be at odds with how they are expected to serve up mathematics in the classroom as they work within a culture of top-down performance management, which brings conflicts and tensions to their practice (Ball, 2013a; Waters, 2013). A shift to performance and teacher accountability reflects a lack of trust in teachers with a demand for accountability (Ball, 2013a). As Ball (2013a) argues, top-down performance management has its origins in Callaghan's Ruskin College speech and the creation in 1974 of the DES Assessment of Performance Unit, which symbolised a move away from local to central government control (ibid., p.82). This shift led to a different relationship between government and education, with the monitoring and publication of performance outcomes that create a culture of judgement and critique (ibid., p.130). This emphasis on assessment represented a view that education was no longer fit for purpose and was not meeting employer needs. In other words, education was to take the blame for economic and industrial

difficulties, in that the needs of industry were not being met. The Education Reform Act 1988 introduced the National Curriculum and national testing as 10 levels of attainment. Ball (ibid., p.132) identifies the establishment of national testing as a significant moment in the process of shifting powers from teachers to central government.

The period from 1999 to 2009 is characterised by interest in early childhood education as it became perceived as an investment in the future, with high quality early childhood education associated with later academic and economic outcomes (Aubrey and Durmaz, 2012; Sylva et al., 2004, 2003; Sylva and Pugh, 2008). The Organisation for Economic Co-operation and Development (OECD 2001, 2006, cited in Aubrey and Durmaz, 2012) and the Economist Intelligence Unit (2012) position early education as a strategy to enhance economic progress, and promote policy makers' interest in strategies to avoid loss of development potential.

New Labour and the Coalition government associated the health of the education system and international economic competitiveness with school performance, resulting in schools becoming vehicles for government reason, regulation and policy (Ball 2013b, p.103). Schools under the pressure of policy with an overbearing focus on raising standards become places where educators are under pressure to perform (Ball, 2013b, p.99). Ball (ibid., p.103) highlights that schools, teachers and children caught in a 'matrix of calculabilities' will act in certain ways. School performance is driven by government policy concerned with international competitiveness, which impacts on how educators interpret and implement curricula policy texts (Ball and Bowe, 1992) and the decisions they

make in the classroom, which is central to how oral story as a pedagogical tool will be approached by participants in this research, which is relevant to this discussion in that how educators interpret curricula will be part of their approach to implementing oral story as a pedagogical choice for mathematics.

International comparisons

Top-down performance management, evident in the setting of national targets, 'initially represented a shift towards a climate of judgement, and later led to a re-conceptualisation of education as a key player in economic competiveness' (Ball 2013a, p.134). Ball (2013b, p.98) suggests that 'policy creates possibilities for who educators are and what they might be in institutional practices'. The way that the state monitors, steers and reforms educational policy (Ball 2013b, p.104) creates 'tensions between competing ideologies' and possible constraints for educators. The pressure for performance 'acts back on pedagogy and the curriculum' narrowing educational experience (Ball 1999, 2003, cited in Aubrey and Durmaz, 2012), positioning early childhood services as instrumental in solving economic and social problems (Aubrey and Durmaz, 2012).

This instrumentalisation of policy can be seen in how primary school experience of children is impacted upon by national strategies and national testing. Ball (2013b, p.99) describes children in a contemporary London year one primary school class, categorised by ability and allocated tables to sit at, which are labelled as circles, triangles, squares and hexagons, the complexity of the shape, associated with that of the child's mind. Such categorisation by ability encourages learners to see themselves in terms of a paradigm of ability, perform accordingly, with little possibility of modification as this categorisation mould sets (ibid., p.99).

Further, Marks (2014) identifies ability grouping and triage processes as outcomes of a policy context of accountability. She (ibid.) documents some of the consequences of educational triage which aim to maximise attainment outcomes by pushing as many children as possible to achieve a Government target Level 4, in a primary school, whereby resources such as 'the strongest staff' are allocated to pupils on the cusp of achieving this level. Marks (ibid.) identifies that some of the practices such as smaller group intervention work resulted in unintended consequences such as reduced mathematical gains for the lower attaining children. Her findings noted that intervention through small group work contributed to 'lower mathematical gains' (ibid., p.50) and will do so unless what characterises the learning is given careful consideration, a discussion which is returned to in Chapter Three.

Williams (2008) was called upon to review evidence, including international practice, and make recommendations for teaching mathematics in early childhood settings and primary schools. The Williams review (ibid., p.4) identified: 'the need for an increased focus on the use and application of mathematics; and the vitally important question of classroom discussion of mathematics'. These principles supported those of the National Numeracy Strategy (NNS); however, an external evaluation team (Earl et al., 2003, cited in Aubrey and Durmaz, 2012) cast doubt as to whether increases in test scores following the introduction of the NNS represented increases in children's learning. The NNS framework recommended whole class interactive direct teaching with oral and mental work featuring prominently (ibid.). The idea of utilising oral mathematical story as a way of facilitating mathematical thinking through discussion and mental work

potentially sits comfortably with recommendations made by Williams (2008), a sound report which was seemingly ignored by the commissioning political party.

Reforms in educational policy have resulted in two curricula relevant to children in reception classes. Ofsted (2017) published a contentious document titled 'Bold Beginnings: The Reception Curriculum in a sample of good and outstanding primary schools'. This document sets out the legal requirement of the Early Years Foundation Stage statutory requirement as note 5 (ibid., 2017, p.8): 'The Reception Year is part of the EYFS. This statutory framework sets the standards of learning, development and care for children from birth to five years. All schools and Ofsted-registered early years providers, including childminders, pre-schools, nurseries and school reception classes, must follow the EYFS guidance. Schools that are maintained by the local authority (maintained schools) must follow the national curriculum…'.

This chapter now considers the content of these curricula which are related to mathematics as a subject using Casey's (2011) conceptualisation framework, to establish how educators might implement these policy texts. First, the complexity of policy implementation is tackled before considering early childhood mathematical curricula as policy texts.

Policy process is complex

Implementation of policy is fraught with complexities and it is unrealistic to expect a uniform or standardised outcome. Ball and Bowe (1992) provide an overview of issues concerning the implementation of National Curriculum as policy. They argue that the policy process is complex, highlighting that policy texts are not

closed, that meaning can be fluid and unclear, and that the process is open to 'interpretational slippage and contestation' (ibid.).ibid. Referring to the 1988 Education Reform Act, they identify that parts of the Act could be taken up differently, producing varying outcomes, and in doing so work against a *National* Curriculum (ibid., italics in original). As policy text is interpreted, reinterpreted and applied to different social contexts, the resulting implementation of a detailed specific piece of legislation will have intended and unintended consequences as part of a continuous policy cycle (ibid.). Thus, uniform implementation of policy is unrealistic and any expectation for standardisation is fraught with complexities (Maguire et al., 2014; Aubrey and Durmaz, 2012; Ball and Bowe, 1992). The thesis now turns to characterising the policy process.

Characterising the policy process

Broadly speaking there are legislators and implementers of policy, and a text such as the 1988 Education Reform Act is legislation translated by politicians and educators into everyday practices. The state relies on teachers to deliver the curriculum, which is achievable only if all educators accept the policy, or if government polices the system of implementation successfully (Ball and Bowe, 1992). In schools, policy is re-contextualised, and within each school there are variables which stretch and strain with and against each other. Bowe, Ball and Gold (1992, cited in Aubrey and Durmaz 2012) describe how teachers are 're-contextualising' policies they receive. The context of schools includes clashes and mismatches between contending discourses some of which include: professionalism vs conformity; autonomy vs constraint; specifications vs latitude; political vs educational (Ball and Bowe, 1992, p.112). Further, they refer to matters of contingency: staff absence or shortage; individual personalities or

capacities; geographical location and catchment area (ibid.). Each school or educational institution represents a different policy arena or micro-political world within which a policy text is re-contextualised.

Ball and Bowe (ibid., p.100) propose that policy analysis requires distinctions between: intended policy; actual policy; and policy-in-use. Intended policy includes competing ideologies from different policy arenas encompassing government, schools and Local Education Authorities, and represents a continual struggle for power (ibid.). Actual policy includes wording of legislation and policy documents which set out the rules and guidance for 'policy-in-use' and are the resources which educators refer to for implementing policy (ibid.). Actual policy for early years education includes statutory curricula (DfE, 2014; DfE, 2013) and 'policy-in-use' is the representation in practice by educators of intended and actual policies, encompassing 'the peculiarities and particularities of their context' (Ball and Bowe, 1992). Characterising the policy process as well as highlighting distinctions between stages prepares the way for outlining constraints and possibilities educators are presented with.

Constraints and possibilities

With the requirement to implement policy come competing constraints: those of the legislators against those of the implementers. Ball and Bowe (1992,p.101) contend that it is in the micro-political processes of the schools that we see not only the limitations and possibilities state policy places on schools, but the limits and possibilities practitioners place on the capacity of the state to influence the micro-world of the school. As implementers of policy, educators impose limits on how far the policy permeates their day-to-day work with children in their classrooms, though this is dependent on the ethos of the micro-political world

they find themselves in and whether this allows a professional or passive response (ibid.) to statutory curricular requirements.

Patterns of response: 'professional' or 'technician'

Ball and Bowe (1992) make the following points about policy implementation. There are powerful contextual factors in schools' responses to change which lead to different kinds of possibilities (ibid.). Policy text is read and appreciated differently in different settings (ibid.). Patterns of responses to curricula vary between schools depending on the 'different capacities, contingencies, commitments and histories of these institutions' (ibid.,p.112), further, 'high capacity, high commitment and a history of innovation provide a greater sense of autonomy and a willingness to interpret text in light of previous practice' (ibid.), a point returned to in Chapter Eight. In these instances, policy intervention results in a school's self-reflection rather than adapting policy passively or blindly. This type of response is what Ball and Bowe (ibid.) describe as 'professional' in preserving what was before, whereas in other cases the response is passive, more what Ball and Bowe (1992) refer to as a 'technician' response. This description of how schools respond to policy as 'professional' or 'technician' is relevant to this research in two ways: first, a 'professional' response is more likely to be receptive to trying a creative approach to mathematics; and second, where educators are part of such a responsive context they are more likely to embrace oral story as a pedagogical approach in the classroom as part of 'policy-in-use' (ibid.).

Possibilities for educational policy are further complicated by how educators view mathematics. Perspectives of mathematics and how children learn this subject

will influence how educators implement policy in practice, as alluded to earlier. Further, theories of learning and development may not become translated into classroom practices because of pressures of national testing and assessment requirements (Eun, 2010; Aubrey and Durmaz, 2012). Thus, 'both institutional and individual factors constrain and enhance the mutual impact of theory and practice on each other' (Eun, 2010, p.416).

The ways in which educators interpret policy and how they respond to the demands of top-down performance management outlined above influence whether and how oral story will be used as a pedagogical approach to facilitate children's mathematical thinking. A downward pressure towards formality results in an emphasis on numeracy in curricula policy texts with a deficit of other aspects of mathematics.

The thesis now considers how the policy texts for early childhood mathematics align with Casey's (2011) model which serves to conceptualise mathematics, in order to identify 'silences' or 'gaps' and contradictions in these curricula texts. Before looking at the alignment of a policy text with Casey's mathematical model, a brief history of early years policy texts is provided to show how such policies change the way mathematics is described as policies evolve.

Historical trajectory of the early years mathematics curriculum

Prior to 1996, there was little Government intervention in pre-school provision in England. However, Government initiatives since 1996 have changed what was arguably considered a less prescriptive approach to pre-school education. In 1996 the Conservative government introduced the Nursery Voucher scheme

linked to a framework titled Desirable Outcomes for Children's Learning on Entering Compulsory Education (SCCA, 1996). These Desirable Outcomes were learning goals that children were expected to achieve before entering school and were worded as follows (SCCA, 1996):

> Children use mathematical language, such as circle, in front of, bigger than and more, to describe shape, position, size and quantity. They recognise and recreate patterns. They begin to use their developing mathematical understanding to solve practical problems. They are familiar with number rhymes, songs, stories, counting games and activities. They compare, sort, match, order, sequence and count using everyday objects. They recognise and use numbers to 10 and are familiar with larger numbers from their everyday lives. Through practical activities children understand and record numbers, begin to show awareness of number operations, such as addition and subtraction, and begin to use the language involved.

In 1997 the Labour Government provided direct funding to pre-school providers. Funding was dependent on meeting government requirements for regular inspection against the framework of Desirable Outcomes. In 1988 the Education Reform Act set out a National Curriculum for England and Wales which represented a restructuring of the educational system in England. In 1999, the Qualifications and Curriculum Authority (QCA) replaced 'Desirable Outcomes' with 'Early Learning Goals', which did not differ greatly from the Desirable Outcomes in their descriptions (SCCA, 1996). The following extract is taken from the Early Learning Goals Curriculum Guidance for the Foundation Stage (QCA 1999) (Archived 2004) and represents something of the ethos towards mathematics:

> Mathematical development depends on becoming confident and competent in learning and using key skills. This area of learning includes counting, sorting, matching, seeking patterns, making connections, recognising relationships and working with numbers, shapes, space and measures. Mathematical understanding should be developed through stories, songs, games and imaginative play, so that children enjoy using and experimenting with numbers, including numbers larger than 10.

> To give all children the best opportunities for effective mathematical development, practitioners should give particular attention to: many different activities, some of which will focus on mathematical development and some of which will draw out the mathematical learning in other activities, including observing numbers and patterns in the environment and daily routines; practical activities underpinned by children's developing communication skills; activities that are imaginative and enjoyable….

The Early Learning Goals were presented as (QCA, 1999):

> Say and use number names in order in familiar contexts;
> Count reliably up to 10 everyday objects;
> Recognise numerals 1 to 9;
> Use developing mathematical ideas and methods to solve practical problems;
> In practical activities and discussion begin to use the vocabulary involved in adding and subtracting;
> Use language such as 'more' or 'less' to compare two numbers;
> Find one more or one less than a number from one to 10;
> Begin to relate addition to combining two groups of objects and subtraction to 'taking away';
> Use language such as 'greater', 'smaller', 'heavier' or 'lighter' to compare quantities;
> Talk about, recognise and recreate simple patterns;
> Use language such as 'circle' or 'bigger' to describe the shape and size of solids and flat shapes;
> Use everyday words to describe position;
> Use developing mathematical ideas and methods to solve practical problems.

It is important to note that this last learning goal is removed from revised versions of this policy text, indicating a move away from a focus on solving practical problems. Early Education (2018) outline how the first version of the EYFS was the product of an intensive period of development, drafting and re-drafting during 2005/6 and that the main task was to bring together in one document three existing frameworks: Birth to Three Matters; The Curriculum Guidance for the Foundation Stage; and The National Standards for under 8s Day Care and Childminding. The final version was published in 2007 and came into force in September 2008. From September 2008 this policy was mandatory for all schools and early years providers in Ofsted-registered settings attended by young

children. This included children from birth to the end of the academic year in which a child has their fifth birthday. An extract from this document includes a focus on assessment (DCSF, 2008):

> …improving quality and consistency in the early years sector through a universal set of standards which apply to all settings, ending the distinction between care and learning in the existing frameworks, and providing the basis for the inspection and regulation regime; laying a secure foundation for future learning through learning and development that is planned around the individual needs and interests of the child, and informed by the use of ongoing observational assessment.

There were six areas covered by the early learning goals and educational programmes of this policy (DCSF, 2008): Personal, Social and Emotional Development; Communication, Language and Literacy; Problem Solving, Reasoning and Numeracy; Knowledge and Understanding of the World; Physical Development; and Creative Development. Mathematics positioned as 'Problem Solving, Reasoning and Numeracy' includes a return to 'problem solving' and 'reasoning' as valued skills. Indeed, though not set out as a learning goal, 'Problem Solving, Reasoning and Numeracy' was described as follows (DCSF, 2008):

> Children must be supported in developing their understanding of Problem Solving, Reasoning and Numeracy in a broad range of contexts in which they can explore, enjoy, learn, practise and talk about their developing understanding. They must be provided with opportunities to practise and extend their skills in these areas and to gain confidence and competence in their use.

The Early Learning Goals (DCSF, 2008) were set out as follows:

> Say and use number names in order in familiar contexts.

> Count reliably up to ten everyday objects.

> Recognise numerals 1 to 9.

> Use developing mathematical ideas and methods to solve practical problems.

In practical activities and discussion, begin to use the vocabulary involved in adding and subtracting.

Use language such as 'more' or 'less' to compare two numbers.

Find one more or one less than a number from one to ten.

Begin to relate addition to combining two groups of objects and subtraction to 'taking away'.

Use language such as 'greater', 'smaller', 'heavier' or 'lighter' to compare quantities.

Talk about, recognise and recreate simple patterns.

Use language such as 'circle' or 'bigger' to describe the shape and size of solids and flat shapes.

Use everyday words to describe position.

A review of the implementation and effectiveness of the EYFS was planned after two years. The resulting recommendations of the Tickell Review (2011) were incorporated into the revised EYFS. The Tickell review (ibid.) promoted focus on the 'characteristics of effective learning' and how disposition to learning rather than what was learnt impacted on future achievement of children. This review recommended areas of learning to be divided into prime and specific areas (ibid.).

The revised version of the statutory framework describes seven areas of learning and development. Three areas, the prime areas, are: communication and language; physical development; and personal, social and emotional development. The specific areas are: literacy; mathematics; understanding the world; and expressive arts and design. The document describes how (DfE 2014):

Mathematics involves providing children with opportunities to develop and improve their skills in counting, understanding and using numbers, calculating simple addition and subtraction problems; and to describe shapes, spaces, and measure.

The early learning goals are worded and presented as (DfE 2014):

Mathematics Numbers: children count reliably with numbers from 1 to 20, place them in order and say which number is one more or one less than a given number. Using quantities and objects, they add and subtract two single-digit numbers and count on or back to find the answer. They solve problems, including doubling, halving and sharing.

Shape, space and measures: children use everyday language to talk about size, weight, capacity, position, distance, time and money to compare quantities and objects and to solve problems. They recognise, create and describe patterns. They explore characteristics of everyday objects and shapes and use mathematical language to describe them.

Mathematics is now categorised as about 'number' and 'shape, space and measures' and, compared with the early learning goals set out in 2008, the revised version could be regarded as having a narrower view of mathematics, with problem solving restricted to 'doubling, halving and sharing' (ibid.).

A further revision of the EYFS was prompted by the Primary Assessment Consultation (DfE 2017) which Early Education (2018) are critical of. The Department for Education (2018) has issued first drafts of a revised EYFS Statutory Framework including redrafted Early Learning Goals. Early Education (2018) express concern about these proposed revisions: Shape, Space and Measure have been removed from content of 'Areas of Learning' and 'Early Learning Goals'. Also potentially relevant to mathematics is the omission of 'cognitive self-regulation', which Early Education (ibid.) recommend is included in descriptions of the characteristics of effective learning. The proposed Educational Programme as referred to by Early Education (ibid., page 23) reads as:

Developing a strong grounding in number is essential for providing children with the platform to excel mathematically. Children should develop a deep conceptual understanding of the numbers to 10, the relationships between them and the patterns therein. By providing frequent and varied opportunities to build and apply this understanding, children will develop a secure base of knowledge from which mathematical mastery is built.

Early Education (ibid.) recommend greater emphasis on practical experience and advises against use of the word 'mastery' in order to avoid potential confusion with a named programme intended for older children. Early Education (2018) show sensitivity to how 'intended policy' and 'policy-in-use' can differ as a result of a culture of accountability and in the way educators interpret these texts. In terms of impact on practice, Early Education highlight how policy text is driven by assessment (ibid.). More specifically, they are concerned that wording such as 'Automatically recall double facts up to 5+5' will impact on pedagogical practice and promote a tick box approach. Early Education (2018) express concern that proposed changes will result in a 'purely number focused' curriculum, and advocate that Shape Space and Measure should be included to avoid narrowing the early years mathematics curriculum.

In summary, this brief historical trajectory shows how evolving policy over two decades moved from developing mathematical understanding 'through stories, songs, games and imaginative play' (QCA, 1999) to descriptions of mathematical learning goals dominated by numeracy. Further, recent proposals for revision of the curriculum are criticised for omission of 'Shape, space and measure'. Such silences and gaps in policy texts influence the early mathematical experiences of young children. These gaps are given further consideration by aligning an Early Years policy text with Casey's mathematical model in the section which follows.

Actual Policy: Statutory Framework for the Early Years Foundation Stage (DfE, 2014a).

The Department for Education (DfE, 2018) states 'The early years foundation stage (EYFS) sets standards for the learning, development and care of your child from birth to 5 years old. All schools and Ofsted-registered early years providers must follow the EYFS, including childminders, pre-schools, nurseries and school reception classes'. Aubrey and Durmaz (2012) find an inter-play between local and global policy, resulting in diverse ways of conceiving and enacting mathematics curricula for young children, concluding that there are two dimensions concerning the implementation of policy texts: first, a horizontal dimension in the different interpretations of the curriculum across settings; second, a vertical dimension in changeover time, as policy evolves (Aubrey and Durmaz, 2012).

Though the Early Years Foundation Stage curriculum (DfE, 2014a, p.5) acknowledges that children develop and learn in different ways and at different rates, the terms 'learning' and 'development' are conflated, and nowhere in the document are these terms differentiated (Wood, 2014). This policy document refers 'to best available evidence' and describes the 'broad range of skills, knowledge and attitudes children need as foundations for good future progress' (DfE, 2014a, p.7) but fails to explain these phrases. Early years providers are advised to guide the 'development of children's capabilities' (DfE, 2014a, p.7) without clarification as to what these capabilities might be. The Early Years Foundation Stage describes what appears as good practice, without providing more explicit definition of what mathematics is and direction as to how this

complex subject can shared with children as part of teaching and learning experiences.

As discussed above, the t early years curriculum (DfE, 2014a) is structured such that priority is given to three 'prime areas' followed by four 'specific areas', one of which is mathematics (Early Education, 2012; DfE, 2014a). The three prime areas are considered 'the basis for successful learning in the other four specific areas' (DfE, 2014a, p.8), which suggests a hierarchy of subject importance, though arguably this could be interpreted as an opportunity to adopt an integrative approach to teaching; through the prime area 'communication and language', children access mathematical ideas, positioning story as the basis for 'successful' mathematical learning.

The EYFS policy document used in the empirical research identifies three characteristics of effective teaching and learning (DfE, 2014a, p.9): playing and exploring; active learning; and creating and thinking critically. Active learning is framed with the disposition that 'children concentrate and keep on trying if they encounter difficulties…' (DfE, 2014a, p.9). Other characteristics of teaching and learning include 'creating and thinking critically' and describe how 'children have and develop their own ideas, make links between ideas, and develop strategies for doing things' (DfE, 2014a, p.9). The proposals that children persevere, develop ideas, make links and develop strategies are suggestive of a 'relational understanding' of mathematics (Suggate et al., 2010; Skemp, 1976). The prescribed statutory early learning goals (DfE, 2014a) described as 'the knowledge, skills and understanding children should have at the end of the

academic year in which they turn five' (ibid., p.5) set out the expected level of progress (ibid.).

Though there is suggestion of exploration and finding pattern as part of the statutory goal for 'shape, space and measures' (ibid., p.11), this policy text for early years mathematics falls short of identifying the complexity of mathematics as proposed by Casey (2011) and Hersh (1998) and presumes an instrumental understanding for young children's mathematical learning (Suggate et al., 2010; Skemp, 1976). The focus of the number goal involves calculation strategies for addition and subtraction, multiplication and division, all of which Gifford (2014) argues is challenging for young children. Gifford (2014) identified that in ignoring research, professional advice, and other countries' policy, the policy makers produced what she considers to be an unachievable and complex number learning goal. There is little in the way of children experiencing other important aspects of early mathematics.

Though it could be argued that the early years policy text (DfE, 2014a) advocates a relational understanding with problem solving and pattern featuring, it is the surrounding discourse of teaching and learning in an accountability culture, promoting for example 'school readiness', which undermines this possibility. Further, the way educators will translate this aspect of policy text to policy-in-action (Ball and Bowe, 1992) will depend on their understanding of mathematics as having a socio-historical meaning (Hersh, 1998) and indeed where this view fits within the micro-culture of the school they work in (School of Hard Facts, 2012; Ball and Bowe, 1992). Referring to the framework based on Casey's model, several features of mathematics are overlooked in this early years curricula policy

text (DfE, 2014a): conjecturing; generalising; the idea of isomorphism; making mathematical errors and developing strategies to correct these; and curiosity for the subject. The early years policy text is aligned with ideas which support the conceptualisation of mathematics, and inherent gaps are noted in Table 2.1 which follows.

Conceptualisation of mathematics based on Casey's model (2011)	Policy text Statutory Framework for the early years foundation stage: Mathematics (DfE, 2014a)
Inner Pentagon • Acquisition of *facts* • Acquisition of *skills* • *Fluency* • *Curiosity* • *Creativity*	• There is little in the way of informing educators about which facts should be acquired by children. The main reference is counting from 1 to 20. • Skills encompass: counting reliably, placing numbers in order, saying which number is more or less than a given number, counting on or back to find the answer when adding or subtracting, solving problems (including doubling, halving and sharing). • Fluency is not specifically referred to, though is implicit for number in the reference to counting. • The statutory learning goals do not refer to curiosity or creativity in relation to mathematics.
Outer pentagon • *Algorithm* • *Conjecture* • *Generalisation* • *Isomorphism* • *Proof*	• Adding and subtracting two single-digit numbers. • Problem solving is positioned in relation to doubling, halving and sharing. • The idea of children explaining and using language such as 'always the case' is not evident. Children are required to recognise, create and describe patterns, which could relate to generalising but depends on how educators understand these ideas: recognising a pattern does not necessarily mean being able to make a generalisation from a pattern. • No reference to children recognising similar mathematical ideas in different context. • There is reference to using language to talk about size, weight, capacity, position, distance, time and money which could support explanations. (continued)

Tensions and contradictions between mathematics and early years policy texts and contradictions within this document:	The document advocates play though expects educators to prepare children for year one. The focus of learning is on 'numeracy' and 'shapes, space and measures' with a deficit of explicit detail.
Play: playing and exploring; active learning	Play is considered valuable as part of young children's learning experiences: 'Play is essential for children's development, building their confidence as they learn to explore, to think about problems, and relate to others' (DfE 2014, P.9). However, where the specific area of mathematical learning is referred to there is no reference to play.
School readiness	Though a play ethos is proposed, the statutory guidance refers to school readiness, which poses a contradiction within this policy text: 'As children grow older, and as their development allows, it is expected that the balance will gradually shift towards more activities led by adults, to help children prepare for more formal learning, *ready for year 1'* (DfE 2014, p.9, my italics). There is an expectation that early years experiences prepare children for year one.
Educational programme	The educational programme is dominated by a focus on numeracy with some reference to shape: 'Mathematics involves providing children with opportunities to develop and improve skills in counting, understanding and using *numbers,* calculating simple addition and subtraction problems; and to describe shapes, spaces, and measures' (DfE 2014, p.8, my italics). An over-emphasis on number potentially represents a deficit mathematical model.

Table 2.1: Early Years curriculum and Casey's (2011) mathematical model

Policy text: National Curriculum in England: framework for Key Stages 1 to 4 (DfE, 2013)

This policy text describes mathematics as a '…creative and highly interconnected discipline' and necessary for most forms of employment (DfE, 2013, p.103). In contrast to the early years curriculum, the ability to reason mathematically, and enjoy and experience curiosity is advocated (ibid.). The National Curriculum for mathematics aims to ensure children: are fluent in the fundamentals of mathematics; are able to recall and apply knowledge rapidly and accurately; reason mathematically by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language; and solve problems by applying their mathematics to a variety of routine and non-routine problems, including breaking down problems into a series of simpler steps and persevering (DfE, 2013, p.103). These aims align with the conceptualisation framework set out earlier. The interconnected quality of mathematics identified as part of Casey's (2011) model is noted in the following descriptors: 'Mathematics is an interconnected subject in which pupils need to be able to move fluently between representations of mathematical ideas' (DfE, 2013, p.103) and '…pupils should make rich connections across mathematical ideas to develop fluency, mathematical reasoning and competence in solving increasingly sophisticated problems' (DfE, 2013, p.103). Additionally, there is a recommendation that there should be connections to other subjects, which opens out the possibility of thinking mathematically through story, a potential integrative feature of both primary and early years curricula (DfE, 2013; DfE, 2014). In the primary curriculum, discussion is described as a way of probing and correcting misconceptions (DfE, 2013, p.104). However, there is a notable contrast between what is described in the general introduction of the primary

curriculum and the wording of learning objectives described in the programme of study; for example, the Key Stage 1 descriptor shows an emphasis on mental work, which is dominated by numeracy:

> The principle focus of mathematics teaching in key stage 1 is to ensure that pupils develop confidence and mental fluency with whole numbers, counting and place value. This should involve working with numerals, words and the four operations, including with practical resources [for example, concrete objects and measuring tools].
>
> (DfE, 2013, p.105)

The focus on problem solving is narrow and positioned in relation to number work and understanding place value. Statutory reference to solving problems is extended under notes and guidance, again positioning this aspect of mathematics within number operations:

> They discuss and solve problems in familiar practical contexts, including using quantities. Problems should include the terms: put together, add, altogether, total, take away, distance between, more than and less than, so that pupils develop the concept of addition and subtraction and are enabled to use these operations flexibly.
>
> (DfE, 2013, p.107).

Another reference includes 'use place value and number facts to solve problems' (DfE, 2013, p.111) and '[children] become fluent and apply their knowledge of numbers to reason with, discuss and solve problems that emphasise the value of each digit in two-digit numbers' (DfE, 2013, p.111). Problem solving is positioned within number and number operation work rather than considered as a more general feature of mathematics. Reference to measurement presents a statutory requirement, which potentially relates to storytelling, in that there is a focus on sequence or order: 'Sequence events in chronological order using language [for example, before and after, next, first, today, yesterday, tomorrow, morning, afternoon and evening]' (DfE, 2013, p.107). Reference to geometry and properties of shapes requires children to 'identify 2-D shapes on the surface of 3-

D shapes [for example, a circle on a cylinder and a triangle on a pyramid]' (DfE, 2013, p.115) which is relevant to later discussions concerning an oral story based on 'Stone Soup' (Forest, 1998). The primary policy text is aligned with ideas concerning mathematics based on Casey's (2011) model with contradictions highlighted in Table 2.2 on the page which follows.

Conceptualisation of mathematics based on Casey (2011)	Policy text: National Curriculum in England mathematics (DfE, 2013)
Inner Pentagon Acquisition of *facts*	These relate to number and go as far as 100 including 'represent and use number bonds and related subtraction facts within 20' (DfE 2013, p.107).
Acquisition of *skills*	A range of mathematical and functional skills are included in the purpose of study description.
Fluency	There is an emphasis on recall of facts and fluency with counting. The aim of the year one/two curriculum for mathematics is about pupils developing fluency.
Curiosity	There is reference to curiosity about the subject under the description for
Creativity	purpose of study '…an appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject' (DfE 2013, p.103).
Outer pentagon *Algorithm* *Conjecture* *Generalisation* *Isomorphism* *Proof*	Four operations included. Conjecturing and generalisations are described as aims associated with reasoning mathematically. No reference to ideas which could be associated with 'isomorphism'. Justification or proof using mathematical language is included as an aim.
Tensions and contradictions between mathematics and the National Curriculum; contradictions within this document:	This policy text is more explicit about what to communicate to children: reference is made to specific 2-D and 3-D shapes. However, there is no reference to a play-based approach to learning.
Purpose of study	Mathematics is described as an interconnected subject and there is reference to solving problems. Mathematics is proposed as a creative interconnected discipline.
Programme of study	There is tension within the document: the programme of study has a narrow focus, is more prescriptive and relates mainly to number facts and operations.

Table 2.2: National Curriculum in England: framework for Key Stages 1 to 4 and Casey's (2011) mathematical model.

The desire to raise standards has what Aubrey and Durmaz (2012) describe as a trickle-down effect on mathematics policy in reception and early years contexts. For reception class teaching, the policy texts (DfE, 2013; DfE, 2014a) do not rest easily alongside a play-based approach to learning (Aubrey and Durmaz, 2012). Further, within each statutory document there are contradictions in terms of general intentions and learning objectives, representing different pedagogical approaches. Tensions identified by Aubrey and Durmaz (ibid.) persist between and within these two curricula with different pedagogical possibilities for mathematics, both of which are formally assessed.

Assessment of early childhood mathematics

The pressure of assessment or testing impacts on the way educators approach teaching, and how they interpret and implement the curriculum, with a growing focus on inspecting and evaluating the quality of early years provision (Spencer and Dubiel, 2014). The proposal that the curriculum is flexible can only be accepted within the constraint that by the end of a key stage 'pupils are expected to know, apply and understand the matters, skills and processes specified in the relevant programme of study' (DfE, 2013, p.104). In other words, the curriculum is flexible as long as the end product is delivered and realised through test results. Ball and Bowe (1992) note how 'the idea that teachers can make the curriculum their own has to take adequate account of constraints that may arise from a national testing regime'. They found where there was a close adherence by schools to assessment policy, this led to a greater dependency on the National Curriculum being implemented prescriptively (ibid.).

The statutory framework for early years incorporates formative and summative assessment and though Burnard (2011, p.142) differentiates between summative and formative assessment – summative indicates where the child is now in terms of creative learning development; formative is where the teacher assesses what the child or children need on the basis of what has been achieved – Newton (2007) challenges a lack of clarity within the professional discourse of educational assessment and advises of the need to sharpen this. He refers to '…ongoing controversy in the UK over whether assessment evidence elicited for formative purposes can also be used for (so-called) summative ones' (ibid.,p.155) which raises concerns as to what the early years profile assessment model (Standards and Testing, 2013) attempts. He identifies that the uses to which assessment results are put are often categorised misleadingly and that the supposed distinction between 'formative' and 'summative' assessment is spurious and that differentiating between the two can hinder practice:

> I believe that there is a simple reason for this: the term 'summative' can only meaningfully characterize a type of assessment judgement (i.e. it operates at the judgement level of discourse), while the term 'formative' can only meaningfully characterize a type of use to which assessment judgements are put (i.e. it operates at the decision level of discourse). The terms belong to qualitatively different categories; to attempt to identify characteristics that distinguish them—within a single category— is to make a category error.
>
> (Newton, 2007, p.156)

Education and care are brought together in a single framework alongside the Early Years Foundation Stage Profile (EYFSP) (Standards and Testing, 2013) which, though it culminates in summative assessment, is based on formative assessment and concluded before a child enters Key Stage 1. The Early Years Profile claims to be a summative assessment of what a child has achieved in line with the learning outcomes of the early years foundation stage; however, the assessment is based on observations of children to make assessment

judgements. In other words, the EYFS (ibid.) profile provides a summative statement based on observational data, thus bringing conflict and confusion to early years assessment. Indeed, Newton (2007, p.155) advises that: '…it is important to distinguish between the aim of an assessment event – which concerns translating an observation of performance into a particular kind of assessment judgement –and the use to which that judgement is put'; practitioners observe children and use this to judge what children have achieved which translates to data which are passed to the child's year one teacher and parent or carer. He (ibid.) makes the point that '…there is no such thing as, for instance, a formative judgement' and that 'whatever the nature of a judgement there would be nothing formative happening unless the judgement was used in an attempt to improve learning'. In practice, these summative assessments inform year one teachers about children's abilities and, therefore, assessment of young children via the EYFS profile (Standards and Testing, 2013) is fundamentally flawed as evidence elicited in a formative way is not necessarily intended 'to improve learning' (Newton, 2007) and contributes to a summative statement about a child, thereby combining two competing purposes.

The purpose of assessment moves away from finding about individual learners when the data are generalised and becomes more of a judgement about an institution's success or failure, as evident with Statutory Assessment Tests (SATs) (Ball, 2013a; Waters, 2013). Carter and Nutbrown (2014, p.127) outline how assessment is used in different contexts to represent different things, and distinguish between 'assessment for teaching and learning' or 'assessment for management and accountability', the latter utilising scores rather than narrative accounts. The Department for Education and Skills (DfES, 2003, p.5)

recommended that 'Learning must be focused on individual pupils' needs and abilities' and that the focus is on developing *assessment for learning* 'which enables knowledge about individual children to inform the way they are taught and learn'. When assessment becomes more about management accountability rather than assessment for teaching and learning, the potential exists for the learner to become invisible, as has happened with the EYFS Profile (Carter and Nutbrown, 2014, p.133); and likewise, since their introduction, the focus of SATs has become about comparing schools rather than assessing children (Ball, 2013a; Waters, 2013).

Intended policy: assessment and school readiness

School readiness as an educational theme brings constraint and challenge for early years educators. The three prime areas of the EYFS curriculum noted earlier are intended to '…reflect the key skills and capacities all children need to develop and learn effectively, and become *ready* for school' (DfE, 2014a, p.9, my italics). The EYFS Profile is intended to provide '… a well-rounded picture of a child's knowledge, understanding and abilities, their progress against expected levels, and their *readiness* for Year 1' (DfE, 2014a, p.14, my italics). Intended policy for early years education is that children are made ready for school, bringing conflict to the practitioner who values early years education for what it is rather than a preparation for the next stage.

Further, the language used to categorise young children as part of the EYFSP summative assessment is potentially damaging as a descriptor for a child's attainment. The language of assessment includes the following categories: 'exceeding expected levels', 'meeting expected levels of development', or, like a

tortoise poking his head from his shell, 'emerging' (DfE, 2014a, p.14); and though these are referred to in the profile (DfE, 2014b), they are not adequately defined. Carter and Nutbrown (2014, p.131) caution that formalised assessment at the age of four can limit the opportunities children are offered rather than opening up opportunities for learning, and advise that practitioners challenge the language of policy when it is at odds with a holistic and developmental view of children's learning (ibid., p.133; Gifford, 2004b). The outcome of flawed assessment is worthy of note as Marks (2014, p.39) points out that ability categorisation of individual potential is often 'immutable' and as such is a fixed determinant of a child's future attainment. Children develop at different rates and statements about whether children are meeting levels of development bring conflict to an ethos of looking at what children can do, where they are at now, and what they potentially can achieve. Duffy (2014, p.120) points out that 'there are contradictions in the way the EYFS curriculum views the child'; it describes how children develop at different rates but has an expectation that all children will reach the early learning goals.

Qualifying as a learner

Bradbury (2013) identifies that the EYFS Profile (Standards and Testing, 2013) assesses the extent to which children qualify as a learner within the framework and considers it to be a restrictive model challenging how statements such as 'a good level of development' can be arrived at. She highlights that for children to be recognisable as learners, they need to perform a complex array of characteristics at the right times and in the right ways. Further, children need to access 'learning' in all its forms, process it, and reproduce it for the purpose of assessment, which she asserts is unrealistic for four and five year olds: half of

children in the 2008/9 results were considered to have failed to reach expected levels of development (DCSF, 2010, cited in Bradbury, 2013). Such outcomes continue and challenge the appropriateness of these assessment models, which continue as early years assessment policy. Roberts (2006, cited in Carter and Nutbrown 2014, p.127) makes the insightful point that whatever the purpose, 'assessment impacts on how children perceive themselves as learners'. The quiet, shy child, the child who is focused on one activity, and the child who struggles to recognise and work with demands of the classroom are considered as failing within this assessment model because they' fail to demonstrate looked-for markers of an ideal learner set out by the profile assessment model' (Bradbury, 2013). This is worthy of mention because later in this research, children who are considered 'quiet' or 'shy' are particularly noted for responding favourably to oral mathematical story. It is worth noting that the EYFS profile was revised in September 2012 and the first assessments under the revised format took place in summer 2013, reducing assessment across what was 117 areas to 13 areas, followed by withdrawal in September 2014 of the profile handbook (Standards and Testing, 2013), with a return to baseline assessment on the horizon (Wood, 2016).

Assessment concerning education is a slippery business and often involves subjective judgement on the part of the assessor and anxiety on the part of the settings being assessed. Education Scotland (2014) provide advice to support educators involved in early years, school and learning community inspections. Educators can take charge of internal and external assessments of their practice by surveying in advance the specifications against which they are measured and by sourcing appropriate evidence. Ofsted (2014) provides an evaluation schedule

to guide inspectors, which educators can scrutinise. The evaluation schedule supports direct observation supplemented by a range of other evidence to enable inspectors to evaluate the impact that practitioners have on the progress children make in their learning. The additional evidence should include ongoing (formative) assessments, including parental contributions. Such guidance opens out the possibility to communicate moments of meaningful practice beyond those observed at the time of inspection and this positions the oral mathematical story observational framework developed as part of this research project as a useful tool. The proposed observation format is a way of documenting mathematical narrative qualitatively, incorporating views of children, parents and educators, and can be shared with third parties. The format based on Casey's (2011) model is a way of exemplifying what children are doing in the setting, a way of communicating moments of mathematical thinking in a meaningful way and is discussed further in the next chapter.

Conclusion

Mathematics encompasses knowledge of facts, application of skills and processes as well as an emotional disposition. A model proposed by Casey to assist with the conceptualisation of mathematics (2011) was outlined and adapted to include additional aspects which feature as part of young children's mathematical understanding. The observational framework based on Casey's model (2011) supports the conceptualisation of mathematics and enables documenting of children's mathematical behaviours. As part of this framework the idea of isomorphism (ibid.) was adapted to include children restructuring mathematical ideas heard in story, in play contexts. Mathematising horizontally and vertically both potentially relate to isomorphism (ibid.) in that children can

reconstruct abstract ideas in concrete ways using story-related props and extend mathematical ideas heard in story as part of alternative play structures.

Mathematics is difficult to conceptualise; policy texts concerning early childhood mathematics are political and hold conflicts and tensions, which educators interpret as 'professionals' or 'technicians' (Ball and Bowe, 1992). The process of policy implementation has a horizontal dimension in the way interpretations can differ and a vertical dimension as policy evolves over time (Aubrey and Durmaz, 2012). Mathematising horizontally and vertically (Treffers and Beishuizen, 1999) is further complicated when positioned within the horizontal and vertical dimensions of policy implementation which for this research concerns the Early Years and National curricula (DfE, 2014a; DfE, 2013).

Recommendations for discussion and mental work (DfE, 2013) open out the possibility of thinking mathematically through story and prompted the research question: how can oral story encourage children's mathematical thinking in reception and year one classrooms? However, positioning oral mathematical story as a pedagogical choice to facilitate young children's mathematical thinking is challenged by the complexities outlined in this and the next chapter.

Chapter Three

Teaching and learning: a sociocultural theory of development

Introduction

The sociocultural perspective proposed by Vygotsky (1978) argues that cognitive development need not precede formal teaching and learning processes; rather, effective teaching drives development. Development and learning cannot be separated from teaching because they are inextricably bound; instead they can be viewed as two sides of the same coin (May et al., 2006, p. 103). May et al. (.,ibid. p. 103) propound that 'the way we teach, what we teach, and why we teach it, will depend on a wide range of interrelated, interdependent variables surrounding the development of the child, the environmental context and the curriculum', some of which was identified in Chapter Two. This chapter explores what it means to teach and learn from a sociocultural perspective in order to construct a framework for teaching and learning mathematics, and analyses the data generated as part of this research project.

May et al. (ibid., p. 95) consider that 'current practice relies on two theoretical strands of knowing': first, 'knowledge as being objective and external to the human condition' (ibid.); second, 'knowing seen as being subject to internal human processes in constant interaction with the environment' (ibid.). Lave and Wenger (1991, p.122, italics in original) share the view that '*Knowing* is inherent in the growth and transformation of identities, and it is located in relations among practitioners, their practice, the artefacts of that practice, and the social organisation and political economy of communities of practice'. Further, environmental contexts extend beyond the classroom to the cultural experience of the child within their family which is 'informed by wider political and social

issues' (May et al., 2006, p. 103). A view of 'knowledge as hypothetical and subject to change, of children as problem solvers who interact with their environment' (ibid., p. 101), attributes importance to past, present and future experience as part of development, much of which extends beyond the classroom to a wider arena. A perspective that the environment is powerful in influencing the success of education represents a view of 'knowing' which starts from the subjective, developing world of the individual, holds implications for teaching and learning, and represents a 'bottom-up' rather than 'top-down' model of education with a top-down model of learning, restricting rather than opening up creative learning opportunities (ibid., 2006, p. 15; Schiro, 2004, p.59). Educators create the environment or context of the classroom, though how they do so depends on a variety of interrelated factors, one of which includes whether the institution they work within is a 'bottom-up' or 'top-down' model of education and their personal perspective about education on what it means to know.

This chapter analyses ideas concerning a sociocultural theory of development, and in doing so presents an argument which positions oral mathematical story as a potentially suitable pedagogical approach to facilitate children's mathematical development. Eun (2010) bases eight instructional principles on four themes relating to the work of Vygotsky's sociocultural perspective on development and learning and an analysis of these principles serves to construct an analytic framework which supports pursuing the research question as to how oral story can encourage mathematical thinking in reception and year one classrooms.

The proposal that if children are provided with real-life problems to solve in school they can develop generalisable and 'adaptive problem-solving skills' (Eun, 2010, p.410; Vygotsky, 1978) is contested as part of this discussion. The idea that

children reconstruct mathematical ideas in play or story narrative is asserted as a possible outcome of these activities.

Mathematical teaching and learning encompasses different forms of knowledge, practices learners participate in, and relationships between the child and the discipline of mathematics (Boaler, 2002, p.177). Through a comparative study Boaler (ibid.) explores the impact of two different approaches to teaching and how these affect the perceptions students develop of mathematical concepts and procedures and of their identities as mathematicians. The apparent chaos of one school where learning is grounded in activities, socially constructed and context driven, is compared with the more didactic approach of another. Before analysing the work of Boaler (ibid.), aspects of Vygotsky's sociocultural theory are considered.

Sociocultural theory of development

The instructional principles proposed by Eun (2010, p.403) are based on four general sociocultural themes: first, the importance of home-school connections; second, the interactive, collaborative, dynamic, and dialogical nature of teaching and learning; third, teaching and learning as a process rather than a product; and fourth, the integrated nature of development. Each of these themes is outlined before considering the principles of instruction in more detail.

Eun's (2010) sociocultural informed instructional model acknowledges that children bring knowledge from home to school and that home and school are the main places where children experience social interaction, warranting that educators connect with these locations in order to plan for effective education.

Therefore any learning a child experiences in school always has a previous history and as stated by Vygotsky (1978, p.84), 'Consequently, children have their own preschool arithmetic, which only myopic psychologists could ignore'. May et al. (2006, p. 43) consider that 'learning at home is a socially constructed activity with parents' and Pound (2006, p.22) considers that insufficient regard is given to children's informal home-based learning, with the use of schemes and worksheets disregarding children's previous understanding and knowledge. Pound (ibid.) refers to potential discontinuity when educators fail to take account of what children already know: 'In order to support mathematical development, children should be provided with ways of making connections between what they already know and what they are learning' (ibid., p.32). This research proposes that oral mathematical story can be positioned as a pedagogical approach which allows children to make connections with what they already know, and that school experiences can be shared with children and their parents.

The interactive, collaborative, dynamic, and dialogical nature of teaching and learning is a characteristic of the sociocultural perspective proposed by Vygotsky (1978). Teachers who view teaching and learning through a sociocultural perspective lens are more likely to encourage dialogue and support diverse learning activities, encouraging children to '…participate as active constructors of knowledge rather than as passive receptors of pre-made knowledge 'made'(Eun, 2010, p.403). This perspective of teaching and learning views dialogue as a way of constantly negotiating learning goals (ibid.). The sociocultural theory of development based on the work of Vygotsky considers that '…the greatest motivating force in development is the social interaction between two or more people' (ibid., p.401), and that communication through spoken language is the

most effective way of facilitating this social interaction (Vygotsky, 1978; Eun, 2010). Educators' perspectives on teaching and learning will be intrinsically linked to their attitude towards using dialogue as part of oral story experiences to teach mathematics. Further, sociocultural instruction is characterised by '…recognising that teaching and learning is a process rather than a product' (Eun, 2010, p.404), with knowledge co-created between teacher and child. The idea of using oral story challenges the notion of an end product; while it is not documented as evidence like a worksheet, it can be recorded by video or audio or both.

Vygotsky (1978) proposes a functional learning system comprising elementary structures and higher structures, with higher structures constructed on the basis of the use of signs and tools. Higher psychological processes are framed as voluntary remembering and deductive reasoning. A fundamental hypothesis of the sociocultural theory is that the higher mental functions are socially formed and culturally transmitted. Rather than individual functions developing separately, it is the integrated nature of development that is central to Vygotsky's sociocultural perspective (Eun, 2010; Vygotsky, 1978) which, in an evidence-based education culture, is problematic as this interrelated quality of development is difficult to assess. As noted in Chapter Two, curriculum policy texts lean towards an instrumental understanding of mathematics driven, as argued earlier, by international competiveness, which at a classroom level can often manifest as a worksheet culture (Carruthers and Worthington, 2011, 2009, 2006). In the context of this research, the implication is that oral story as a pedagogical approach may require a shift in educator perspective about what is important about teaching and learning. Consequently, changing the way mathematics is taught opens up a new discourse which potentially allows or legitimatises a

different way of thinking of mathematics, creating the opportunity for a more qualitative approach to assessment. Assessing mathematics in qualitative ways will require a different perspective about what it means to teach and learn mathematically.

The characterisation of effective instruction captured by the eight instructional principles set out by Eun (2010, p.401) proposes that for instruction or teaching to be effective it needs to be: mediated; discursive; collaborative; responsive; contextualised; activity-orientated; developmental; and integrated. From a sociocultural perspective, acquisition of knowledge and understanding stems from exploration, mediated learning experiences and discursive communication (Eun, 2010; May et al., 2006; Rogoff, 2003; Vygotsky, 1978). Each principle of instruction contributes to a framework against which oral storytelling is positioned as a potentially powerful instructional approach for teaching and learning mathematics. The first principle is that of instruction being a process of mediating ideas through adults, language, and other tools, and in so doing supports 'mediated remembering '(Vygotsky, 1978, p.45).

1.1 Mediated instruction

This research draws on sociocultural perspectives, where individual development is influenced by social, historical and cultural factors. The concept of mediation is a fundamental element of Vygotskian principles of instruction as detailed by Kozulin (1998),); Eun (2010) and Daniels (2016). Daniels (2016) holds the view that it is through understanding the Vygotskian mediational model which is central to instruction, that possibilities for pedagogical intervention can be realised. Thus, Daniels positions the mediational model proposed by Vygotsky as of great

importance in developing our understanding of the possibilities for interventions in processes of children's learning and development. This thesis concerns possibilities for oral story as a mathematical intervention and, with this in mind, further analysis of what constitutes the mediational model, particularly the role of mediating tools/artefacts and contexts, is considered.

The Vygotskian sociocultural historical perspective intertwines three phrases: social, cultural, and historical. Cole (1997, p.108) reflects on how each term framing this perspective is '…tightly interconnected with, and in some sense implies, the others'. Cole (ibid.) sets out the basic principles of cultural-historical psychology as follows: mediation through artefacts; historical development; and practical activity. He explains how 'the central thesis of the Russian cultural-historical school is that the structure and development of human psychological processes emerge through culturally mediated, historically developing, practical activity' (ibid. p.108). Sierpinska (1994, p.138) concurs taking the view that 'understanding is both developmentally and culturally bound'. The implication of this perspective is that children's mathematical understanding is connected to individual development and culture. This interconnectedness from a Vygotskian perspectives maintains that 'what a person understands and how he or she understands is not independent from his or her developmental stage, from the language in which he or she communicates, from the culture into which he or she has been socialised' (ibid.). Different communities offer different backgrounds and historical traditions with their own cultural rules and conventions which are acquired by children in these communities. Children come to realise ways of behaving which are valued both at home and at school and, in the context of this research, what are favoured mathematical behaviours. This thesis adopts a

socio-cultural approach to children's development and learning. Consideration is given here and later, in Chapter Seven, seven to cultural influences on children's mathematical narratives. Though the empirical research pays particular attention to the cultural influence of the classroom the thesis acknowledges the complexity of cultural influences beyond those of the classroom.

A cultural mediational model

The child is surrounded by contextual experience imbued with the social, cultural and historical nature of their community. They are also located in a school context and through mathematical story narratives they interact with their teacher and their peers. A Vygotskian perspective proposes that the child's individual development is influenced by social, cultural and institutional factors (Daniels, 2016; Cole, 1997). The child is positioned between their home culture and that of their school. Culture and community are not independent factors removed from the child; instead they are, as it were, the mediational medium within and through which ideas are developed. In this work, the culture of the school, the community of the classroom and the culture of a child's community are all recognised as mediational channels through which mathematical ideas are developed. There is a continuous mediational exchange between these channels all of which contribute to towards individual development. For example, when counting, representations or mediational tools support mathematical thought processes as children use number names as labels and actions such as moving items to one side as they are counted. When counting, the child draws on what have become the accepted mathematical systems of their community and school.

It is proposed in this research that the child draws on the shared cultural practices of their community. Classroom and community culture influences the child's words and actions, as they use mediational tools and experiences to construct mathematical meaning in imaginative ways through story narratives. Specific cultural values and practices associated with mathematics and what it means to think and behave mathematically permeate from home and school and more specifically the classroom, or oral story spaces. The mediators of surrounding culture influence the mathematical ideas, actions, words and story narrative the child creates. The thesis now focuses on the cultural nature of the mediational process concerning oral mathematical storytelling.

Cultural influences on children's narratives

Cultural tools developed over time used to support mathematics are artefacts through which thinking about ideas is mediated, examples of which include the abacus for counting, and hundred square grids. In this work, story narrative is included under the term artefact along with words, mathematical manipulatives and actions. Children's mathematical stories are viewed as artefacts influenced by the cultural context of communities children are born to and classrooms they belong to.

The special structure of artefact-mediated action (Cole 1997, p.118)

The Russian cultural-historical psychologists used a triangle to represent the structural relation between the individual and the environment (Cole 1997, p.118). This mediational triangle with subject, artefact and object at each corner is such that the subject and object are not only directly connected but also indirectly connected through a medium constituted of artefacts or culture (ibid.). Two

pathways arise from this model as follows (ibid.): subject to object (s-o); and, subject to artefact to object (s-a-o). Daniels (2016, p.14) considers that the triangular model 'represents the possibilities for subject-object relations', which these pathways describe. Daniels (ibid.) acknowledges that artefact can be replaced with tool in some representations using this triangular image. The terms 'tool' and 'artefact' are used interchangeably above and are differentiated next.

Tools or artefacts

Daniels (2016, p.21) distinguishes artefact from tool as follows: 'the idea of meaning embodied or …sedimented in objects as they are put into use in social worlds is central to the conceptual apparatus of theories of culturally mediated, historically developing, practical activity'. Cole (1997, p.117) explains how from his perspective an artefact 'is an aspect of the material world that has been modified over the history of its incorporation into goal-directed human action'. Both Daniels (2016) and Cole (1997) associate artefact with the idea of embodiment of cultural-historical meaning. Mathematical knowledge in a Vygotskian sense is sedimented in cultural artefacts such as the abacus and the hundred square and educators play a role in demonstrating to children how to use and how to think about these mathematical tools. Returning to the idea of the mediational triangle proposed by Cole (1997), the thesis advances this idea further.

The general concept of mediation based on subject-object relations represented as a triangular model can be: unmediated, direct and natural; or, mediated through culturally available artefacts (Cole 1997, p.119). The unmediated representation is that of subject to object; the mediated pathway is that of subject

to artefact to object (ibid.). Cole describes how unmediated functions are those along the base of the triangle; mediated functions where the subject interacts with their environment are linked through the vertex of the triangle (ibid., p.119). Daniels (2016, p.14) proposes that these subject-object relations are either unmediated, direct and in some sense natural, or they are mediated through culturally available artefacts or tools. This 'triadic relationship of subject-medium-object' (Cole 1997, p.119) relates to this research concerning oral mathematical story in that the child, as subject, experiences the medium of oral story with associated artefacts to understand mathematical concepts.

However, Cole (1997, p.121) cautions against relying on the 'minimal mediational structure' of this triangle, suggesting a need to consider 'aggregations of [artefacts] appropriate to the events they mediate and to include the mediation of interpersonal relationships along with mediation of action on the nonhuman world' (ibid.). He modifies the original simple representation to a set of interconnected triangles which include: other people (community); social rules; and division of labour between the subject and others (ibid. p.140). Cole explains the terms as follows: 'the *community* refers to all who share the same general object; the *rules* refer to explicit norms and conventions that constrain actions within the activity system; the *division of labor* refers to the division of object-oriented actions among members of the community' (ibid., p.141, italics in original). Cole (ibid., p.141) concludes that 'The various components of an activity system do not exist in isolation from one another; rather, they are constantly being constructed, renewed, and transformed as outcome and cause of human life'. Thus, artefact-mediated action is a complex and dynamic interplay between culture, historical and social factors. Representation of the mediational structure as a more complex

arrangement including community highlights the complex role culture plays in mathematical development.

The role of cultural tools in mathematics learning

The subject-object-artefact (tool) relationship presented as a triangulated image by Cole (1997) and Daniels (2016) provides a framework for Cobb's (1995) ideas concerning the role of cultural tools. Of particular interest to Cobb (1995) is children's use of instructional devices (artefacts/tool) and the role these play in the construction of mathematical concepts such as place value. He investigates children's transition from counting in ones, to counting in tens and ones, and clarifies the differing roles of cultural tools such as the hundreds board in this field of mathematical thinking. Through observing the arithmetical problem-solving activity of children, Cobb (1995) provides insights into individual children's mathematical construction of ten. He notes how some children persist with counting in ones and others are observed counting in tens and ones, or, more notably, making the transition to this more efficient way of completing calculation problems. Cobb (ibid.) finds that ability to make the transition relies on the individual child seeing ten as an abstract composite of ten; for example, they use one finger to represent the value of ten.

The role of cultural tools or artefacts in mathematical learning is more complex than might be supposed, as is evident in the research presented by Cobb (1995). As discussed earlier, a sociocultural perspective recognises the crucial role played by interaction between individuals and by children's mastery of tools that are specific to the culture they are born to (Cobb 1995). Cobb (ibid.) proposes that place value numeration or notation might be viewed as a culturally organised

way of thinking. Cobb (ibid.) investigates how children interact with a specific cultural tool of place value numeration, a hundreds board (ten by ten grid, starting with 1 and ending in 100). This tool is deemed in his research to be an efficient way of supporting calculations (ibid.). The framing of a sociocultural perspective as the mastering of cultural tools is stated by Cobb (ibid., p.383) as: 'We see the abstract mathematical reality we create symbolically as we look through the cultural tool we use'. Representation of abstract ideas concerning place value in symbolic ways through culturally derived tools suggests these tools play a role in supporting mathematical learning. Cobb's (1995) research on a hundreds board, as a mathematical cultural tool selected to develop mathematical ideas concerning place value, is analysed next. This is with the aim of highlighting the complexity associated with the role mathematical artefacts potentially play as mediators in this research.

The role of the hundreds board as cultural tool

Cobb (1995) found children's use of the hundreds board did not support the construction of increasingly sophisticated concepts of ten. More specifically, Cobb (ibid.) emphasises how the hundreds board did not play a significant role in supporting 'conceptual advance': it was prior ability to abstract about the value of ten which enabled use of the hundreds board in this way. Children's use of the hundreds board appeared to support their ability to reflect on their mathematics activity after they had made the conceptual leap of seeing ten as a complete unit rather than as ten ones (ibid.). Cobb's observations of the board as a cultural tool was that it did not support the emergence of understanding; rather, as a cultural tool it facilitated reflection on mathematical activity (ibid.).

Cobb's findings highlight the importance of not assuming the role cultural tools will play as mediators. Cultural tools can work as mediators of mathematical thinking, though not always; in the case outlined by Cobb (ibid.) the hundreds board facilitated reflection on place value computation strategies as mathematical activity, rather than advancement of mathematical development with this concept. His work highlights the need to consider carefully the role artefacts may play in the construction of mathematical concepts. In the case of Cobb's (1995) work, children reflected on instruction through the hundreds board tool; the tool was not the instructor of place value.

Cole (2007, p.73) refers to the work of Giyoo Hatano and the ways in which the use of an abacus mediated arithmetic problem solving. This particular kind of mediational artefact serves as a psychological tool for accomplishing culturally valued problem solving (ibid.). He explains how when the internalisation of the abacus has advanced and calculations can be carried out without it, it becomes a 'mental abacus' or, from a Vygotskian perspective, a 'psychological tool' (ibid., p.78). Daniels (2016, p.15) outlines how Vygotskian psychological tools include various systems for counting, algebraic symbol systems, and diagrams; these tools are considered relevant to this thesis concerning mathematics education. Using this framework, systems for counting are artificial, of social and of cultural origin, and as tools assist with mental mathematical processes.

Numbers and counting

Mathematics as a discipline has evolved historically and continues to evolve socially, culturally, in the context of educational policy and institutions. Sierpinska (1994, p.160) describes how 'in different cultures, different things are attended to. Numbers and counting are important in certain cultures. Children are trained in memorising the sequence of numerals…'. In these cultures young children are praised for counting to 100 (ibid.). However, other cultures place less emphasis on this and '…have not found it worthwhile to invent numerals above a certain small number, and do not bother to think about numbers as objects in themselves' (ibid.). Cultural tools such as the number or counting systems and definitions or delineations of shapes have over time specifically developed to support mathematical thinking. The number system is a good example of diversity of cultural tools developing historically in that different cultures have elected to use different systems to represent counting. The base ten system is a culturally based system framed by specific language and visual representations such as a hundred square grid sometimes used in contemporary classrooms. How shapes are described and categorised is another example of a culturally acceptable way of thinking about mathematics. For example, triangles can be categorised as having or not having 'right angles', which children need to understand as '90 degrees' or an 'upright angle'. The use of cultural tools, developed over generations to mediate mathematical thinking, include counting and number systems. Other examples include the naming and categorising of shapes which constitute cultural constructions of mathematical ideas or artefacts.

This thesis acknowledges that though children can explore counting systems, freedom is constrained by language and culturally agreed ideas or ways of

relating to this concept. Chapter Seven will consider how this idea of culturally mediated thinking about mathematical artefacts plays out in the context of school-based mathematical narratives. Though children are offered freedom in telling these stories, it is acknowledged that culturally mediated artefacts inevitably constrain mathematical thinking; culture structures the way we are expected to think and behave mathematically.

In the empirical research, a range of mediational tools are utilised by children and educators which influence the mathematical narratives that children construct. The discussion thus far about mathematical objects as cultural artefacts is relevant to this work for several reasons: first, understanding the complexity of the role they play cautions our interpretations of data; second, it suggests that mediational artefacts may be internalised as psychological tools; third, these tools may not always mediate the intended mathematical ideas, as found by Cobb (1997) and Cole (2007).

Cultural mediators: freedom and constraints of the mediational process

Referring to the work of Bakhtin, Daniels (2016, p.12) states '…that the processes of mediation are processes in which individuals operate with artefacts (words/texts) which are themselves shaped by, and have been shaped in, activities within which values are contested and meaning negotiated'. Importantly, he explains how 'in this sense cultural residues reside in and constrain the possibilities for communication' (ibid., p.12). In a similar vein, Sierpinska (1994, p.159) positions the beliefs or world views acquired by children from the culture they are born to, as potential constraints or 'sources of obstacles' to understanding. Sierpinska (ibid.) considers that these obstacles are nurtured by the culture the child is born into: '…from the implicit and explicit ways in which the

child is socialized and brought up at home, in the society, in the school institution'. Thus, on the one hand, culture affords children beliefs and insights; on the other hand, these cultural mediators potentially constrain communication. That the meaning of mathematical cultural artefacts has been negotiated and potentially constrains possible ways of communicating mathematical thinking is considered in relation to the findings of this research in Chapter Seven.

Three levels of artefacts

Cole (1997, p.121) refers to the work of Marx Wartofsky, who proposed a three-level hierarchy for artefacts. The first level of this framework consists of primary artefacts, which are 'those directly used in production' (ibid.); Cole provides his own examples, which include 'words, writing instruments, telecommunications networks, and mythical cultural personages' (ibid.). Such primary artefacts align with Cole's ideas of 'artefact as matter transformed by prior human activity' (ibid.). 'Secondary [artefacts] consist of representations of primary [artefacts] and of modes of action using primary [artefacts]' (ibid.). He considers (ibid.) secondary artefacts important as they 'play a central role in preserving and transmitting modes of action and beliefs' (ibid.), and provides examples such as 'recipes' and 'traditional beliefs' (ibid.). The third category Cole advises (ibid.) were termed by Wartofsky as 'imagined worlds'.

In the context of this research, primary artefacts are simple items such as counters or buttons or cut-out spots as part of the Ladybird storytelling; secondary artefacts, the action of counting including moving the items as part of this process, for example Jake removes the spots from the cut-out ladybird; and tertiary

artefacts, for example, the imagined ant and rain which are central to the Ladybird story. This means that, potentially, oral mathematical story can have three levels of artefact working together as part of this form of cultural mediation.

The process of mediated instruction is recognised by Vygotsky as the way of developing higher psychological functions (Eun, 2010). The very essence of human memory consists in the fact that human beings actively remember with the help of signs (Vygotsky, 1978, p.51). Mediated activity through signs and tools supports memory, which in early childhood is one of the central psychological functions upon which all the other functions are built (ibid., p.50). Higher structures are constructed on the basis of signs and tools and younger children, particularly between the ages of four and six, rely on meaningful, ready-made connections between the 'reminder' sign and the associated word to be remembered (ibid., p.47).

Three categories of mediation can be visualised as points of a triangle: 'tools', 'symbols' and 'other human', with the learner in the centre. Children's learning experience is mediated through material tools, symbolic systems (which include spoken language), and through other human beings, more specifically teachers (Eun, 2010; Kozulin, 1990; Vygotsky, 1978). Although these categories of mediation work together to mediate learning, each is discussed separately.

The process of mediation through another human directly relates to Vygotsky's theoretical perspective concerning the Zone of Proximal Development (ZPD). Vygotsky places value on children learning from adults and more capable peers when he proposes the concept of the ZPD:

> It is 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, p.86)

He proposes that an essential feature of learning is that it creates the ZPD: '…that is, learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers' (ibid., p.90). The ZPD conceptualises the idea of learning supporting development with a caveat that '…the only "good learning" is that which is in advance of development' (ibid., p.89); the quality of learning determines the possibility of the ZPD. Vygotsky (1978) develops this idea further, positioning learning ahead of development, and valuing children imitating adults, which illuminates what he refers to as a Zone of Proximal Capability (ZPC).

He (ibid.) identifies how demonstration influences the way a child might solve problems independently and advocates that child development can more accurately be determined by considering actual and proximal development, arguing that diagnostic tests of development should include assessment of imitative activity in order to be conclusive. He (ibid., p.87) argues for a re-evaluation of the role of imitation in learning, basing this on a belief that 'To imitate, it is necessary to possess the means of stepping from something one knows to something new' (ibid., p.187) and suggests that it is children's imitative activity which offers rich insight into their mathematical capabilities. Gifford advises that educators provide opportunities for children to learn through 'observation, instruction and rehearsal' (2005, p.17) and, thus, adult or peer demonstration of oral mathematical storytelling can prompt children's imitative activity. This approach opens out the possibility of understanding children's

capabilities and in this way the ZPD is supported mathematically through oral story.

Language as a symbolic mediator

Language and thought are related, and Vygotsky considers especially spoken language as a social activity that supports thought through problem solving. Vygotsky (1978) views the use of spoken language as a cultural tool (in social interaction) and as a psychological tool (for organising our own, individual thinking). Bruner (1986) extends Vygotsky's ideas about the social construction of language by proposing that language and thought are regulated by cultural practices (May, 2006, p.74). Bruner and Vygotsky see the role of adults as essential in relation to talk and the child's understanding (ibid., p.74). Children creatively construct talk that incorporates what May (2006, p.75) refers to as 'a rich intertext of meaning'. May considers that language is more than a tool of communication, that it is a culturally value-laden way of making meaning, is social, and provides the dialectic base for early years pedagogy (ibid., p.73). Spoken language is the channel through which we achieve shared knowledge: '…language provides us with a means for *thinking together,* for jointly creating knowledge and understanding' (Mercer, 2000, p.15, italics in original). The idea of spoken language as a channel through which children develop shared knowledge is discussed further when the collaborative instruction principle is considered.

The importance of sustained, shared spoken conversations is recognised as part of learning in the early years and is in line with curricula requirements (DfE, 2014a; DfE, 2013; Early Education, 2012). However, Pound (2006, p.25) argues that there are opposing views to this perspective, citing Tobin (2004), who

stresses the importance of sensorimotor thinking, cautioning that insistence on verbal expression may be at the expense of a child knowing and understanding in other ways.

Piagetian theory is considered relevant to this research particularly as there is an acknowledged connection between the work of Piaget and Vygotsky. Piaget (1955, p.350) analyses the origin of intelligence and shows how 'the forms of intellectual activity are constructed on the sensori-motor level'. He (ibid.) theorises about the transition from sensorimotor intelligence to conceptual thought and describes how sensorimotor or practical intelligence characterises the first two years of a child's life as they assimilate the external environment and progress to 'forms an increasing number of schemata' (ibid., p.xi). From a Piagetian perspective the idea of transitioning from sensorimotor to conceptual intelligence is relevant to this research as the children are, for the most part, four and five years of age.

Piaget explains (1952, p.17) how 'it is not that a perception *begins* by being interesting or meaningful and *later* acquires a motor power through association with a movement: it is interesting or meaningful *just because* it intervenes in the performance of an action and is thus assimilated to a sensory-motor schema'. He (1951, p.134) considers how 'participation between thought and things gives rise to actions which tend to become symbolical.' Piaget (ibid., p.3) states 'Then it is that language, a system of collective signs, becomes possible, and through the set of individual symbols and of these signs the sensory-motor schemas can be transformed into concepts or integrate new concepts'. Interaction between language and action as symbolic mediators is noted in these mathematical story

narratives and theorised about in Chapters Three and Seven as part of a discussion about cultural tools and the mediating role of artefacts from a Vygotskian perspective.

A child's awareness of thought takes time and Piaget (1951, p.60) concludes that '…until about 11, to think is to speak – -either with the mouth or with a little voice situated in the head – and speaking consists in acting on things themselves by means of words, the words sharing the nature of the things named as well as of the voice producing them'. After the age of 7 or 8 the child becomes aware of his own thought (ibid.). Therefore it is important to note that these children are four and five years old and so for them, 'to think is to speak' and they may be less aware of their own thoughts than older children. Further, Piaget (1951, p.87) raises the point about how '…this awareness is itself dependent on social factors…' The important role of discussion is highlighted again by Piaget (ibid.) when he says '…it is through contact with others and the practice of discussion that the mind is forced to realise its subjective nature and thus to become aware of the process of thought itself'. Discussion during and after oral stories was noted as an important social factor in the mathematical story experiences referred to.

An emphasis on spoken language should not be at the expense of intuition, physical and sensory ways of thinking (ibid., p.25). Referring to the work of Claxton (1997), putting ideas into words '…should not *supplant* but *supplement* other forms of representation' (italics in original, ibid., p.25). A range of representational forms or ways of knowing draws on the work of Reggio Emilia, and the 'hundred languages of children' (ibid., p.26). Oral language is one of many possible representational forms (ibid., p.26); others which feature in oral

mathematical stories include props, artefacts and actions or gestures, which are potential representational forms of knowing.

Oral story tools: other representational forms of knowing

Tools used as part of storytelling support involvement and the development of mental images and memory. Vygotsky argues that 'the effect upon humans of tool use is fundamental, not only because it has helped them relate more effectively to their external environment but also because tool use has had important effects on internal and functional relationships within the brain' (Afterword, Vygotsky, 1978, p.133). Schiro (2004) sees 'manipulatives' as being like 'magic objects' and suggests that they hold attention and promote involvement. Pound (2006, p.132) advises that adults use tangible materials to support verbal explanations: 'Before children can think in abstract terms they represent ideas in physical action (enactive or sensorimotor thinking)' (Bruner, 1986; Gardner, 1993, cited by Pound, 2006, p.26).Pound (2006, p.91) describes how 'action rhymes, supported by props, allow children to rehearse mathematical ideas playfully with physical action that reinforces learning'. Tools or props, and gestures, will be employed to support adult-led oral story experiences and allow children to retell stories using concrete materials to represent abstract story-contextualised ideas.

Representing and translating mathematical ideas

Children translate adult representations into their own worlds of play narratives, often using objects to represent their thinking (Vygotsky, 1978). Translation describes the process of moving between different representations of mathematical ideas (Hughes, 1986) with young children capable of extraordinary

powers of abstraction (Pound, 2006; Hughes, 1986). Thought is supported by 'translating between different representations' (Pound, 2006, p.48) and it is the 'process of translating between representations (those of children and of others) that helps children understand the world' (ibid., p.30). School mathematics requires that children translate between representations, but the ability to translate between contexts may be a cause of difficulty for some children (Hughes, 1986), which the thesis considers next.

Mathematical difficulties

Hughes identifies that it can be difficult for children to translate between their own concrete knowledge and the abstract or 'context-free' nature of arithmetic statements (1986, p.45). When Hughes (1986, p.45) asks a four-year-old boy (who with concrete objects offered the correct response) 'How many is three and one more?' the boy asks 'One more what?', not applying his concrete knowledge to this abstract question; but, as Hughes (1986) points out, this boy's response is unusual in that he is explicitly prepared to translate the abstract question into concrete form by trying to locate the context through the word 'what'. Translating is an important way of children thinking about mathematics, and an inability to translate fluently between different modes of mathematical representation can be misleading about true capabilities (Hughes, 1986; Nunes and Bryant, 1986).

Hughes suggests that translation can be supported by devices such as Turtle Graphics devised by Papert, which allows links to be made between the concrete world of the Turtle and the formal language of mathematics (1986, p.165). Hughes states that 'In Papert's terms, the Turtle is a *transitional device* which helps children link the formal and the concrete' (italics in original, ibid., p.172).

Oral story is proposed as a 'transitional device' which will allow children to connect abstract story-related mathematical ideas to concrete representations through story-related materials, and that the mathematical ideas become 'context bound'. Story as a medium (Casey et al., 2004) supports this translation and provides meaningful, memorable, metaphorical contexts which help children think about and articulate mathematical ideas. Children in the project will listen to and tell stories, translating between abstract and concrete and vice versa, through physical manipulation of props. Oral mathematical story and associated props will help children to visualise in ways which support making sense of abstract mathematical ideas.

The process of mediation through tools, symbols (spoken language) and educators requires attention when considering oral story as a pedagogical choice for mathematical thinking. The tools are selected by adults who judge how these are employed and when to remove this scaffolding. Educators create social environments and classroom cultures conducive to teaching, and as part of these cultures Eun (2010) stresses the importance of teachers participating in the learning process themselves. Educators are the holders of the keys, but not all the keys to all the doors, and they need to be willing to co-explore ideas with children (Pound, 2006; Schoenfeld, 1996). Teachers, as enquirers themselves, model the process of learning (Eun, 2010) and from a sociocultural perspective, educators are participants and observers, operating as mediators of learning. Adults create the oral mathematical social environment, and as storytellers model and potentially make connections which children imitate. Further, the symbolic use of spoken language in oral story is central to developing mathematics as a higher order function.

This section of the framework raises the following questions for the research: how will mathematical ideas be symbolised as part of oral storytelling? And, how will children translate between abstract and concrete representations of ideas and vice versa?

1.2 Discursive instruction

Vygotsky propounds that 'All higher functions originate as actual relations between human individuals' (1978, p.57) and the internalisation of higher psychological functions is central to development. The internal reconstruction of an external operation is referred to by Vygotsky (ibid., p.56) as 'internalisation' and 'as a process consisting of a series of transformations'. Vygotsky (ibid.) proposes that every function in the child's cultural development appears twice, 'first on the social level, and later on the individual level'. He proposes how this is 'first between people (inter psychological) and then inside the child (intra psychological)', explaining that, 'Once these processes are internalised, they become part of the child's independent developmental achievement' (ibid., p.90). The relationship between these external and internal operations is iterative: 'There remains a constant interaction between outer and inner operations, one form effortlessly and frequently changing into the other and back again' (Vygotsky, 1986, p.88). Thinking alone is distinguished from thinking together, with Mercer (2000, p.17) introducing the term 'interthinking' and relating this to '…the joint, co-ordinated intellectual activity which people regularly accomplish using language'. This movement between a child's individual thinking and the community they relate to involve a dynamic between communicative activity and individual thinking, each having a continuous influence on each other (ibid., p.9).

Though a child's internalisation of mathematical ideas will be inaccessible, some of this thinking will possibly be externalised in oral story-related discussions, children's play, and story-related narratives.

A social constructionist epistemological stance is based on a belief that knowledge is constructed through conversation and that spoken language used collectively allows a common understanding which may not otherwise be realised. That the product of a conversation is usually the achievement of some new, joint, common knowledge, and that language is designed for doing something much more interesting than transmitting information accurately from one brain to another is a premise for this work: conversation '…allows the mental resources of individuals to combine in a collective, communicative intelligence which enables people to make better sense of the world…' (ibid., p.6). Internal thinking is projected outwards through language to instigate change beyond ourselves. In order that ideas have 'any social impact, we must either act them out or communicate them to other people in ways which will influence the actions of those people' (ibid., p.8). Language transforms individual thought into collective thought and action, which is relevant to this research in that children's spoken language alongside actions will be observed and considered as symbolic of their thinking.

The role of discussion in mathematics

Mathematics is not commonly viewed as a discursive subject although the Cockcroft report, as part of its recommendations for broadening the range of mathematical experiences which pupils encounter in class, called for discussion

to play a wider role in the teaching and learning of mathematics (Pimm, 1987, p.46). Vygotsky (1986, p.219) advises that,

> Thought and word are not cut from one pattern. In a sense, there are more differences than likenesses between them. The structure of speech does not simply mirror the structure of thought, that is why words cannot be put on by thought like a ready-made garment.

The relationship between thought and speech is complex: 'Thought undergoes many changes as it turns into speech. It does not merely find expression in speech; it finds its reality and form' (ibid.). This relationship between thought and speech is relevant when considering how children internalise their thinking: 'But while in external speech thought is embodied in words, in inner speech words die as they bring forth thought. Inner speech is to a large extent thinking in pure meanings' (ibid., p.249). Mediated instruction as an instructional principle proposes that thought is mediated by signs externally, but thought is 'also mediated internally this time by word meanings', and 'so communication can be achieved only in a roundabout way. Thought must first pass through meanings and then through words' (ibid., p.252). Thus, children's internalisation of mathematical thinking is complex, mediated externally by signs and internally by word meanings.

Spoken language helps children to organise their thoughts and within the context of a classroom there are two main reasons for pupils talking: first, to communicate with others; and second, to talk and think for themselves. *Talking for others,* in an attempt to make someone else understand something or to pass on some piece of information, is one of the many communicative functions which spoken language permits. Pimm (1987, p.24) states '*Talking for themselves* involves situations where pupils may be talking aloud, but where the main effect is not so

much to communicate with others as to help organise their own thoughts, this second function of language allowing children to reflect on their thinking'. There is also a further justification, which is for the teacher to gain access to and insight into the ways of thinking of children: when talking, children's thoughts are externalised, 'making them more readily accessible to speaker's own and other people's observations' (ibid., p.24). The focus on discussion attempts to 'redress the balance of mathematical activities towards the oral' (ibid., p.45), which is advocated by the National Curriculum (NC) which claims to reflect the importance of spoken language in pupils' development across the whole curriculum (DfE, 2013, p.104). Further, the primary curriculum advocates that children make their thinking clear to themselves and others, and that discussion is utilised to remedy misconceptions (DfE, 2013, p.104). Spoken language offers a system for thinking collectively and opens intellectual networks for making sense of experience and solving problems. Spoken language is a tool for creating knowledge, and is a joint activity between educator and children, between children, and within children (Mercer, 2000; Vygotsky, 1978). The shared talk facilitated by the classroom teacher is one way that shared mathematical knowledge is constructed. This cumulative talk is how children 'build on each other's contributions, add information, of their own in a mutually supportive and uncritical way' (Mercer, 2000, p.31). Spoken language as a tool used by educators improves educational practice through the words chosen and the questions constructed to prompt thinking, which is noted in the contrasting practice of two teachers discussed in Chapter Seven.

Mercer (2000, p.141) develops Vygotsky's ZPD to emphasise the relationship between the teacher and learner and the quality of this interaction by constructing

the idea of an 'intermental development zone' (IDZ). This zone is reconstituted constantly as the dialogue continues, and as the teacher and learner negotiate their way through the activity in which they are involved. Mercer advises how, 'if the quality of the zone is successfully, the teacher can enable a learner to become able to operate just beyond their established capabilities' (ibid., p.141). If the quality of dialogue is such that it ceases to keep both the educator's and child's 'minds mutually attuned', the IDZ collapses and the scaffolded learning grinds to a halt' (ibid., p.141). The dialogue of oral story will potentially provide context and scaffolding to potentially extend learning beyond what is already secure; in a mainstream classroom the challenge is connecting thirty 'intermental' zones to one collective developmental zone.

Vygotsky (1978) places communication at the centre of his theory concerning spoken language and thought with the proposition that, in order that good learning drives development, there is discursive instruction. Eun (2010, p.407) confirms that 'communication is the means by which all participants engage in the instructional process to negotiate and generate knowledge. Eun (2010, p.407) explains that 'these forms of collaborative dialogue later get internalised to serve individual cognitive functions, such as problem-solving reasoning, and logical thinking'. Eun (2010) refers to the work of Pontecorvo and Sterponi (2002), who advocate the value in taking reasoning abilities to a higher level, when 'teachers ask their students to predict what might happen in the story, to explain their reasoning, and to evaluate others' predictions and explanations' (Eun 2010,p.407). Discursive instruction, with quality dialogue serving to keep educators' and children's minds attuned in 'intermental zones' (Mercer, 2002) which allow children to achieve ZPDs, is a theoretical construct relevant to oral mathematical story experiences.

This discussion prompts the following questions for the research: how can oral story be facilitative of the transformation of ideas shared socially to individuals? What will characterise a quality 'intermental zone' and allow children access from a ZAD to a ZPD? How will the spoken language of these stories allow children to express their mathematical thinking? The thesis now turns to Eun's (2010) third category, which discusses collaborative instruction.

1.3 Collaborative instruction

A sociocultural belief in knowledge as shared and constructed rather than the adult being the transmitter and holder of knowledge supports Vygotsky's belief that 'all higher psychological functions develop in the process of cooperation and collaboration' (Eun 2010,p.407). It is through quality collaborative work that students are enabled to solve problems which they may not have solved on their own (Eun, 2010). Discourse concerns language, and language is not fixed in that a distinctive feature of language is its 'openness' and the flexibility of the meaning of words that allows new sense to develop between people (Pratt, 2006, p.25). Mercer (2000, p.106) considers the 'specialised language of a community can be called its *discourse*, and so the specialised language of a classroom learning mathematics can be termed mathematical discourse.

Community or classroom discourse

Mercer (2000, p.105) considers that 'The Latin origins of the word 'community' relate it closely to 'communicate' and 'common', which make it an appropriate term for groups of people who share experience and interests and who communicate among themselves to pursue interests'. He describes how

communities enable collective thinking and these communities include, '…a history; a collective identity; reciprocal obligations and a discourse' (ibid., p.106). The community or classroom is made up of social structure and power relations, which create possibilities for learning. Differences between classroom communities impact on the application of what is gathered or learnt within these communities (Boaler, 2002).

Collective thinking

Mercer (2000, p.132) describes how, 'as children communicate with people around them, they learn to perceive and understand the world from the perspective of being a member of a community'; this means, their thinking is becoming more collective'. Language allows 'individuals with different talents, dispositions and experiences to collaborate in sophisticated ways when solving problems, and transforms a group of diverse individuals into complementary contributors to a collective mind' (ibid., p.168). As part of their community children are also becoming aware of the significance of the distinction between their knowledge and understanding and that of other people. As they communicate, children are also learning how to take account of people's individuality when thinking collectively.

Children participating in collective thinking can use the mathematical thinking which is shared as part of collaborative teaching to make more sense of ideas than they might alone. Lave and Wenger (1991, p.15) express the view that '…learning is a process that takes place in a participation framework, rather than in an individual mind' and within a participatory framework children and their teacher will hold different perspectives; learning is mediated by the 'differences

of perspectives among the co participants' (ibid., p.15). Mercer (2000, p.172) highlights how 'human communication partners need not just take what the others give and then go and carry out individual activities, like honey-bees; instead they can use information which has been shared as an intellectual resource, and work on it to make better sense than they might have if left alone'. Collaborative instruction allows children to participate, listen to alternative view points, and use what they receive as a resource for themselves.

Encouraging shared responsibility and joint problem solving is achievable when students take turns with various roles and in doing so 'understand the social and collaborative nature of learning and development' (Eun, 2010, p.408); and where roles include reflection on the learning process, this mediates learning further (Eun, 2010; Ginnis and Ginnis, 2006). The proposed observation tool outlined in Chapter Two includes a facility to include reflections by children, parents and professionals with the intention that this will mediate mathematical learning.

Guiding collective thinking activities

Mathematical knowledge is shared and developed within classroom communities. Mercer (2000, p.129) describes how 'within communities, knowledge resources are normally shared and developed through language; knowledge commonly exists in the form of discourse' and he emphasises the need to learn the discourse through apprenticeships, and how this is achieved through more 'expert' others (ibid., p.130). In the case of classrooms, this is achieved by drawing on educator knowledge and more expert children who have greater fluency with the language needed to express mathematical ideas.

Rogoff (2003) describes the induction of children into the intellectual life of their community as 'guided participation'. The role of the adult is important in guiding this participation: '…socio-cultural explanations recognise the role that parents and other people play in helping children learn' (Mercer, 2000, p.134). Mercer suggests explaining children's development as 'interthinkers' and that to do so, we need to understand how experienced members of communities act 'as *discourse guides,* guiding children (or other novices) into ways of using language for thinking collectively' (ibid.). Mercer (2000, p.170) proposes the socio-cultural concepts of 'guided participation' as a useful tool for describing this process. This theoretical perspective supports the ideas of Vygotsky (1978), and acknowledges that teachers have particular responsibility for 'guiding collective thinking activities' (Mercer, 2000, p.117) as part of collaborative instruction which includes classroom communities of learning.

Whole class communities of learning

Large groups of thirty can offer collaborative instruction, though such large group sizes need careful consideration to meet the needs of younger children, those acquiring English, and those with Special Educational Needs. Fisher (2009) identifies four purposes of whole class teaching: telling children things; imparting knowledge to them; making them enthusiastic; and sharing ideas. Referring to whole class learning, Merthens (1997, cited in Pound, 2006, p.45) suggests these interactive processes allow children to imitate and respond to the mathematical thinking of others. Montessori (1912, cited in Pound, 2006, p.45) emphasised the value of criticisms children can make of one another when they are part of classroom communities. Group interaction can enlighten children about other possibilities and challenge an individual child's thinking (Pound, 2006, p.96; Tobin

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et al., 2011). Social interaction contributes to sustained shared thinking (Siraj-Blatchford, 2004; Siraj-Blatchford and Sylva, 2004), which contributes to problem solving, clarifying ideas or concepts, evaluating experiences and extending stories. However, contrary to this is the belief that for younger children extended stretches on the carpet are not appropriate, as this presents difficulties; larger groups do not permit all children to talk. Ofsted documents the efficiency of whole class teaching, which Pound (2006, p.94) points out for work with young children can be problematic, advising that large groups should be used sparingly in view of the language and thinking associated with learning mathematics and the need for an interactive approach. Large groups make it difficult for children to experience sufficient interaction and to ask questions which allow them to make sense of what is under discussion, which is particularly the case for children acquiring English (ibid., p.94). The project progressively focused on work with smaller groups of children as noted in Chapter Five.

The principle of collaborative instruction draws on the ZPD (Vygotsky, 1978), and the idea that knowledge is co-constructed between educator and children as they co-explore. Schoenfeld (1996) describes 'interpretative discussion' as where students and instructors work together to develop and address questions to which neither knows the answer. In oral mathematical story work, co-operative learning groups allow children to construct group as well as individual meaning (Schiro, 1997, p.61). Collaborative instruction extends to include the idea of both adults and children taking different roles as part of learning experiences, and for educators to be responsive to the needs of young children.

The thesis thus far supports Lave and Wenger's (1991) situated learning theory, which proposes that learning is social and situated and has participation at its centre. However, Boylan (2010) contests the concept of legitimate peripheral participation as a construct identifying that its applicability to school classrooms is problematic and considers that participation needs to be viewed as a 'multi-dimensional phenomenon with many possibilities'. Further, participation cannot be abstracted, as it changes moment to moment and is socially constructed in time (ibid.). Boylan (ibid.) rationalises that learning in a mathematics classroom is not like apprenticeship contexts and that the classroom-based midwifery instructor described by Lave and Wenger (1991) continues to be a member of the midwifery community of practice whereas the mathematics teacher is not necessarily participating as a mathematician or in practices that involve mathematics. However, Boylan (ibid.) acknowledges that participation is an epistemological and ontological '…account of the nature of knowing and being in the world' and as such is central to learning and it is in this vein that this thesis uses Lave and Wenger's (1991) conceptual idea of participation.

The thesis proposes that oral story will potentially change the nature of mathematical teaching allowing the teacher to use the story to act as the vehicle for thinking mathematically in ways that allow children to participate with mathematical problems and also with each other in more meaningful ways as part of what Lave and Wenger (1991) describe as a 'participatory framework', and where differences of perspectives evoke learning about mathematical ideas.

These contributions to the framework raise the following questions: How will children and educators participate in this different form of pedagogy? How will

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mathematical learning happen as part of an oral story participatory framework? What will be legitimised as appropriate classroom practice for children and their teachers as part of these story experiences? The chapter now turns to Eun's (2010) fourth category, which discusses responsive instruction.

1.4 Responsive instruction

This principle is based on the premise that educators need to be responsive to children of different cultural and linguistic backgrounds as well as to individuals in a group. Pratt (2006, p.5) describes how the quality of interaction between a class of children and their educator is dependent on the human relationships involved, and Eun (2010, p.408) attributes importance to educators building relationships based on 'mutual respect and care'. Children learning through a different culture and language require particular attention, and educators should be aware that a common cultural background may not exist between teacher and learner (Eun, 2010; Pound, 2006). The cultural community of the child should be considered if instruction is to be responsive. However, it cannot be assumed that story as we understand it transcends all cultures. Rogoff (2003, p.310) draws our attention to the fact that some non-western cultures hold socialisation examples which 'rely less on verbal communication'. In addition to culture and language, educators need to respond to 'the variations that exist among students along their development pathways (emotional and social)' (Eun, 2010, p.409). These culturally related variables contribute to the membership of learners as part of a community of learning.

Sensitivity to the fluency of individuals as members of a community of learning is important in the context of learning mathematics through story. Mercer (2000)

associates fluency with membership; if some children lack fluency with mathematical discourse they may be excluded from membership. Therefore, children acquiring English as an additional language, or less vocal children, may not contribute to the classroom discourse about mathematical ideas and oral mathematical story experiences may challenge the membership of some children if they do not share the same fluency as their peers. In order to support young children and those acquiring English, Pound (2006, p.94) proposes that the following strategies are employed: opportunities to communicate ideas with the support of children and adults; visual materials which give clues about the topic; a group size which allows children time to contribute and listen in meaningful ways; and questioning to check understanding. In addition to consideration of appropriate group size, children need to be assisted by responsive reflective questioning of adults and other children in the group. This idea about responsiveness to culture is developed further when discussing the importance of contextualised instruction below.

This section of the framework prompts the following question: How will educators respond to and manage interactions with children as part of the orchestration of these alternative mathematical experiences? Eun's (2010) fifth category which discusses contextualised instruction is considered next.

1.5 Contextualised instruction

Baumer and Radsliff (2009) argue that as a consequence of high-stake testing '…play has been relegated to a marginal position, even in early childhood curricula, where it traditionally held a dominant role'. They (ibid.) refer to the work of the Swedish scholar Gunilla Lindqvist (1995),) who describes playworlds as

'an educational practice that includes adult-child joint pretence and dramatization of texts from children's literature combined with the production of visual art'. The 'immersive character of play experiences' (ibid.) extends to the development of adults and they suggest that 'as a part of the playworld intervention, the traditional classroom discourse has been replaced by a more egalitarian Socratic dialogue that creates a zone of proximal development, which enables both adults and children to advance their social competence and conflict resolution strategies' (ibid.). Educators in this research embraced storytelling in playful ways and describe the value of this to themselves as individuals (Appendix 12). This mathematical story 'playworlds', which took the shape of problem-solving situations within a sociocultural framework, were enjoyed by children and enhanced educators' pedagogical practice.

Contextualised instruction recognises the gradual nature of learning, and values the connection between home and school. Children's mathematical development is characterised by the context a child is born to, as children learn about the different ways mathematics is used in their culture (Pound, p.20). May et al. (2006, p. 14) describe how 'the nature of the community' a child comes from is an important factor contributing to their learning experience. A failure to build on children's experiences before school, to work from what they know, to exploit interests, limits later understanding (Pound, 2006, p.18). The theme of connecting between home and school is relevant to a discussion concerning cultural context as children move between two cultures or contexts: that of the classroom and that of home, with the former needing to acknowledge the latter, as discussed earlier.

Cultural context

From a sociocultural perspective it is important to consider the cultural context in which learning takes place (Eun, 2010; Vygotsky, 1978). The cultural context, or where learning occurs, is a central feature of a situated learning perspective and Lave and Wenger (1991, p.33) propose that there is no activity that is not situated, basing their theory on the 'premises of the whole person activity in and with the world'. They hold the view that agent, activity and the world 'mutually constitute one another' (ibid., p.33). They argue that schooling as an educational form is 'predicated on claims that knowledge can be de-contextualised, and that schools themselves as social institutions and as places of learning constitute very specific contexts' (ibid., p.40). Boaler (2002, p.134) develops this idea further, identifying different specific contexts within school, for example the examination hall and the classroom. Further, the specific contexts of schools and within schools are different from home and 'real world' contexts, with de-contextualisation of knowledge from one context to another being more complex than a mere shifting of what one knows between situations or contexts. Although, as Vygotsky (1978) proposes, development is driven by learning, Boaler (2002) argues that this in turn is determined by how and where the learning is situated.

As part of his discussion on contextualised instruction, Eun (2010, p.410) proposes that students are 'equipped with adaptive problem-solving skills', identifying that it is the ability to generalise problem solving to life outside the classroom which differentiates between development and learning. However, his suggestion that an effective way to realise contextualisation in instruction is to provide children with 'real-life' problem-solving situations (ibid.), is problematic, as a school-based context cannot be representative of a 'real world' context.

Boaler (2002, p.85) argues that the way students respond to applied tasks in school cannot be used to predict how students will react to real-life mathematical situations. She finds that children themselves perceive that environments created by the real world and the classroom are inherently different, and that these differences can cause students to abandon school-learned methods and, in some cases, invent their own methods (Boaler, 2002; Gifford, 2005; Nunes and Bryant, 1986). It is how the learning is contextualised or situated in a context that influences whether learners may later take what they have learnt in one context to another. For the purpose of this work it is about whether children take mathematical ideas from a story experience to a play opportunity with story-related materials.

Boaler's (2002, p.2) comparative study explores contrasting situated learning contexts, and investigates the experiences of learners in these different learning contexts, and how these students respond when they need to apply mathematics from a classroom to a test situation. Students exposed to 'inflexible and inert' teaching when presented with slightly different situations, failed to apply what they had used in textbook classroom situations to the exam context (ibid., p.130); their knowledge was only effective in textbook situations. These students were 'extremely successful participants' in their classrooms, working through exercises and interpreting cues; however, they failed to adapt what they had learned to new situations, partly because they did not see themselves as problem solvers (ibid., p.130). These students were 'rule followers' rather than 'active agents' (ibid.; Lave and Wenger, 1991). The classroom practices these students experienced lacked problem-solving activities and created passive rather than active identities (Boaler, 2002, p.134). In contrast, students who experienced

project-related activities were able to use mathematics in different situations because they had participated as mathematical problem solvers in the classroom (ibid., p.134). The knowledge of mathematical procedures was similar for both sets of students, but the connections students had with mathematics was different because of the classroom practices both groups experienced (ibid., p.135).

Using mathematics within school is a different experience from using it outside school, and a student's ability to use what they know in a different context, depends on how they have come to know it (ibid., p.112). Boaler's (ibid.) work challenges Eun's (2010, p.410) proposal that school-based problems enable children to generalise or adapt their problem solving to other situations or contexts, arguing instead that learning needs to build on children's experience, to be situated in a learning experience which requires problem solving. This research asserts that oral story could promote a problem-solving way of learning mathematics and that oral story situates mathematical thinking in a context which requires problem-solving thinking, and offers a different way of knowing mathematics.

Young children are highly motivated to explore learning in contexts that are meaningful to them; a further challenge concerns the contextualisation of learning in classroom contexts or situations. Mercer suggests that a context is about '…*whatever information listeners (or readers) use to make sense of what is said (or written)',* (italics in original, 2000, p.20)*.* Taking this further, 'Context is created anew in every interaction between a speaker and listener or writer and reader' (ibid., p.21), which suggests context as evolving and changing, and that the context of storytelling extends further in the conversations which follow. He (ibid.,

p.21) advises that for communication to be successful, the creation of context must be 'a co-operative endeavour', and that 'conversations run on contextual tracks made of common knowledge'. Based on the work of Mercer (ibid., p.44), contextual resources include: 'classroom physical surroundings; past shared experience and relationship between the storyteller and children; the storyteller's mathematical goals; and the storyteller's experience of similar kinds of conversation' with children as a large group, as smaller groups or individuals. Thus, it is proposed that oral story as a pedagogical choice can potentially create the contextual track for mathematical knowledge to run on.

The cultural context in which learning occurs is one aspect of contextualisation; another is providing children with a context through which learning is mediated in meaningful ways, for example through story or play. Thus the contextualised instruction principle proposed by Eun (2010) is extended further to include story and play as contexts which mediate young children's learning, and which are considered in more depth as part of the discussion concerning activity-orientated instruction.

This section of the framework prompts the following questions for the research: How will differences between classroom practices impact on oral story experiences? Will there be any 'isomorphism' (Casey, 2011) of mathematical ideas heard in story in other contexts such as play? Eun's (2010) sixth category, which informs of activity-orientated instruction, is considered next.

1.6 Activity-oriented instruction

Activity-oriented instruction acknowledges the mediating function of human activity in developing psychological processes. The sociocultural theory based on Vygotsky's (1978) work acknowledges how 'both practical activities and symbolic activities contribute to the development of cognitive functions' (Eun 2010, p.410). He states that 'these types of activities have interdependent impact on each other in developmental process' (ibid., p.410). Referring to Jones (2001), Eun (2010, p.410) acknowledges 'that genuine thinking is formed only when the work of language or (i.e. symbolic activity) is inseparably united with the work of the hand, which is the organ of objective activity (i.e., practical activity)'. Socio-dramatic play is an activity which leads development in young children (ibid.) with the mind, eye and hand together engaging small children. Lave and Wenger (1991, p.122) describe how 'if the person is both member of a community and agent of activity, the concept of the person closely links meaning and action in the world', which suggests that as a member of class and agent of play, the child may link mathematical meaning heard in a story to activity in play.

Play

Vygotsky sees 'play as the primary means of children's cultural development' (Afterword, Vygotsky, 1978, p.123). Vygotsky identifies a tension in that, at an early stage there is an immediate fulfilment of a child's desires, which later at a pre-school age are not immediately gratified, and notes that in order to resolve this tension, '…the preschool child enters an imaginary, illusory world in which the unrealisable desires can be realised, and this world is what we call play' (Vygotsky, 1978, p.93). Observing a child, playing with story-related props, is based on the premise that play is a representation of memory in action as part of

imaginary situations. Vygotsky associates play with memory, in that 'Play is more nearly recollection of something that has happened than imagination' (ibid., p.103): the possibility that children will recall the mathematical ideas of stories heard in play narratives is explored as part of this work. In addition, play experiences support children's ability to think in the abstract (Pound, 2006, p.33). Rich play experiences provide first-hand experiences, allow connections in the brain, and allow abstract thinking, all of which support mathematical learning (ibid., p.33). Children creating imaginary situations can be regarded as a means of developing abstract thought (Vygotsky, 1978, p.103), which supports earlier arguments concerning young children translating between abstract ideas of oral mathematical stories and concrete play-related materials, and vice versa. Razfar and Gutierrez (2003, p.40) argue that the wide range of tools used in play make it an optimal activity for promoting zones of proximal development. Observations of children playing, with the intention of capturing their mathematical thinking by noting their language and gestures, is central to the research, because it is anticipated that through play, children will restructure mathematical ideas constructed as part of oral story activity and this will be observed and recorded as observational data.

The purpose of play may be to coordinate: exploration and discovery; construction; repeating and practising; representing; creating; imagining; and socialising (Edgington, 2004, cited in Pound, 2006, p.69). Griffiths (2005, cited in Pound, 2006, p.84) proposes reasons for promoting mathematical learning through play: play-based activity gives a purpose for learning; provides a concrete context for mathematics; allows children to take both control and responsibility; provides an opportunity for pressure-free practice; and is practical rather than

written. In play-based activities children explore ideas confidently, without fear of failure (ibid., p.89). Play characterised by open-endedness, problem-seeking and joyfulness has an important role in supporting children's all-round development, including their mathematical development (ibid., p.69). Playfulness is a way of children making connections which, when unusual or unexpected, are the essence of creativity and innovation, both artistic and scientific (ibid., p.48). Brain studies indicate that broad early experiences open up channels of thought, and that establishing well-used connections impacts on further development (ibid., p.51). Pound (2006, p.51) suggests that when children play, a combination of repetition, trial and error, and pleasure, work as a way of creating and maintaining connections. This thesis proposes that oral mathematical story locates mathematical ideas in positive emotional experiences where children find relevance to expressing mathematical ideas as part of story contexts in playful ways.

Imaginative play is vital to mathematical development, but unless children are in charge of their play, are focusing on their own interests, are enjoying the experience, and are free from external expectations, it does not qualify as play (Edgington, 2004, cited in Pound, 2006, p.68). Thus, an expectation that children will utilise story-related materials to recall mathematical ideas, and possibly re-enact oral mathematical stories may be problematic, in that though it supports the intention to resolve research questions, it is at odds with the idea of children being in charge of their play because of the associated adult agenda. Further, Gifford (2005) found that socially constructed knowledge like number is not easily 'discovered through independent play' and implicit in this is that such activity will not easily be observed in children's play. However, the notion of being playful

with mathematical thinking sits comfortably with combining story, mathematics and play. Further, it will be interesting to see whether or how adult-led number activity through oral story, influences children's play if they are given access to the story-related materials.

Children's disposition to learning mathematics is inextricably linked to emotions and experiences (ibid., p.47), and when an experience carries a powerful emotional charge it can become unconsciously attached to mathematical knowledge (Brown, 1996, in Pound, 2006, p.47). Stories and play are thought to be important and effective ways of enhancing young children's enjoyment of mathematical concepts (Haylock and Cockburn, 2013, p.86); oral mathematical story is anticipated to allow playful problem posing with story and related materials in ways which potentially support enjoyable thinking about mathematical possibilities.

Story

In the past, professional storytellers combined education with story, and this is still the case in certain cultures (Rogoff, 2003). Schiro (2004, p.53) describes how 'stories allow the story teller to speak to children (while passing on cultural information, attitudes, and values) in a way and on a level that is uniquely suited to children's way of making meaning'. Rogoff (2003, p.314) describes how 'narratives have widespread application around the world as a means of instruction'; narrative is how humans make sense of experience (Grugeon and Gardner, 2000). Griffiths (2007) promotes story as a context and stimulus for learning, with inherent opportunities for practical application and visual reinforcement.

Children's literature provides a context for concept development (Grugeon and Gardner, 2000; Welchman-Tischler, 1992). Keat and Wilburne (2009) advocate that reading literature which contains mathematical concepts is a strategy which educators can employ to engage children's enthusiasm and interest in mathematics. Stories offer what Schiro (1997) refers to as 'mathematical benefits'; stories offer children effective ways to envision the meaning of mathematics in the context of human endeavours and the role that mathematics can play in human lives; further, stories stimulate the emotions and the imagination (ibid., p.64). The very nature of stories makes them a more personal and powerful medium for learning and expression than worksheets, which re-contextualise mathematics into a form of activity appropriate for school and which many teachers traditionally use when teaching mathematics (Carruthers and Worthington, 2009; 2006). In order that the mathematics can be framed in problematic or investigative ways, educators can reorganise the learning intention into a story-related context (Pratt, 2006, p.54). This research asserts that through the context of story, children will develop a more connected understanding of mathematical ideas as story allows a deeper contextualisation than might otherwise be realised.

Oral story is social in nature, and potentially will involve individuals making connections with others, as it represents a social constructionist way of thinking. This research explores how oral story allows children to make mathematical connections as part of discursive and collaborative instruction. When Schiro (2004) compares educators employing children's storybooks with engaging in oral storytelling, he finds a different experience: the storyteller is free from text;

needs to be spontaneous; has a closer connection with their audience; and has a personal consciousness. When educators create oral story, a more intimate relationship with both the story and audience develops; when educators read a prescribed story they can remain separate (ibid.). Schiro (2004, p.55) describes how a story delivered orally is different 'because the human voice is a different medium from the written word'. One of the educators featuring in his (ibid., p.104) work describes a different energy in the room when she tells story orally, and refers to the 'intrinsic power of an oral story'. Oral story takes teaching and learning to a higher level, as it transforms abstract, objective, deductive mathematics into a subject surrounded by imagination, myth, subjective meanings and feelings, creating a different experience (ibid., p.viii). Oral mathematical storytelling is an experience out of which children construct their own individual meanings and shared group meanings, which will depend on their perception of the story heard, their prior experiences, their understanding of the world, and their way of organising these understandings and purposes (ibid., p.59). The child constructs meaning by interacting with peers through discussions in which children use various forms of language (verbal, written, and diagrammatic) to share meanings, clarify thought, and test the adequacy of understandings related to the story (ibid., p.60). These interactions can take place in cooperative learning groups where the social setting allows children to construct and share meaningful verbalisations with others, and to listen to the verbalisation that others share back in response (ibid., p.60). Steffe (2004, cited by Pound, 2006, p.55) refers to the mathematics of children emerging from within children and constructed by children, which captures the intention of the oral mathematical story project.

Children's interaction with story, peers and teacher helps them understand the story and the mathematical ideas. It is the teacher who constructs the physical, affective, social and intellectual environment in which the child shares meaning, clarifies reflections, tests hypotheses generated, and models behaviour (Schiro 1997, p.61). This experience coordinates children's new experiences, responses, and reflections and prior understandings in a way which requires thinking about how a variety of things contribute to their development.

This section of the framework prompts the following question for the research: How playful will children be with mathematical ideas and how will this be expressed? Eun's (2010) seventh category, which informs of developmental instruction, is considered next.

1.7 Developmental instruction

The developmental instruction principle focuses on cultivating knowledge and skills that learners can generalise to other situations that 'require similar intellectual functioning' (Eun, 2010, p.411). An important criterion of development 'is the generalisability of learning' (ibid., p.412), which means that children can use 'knowledge and skills in various ways and to solve meaningful tasks with a clear purpose' (ibid.) Qualitatively different ways of thinking mathematically influence mathematical development and divergences in attainment test performance. Vygotsky (1978) viewed learning to be the driving force of development, and differentiated between development and acquisition of knowledge or skill: 'Learning is more than the acquisition of the ability to think; it is the acquisition of many specialised abilities for thinking about a variety of things' (Vygotsky 1978, p.83). Project-based learning experiences equip children

with the ability to adapt what they know or to generalise 'to other domains that require similar intellectual functioning' (Eun, 2010, p.411), which is development rather than mere acquisition of knowledge or skills (Eun, 2010; Boaler, 2002). Boaler (ibid.), as argued earlier, proposes that it is the nature of the learning experience which influences whether learners generalise what they learn to other situations.

As discussed in Chapter Two, educators interpret the National Curriculum as 'professionals' or 'technicians' (Ball and Bowe, 1992) and measure attainment through procedural aspects of mathematics, with less focus on conceptual knowledge, arguably because it is harder to assess (Skemp, 1976), though ironically it is this 'relational' understanding which represents flexible thinking and a 'knowledge rich in relationships' (Gray and Tall, 1994). The more able learner more easily manipulates known facts to arrive at what they call derived facts (ibid.); the more able learner remembers less and generates more than their less able inflexible thinking peers. That oral story experience supports a 'mathematical knowledge rich in relationships' (ibid.) facilitated by the flexible manipulation of tools and symbolic representations is a claim this thesis sets out to explore.

This thesis proposes that there is a connection or relationship between different kinds of knowing and the quality of different learning experiences. The quality of the learning experience, whether as groups of thirty or smaller groups of children, contributes to attainment, and though smaller groups could be considered advantageous, it is the quality of the small group experience which is important. Marks (2014, p.38) examines an educational triaging process where, similar to a medical model for war victims, resources are directed at pupils believed to have

the 'most potential to benefit' or achieve the next level up. She notes how it is the nature of the experience these children had rather than the size of the group which led to reduced mathematical gains for the lowest attaining children and a widening of the attainment gap. Unexpected outcomes of small group intervention was attributed to the following (ibid.) These small groups moved to alternative spaces which took time away from teaching and learning; a lack of a consistent space meant resources had to be selected and limited as these needed to be carried; and lower qualified staff were allocated to these children. Further, she noted poor interactive dynamics, and less in the way of self-correction strategies which encouraged a correct answer view of mathematics. The small group mathematical experiences described by Marks (ibid.) and intended as a positive intervention failed because they were characterised by among other things: limited opportunity for mathematical talk because talk was considered a pathway to behaviour-related problems; and low level repetitive worksheets which children completed individually. If, as Pratt (2006, p.17) advises, the purpose of teaching is to enable children to abstract mathematical ideas from the tasks they are given, the small group experiences described by Marks (2014) diminished this intention. The findings of Marks (ibid.) prompt the following question: What will characterise positive oral mathematical learning experiences? Eun's (2010) eighth category, which informs of integrated instruction, will conclude the components of the instructional framework.

1.8 Integrated instruction

Development is based on a balanced integration of various psychological and physiological processes. Within the system called cognition, perception, memory and attention develop separately but their interrelationship changes (Eun, 2010,

p.412). In order to uphold Vygotsky's sociocultural perspective, school instruction should focus on the 'interrelated nature of development of the entire human being' (ibid.). Domains of learning should come together to form an integrated curriculum and create learning activities that cut across diverse subject areas in ways that enable children to take learning to the wider world beyond the classroom (Eun, 2010; Boaler, 2002; Vygotsky, 1978). The integration principle described by Eun (2010) is developed through discussion concerning the integration of different curriculum strands.

From an early stage, children need to make use of both sides of the brain, with the dominant hemisphere of the brain supporting the logical, rational, factual and analytical approaches to learning (Atkinson and Claxton, 2000, cited in Pound, 2006, p.42) and the other side of the brain supporting spatial awareness, emotion, intuition, and making connections. Pound (2006, p.42) explains that if children are to develop both logic and poetic mathematical abilities, both thought processes need to be provided for, highlighting that physical movement allows humans to develop complex thinking in both sides of the brain. Though it is beyond the scope of this work, oral story is proposed as satisfying the call for development based on a balanced integration of various psychological and physiological processes using both sides of the brain.

A goal of education, and an indicator of development, is the ability to apply learned knowledge and skills to problems in other areas of human living, for example driving a car, where the solution requires a balanced development of many domains of human functioning including physical manoeuvres, perceptions of road conditions, and potentially dealing with encounters with other drivers that

potentially fuel a range of emotional responses (Eun, 2010). The young child is integrating information across domains to arrive at points of connection, and their 'development is based on a balanced integration of various psychological and physiological processes' (ibid., p.413). Eun (2010, p.412) propounds that teaching should focus on the 'interrelated nature of development' of the child: this research suggests that story construction offers the possibility of exercising 'all domains of human functioning' (ibid.) in an integrated way. Further, at least two curriculum areas, literacy and mathematics, are united by using story to construct mathematical understanding (Casey et al., 2004; NACCCE, 1999, p. 12).

Integrating children's literature and mathematics

As discussed in Chapter One, interest in literature-based approaches to teaching has led educators to using children's literature as a way of contextualising mathematics in meaningful ways (Schiro, 1997, p.1). The unity between children's literature and mathematics both poses interesting problems for children to solve, and develops the intellectual endeavour of problem solving (ibid., p.11). Schiro (1997, p.9) identifies a move towards connecting mathematics and oral storytelling and provides reasons for this: to help children learn mathematical concepts and skills in ways that capture their imagination; to provide children with a meaningful context for learning mathematics by providing a context children can relate to; to facilitate children's development and use of mathematical language and communication; to help children learn mathematical problem solving, reasoning and thinking; to provide children with a richer view of the nature of mathematics; to provide children with improved attitudes towards mathematics by gaining enjoyment and confidence in their mathematical abilities; and to help children integrate mathematics and literature study.

Curricular integration is at the core of this approach, but can take two potential directions. Educators can use literature as a tool to facilitate teaching of mathematics, or the integration can be such that both disciplines are learnt simultaneously (ibid., p.12). The latter approach intertwines both literature and mathematics with neither the servant of the other. However, Schiro (1997) focuses on mathematical literary criticism and editing, which detracts from stories such as 'The Door Bell Rang' (Hutchins, 1968) and denigrates the picture book as the servant of mathematical ideas. This empirical research will explore whether a balance between story and mathematics can be achieved to preserve a genuine, rather than stylised, mathematical story experience.

The nature of instruction within a Vygotskian paradigm as proposed by Eun (2010) offers a framework within which the theoretical constructs for this research are positioned. This discussion results in a sociocultural-based instructional model, which characterises effective instruction and supports an argument for oral mathematical story as a pedagogical choice for teaching and learning represented in Table 3, on the pages which follow.

Based on Eun's (2010) interpretation of Vygotsky's theoretical perspective.	Oral mathematical storytelling as a pedagogic tool. Proposed relationship between oral mathematical story and instructional principles.
Mediated Instruction • Three categories of mediation can be represented as a triangulated relationship between symbolic systems (language), tools, and adult. • Translating between abstract and concrete can present mathematical difficulties. • Diagnostic tests of development should include assessment of imitative activity (Zone of Capable Development, ZCD). • Educator as enquirers, model learning. • Mediated activity through signs and tools supports memory, which is a central psychological function.	Oral mathematical storytelling • Oral story allows mediation of mathematical ideas through words, tools (story-related materials and actions) and educators. • Oral story can be seen as a transitional tool where mathematical ideas are context bound and related materials allow concrete expression. • Oral story tools allow children to translate between abstract and concrete representational forms of story-related mathematical ideas and vice versa. • Imitative activity in children's narratives will reveal something of their mathematical capabilities. • There is potential for the adult to adopt an open 'enquiry' stance. • Memory will be supported with the help of story maps, story-related materials, gestures and language which together mediate the meaning of mathematical ideas communicated through memorable story context.

Discursive Instruction	Oral mathematical storytelling
• Higher functions originate as actual relations between human individuals. • Collective, communicative intelligence enables children to make better sense of the world. • Internalisation of mathematical thinking is complex.	• Quality oral story dialogue creates shared communicative spaces which potentially lead to mathematical Zones of Proximal Development. • Quality dialogue of oral mathematical story keeps educators' and children's minds attuned and allow children to benefit from a collective understanding. • In play narratives children may express their internalised mathematical thinking associated with the stories heard. (continued)
Collaborative Instruction	Oral mathematical storytelling
• Higher psychological functions develop as a consequence of cooperation and collaboration. • Communities of practice give different meaning to a discipline. • Within a participatory framework collective thinking allows children to see differences of perspectives and to take what they want to their individual activity. • Guiding collective thinking activities is a responsibility for educators and can be achieved through interpretative discussion.	• Oral mathematical storytelling lends itself to collaborative work where educators are willing to construct story with children. • A community of practice experiencing oral mathematical story will potentially think of mathematics in a problem solving way. • Collaborative story work allows children to hear ideas and fashion these for themselves. • Where educators are willing to embark on discussions where they do not know the answer and take different roles, possibilities for genuine collective thinking open up.

Responsive Instruction • Educators need to be responsive to children of different cultural and linguistic backgrounds as well as to individuals. • Sensitivity to a child's fluency and how this impacts on their membership to a community of learning. • Responsive reflective questioning assists instruction.	Oral mathematical storytelling • Educators can consider the cultural community of the children by establishing contact with families and the wider community. • Oral mathematical story may challenge the membership of some children who are acquiring the language through which the story is told. • Visual tools can give clues about the topic which when combined with skilful questioning contribute to positive experiences.
Contextualised Instruction • Cultural context is a feature of a situated learning perspective: Knowledge needs to be situated in an experience which requires problem solving. • Development and learning are differentiated by an ability to generalise problem-solving skills.	Oral mathematical storytelling • Oral story situates mathematical ideas in an experience which contextualises these in a story structure, which usually requires a problem to be solved. • Through oral story, children think in a problem-solving way which may more readily facilitate thinking of mathematical ideas in other contexts. (continued)
Activity-orientated Instruction • Socio-dramatic play leads development in young children. • Play is a representation of memory in action as part of imaginary situations. • Imaginary situations develop abstract thought.	Oral mathematical storytelling • Story-related play opportunities will be planned for by providing space and time along with story-related materials following storytelling sessions. • In play, children may recall mathematical ideas heard in stories. • Play and story are imaginary ways of contextualising abstract mathematical ideas, both of which feature in this research project.

Developmental Instruction	Oral mathematical storytelling
• Cultivating knowledge and skills that learners can generalise to situations requiring similar intellectual function. • Divergence in attainment is driven by qualitatively different ways of thinking mathematically.	• The application of what children learn to other situations requiring the mathematical thinking of stories heard will be difficult to track though possibly apparent in their use of story language to explain ideas. • Oral mathematical story opens out problem solving, proceptual and flexible ways of thinking about mathematics.
Integrated Instruction • Development is based on a balanced integration of intellectual functions such as cognition, perception, memory and attention. • Teaching should focus on the interrelated nature of development of the child. • Curricular integration of literacy and mathematics needs to be balanced to avoid stylised mathematical stories.	Oral mathematical storytelling • Intellectual functions in oral story include the building of memory as children recall the plot sequence, associated phrases and actions. • Mathematical oral story interrelate several developmental areas: literacy, mathematics, and social and emotional development. • The relationship between story and mathematics will need managing to achieve genuine story experiences.

Table 3: Vygotskian instructional principles and oral mathematical storytelling instructional principles.

Orchestration of oral mathematical story

Oral mathematical story require that ideas, words, gestures and related props are orchestrated by the storyteller to create a satisfying experience. This diversity of mediational means should not be seen as a single undifferentiated whole, but as diverse items which, when working together, make up a tool kit (Wertsch, 1991, p.117). He (ibid., p.119) questions how the relationship among the various mediational means or tools in the tool kit is formulated, noting that separately they have no magical power and that it is only by being part of action that mediational

tools come into being and play their role. Relationships between the mediational tools are formulated by the storyteller's orchestration of these components, which constitute the story harmony.

Orchestration of oral story to offer learning opportunities in mathematics is characterised by Carlsen (2013, p.504), who takes a sociocultural perspective and defines the resulting learning experience '…as a process of appropriation in which individuals make mathematical concepts their own by collaborating and interacting with others'. He (ibid.) refers to the teacher's mathematical epistemological stance, which he describes as 'activity and problem solving', in the way it nurtures children's development of mathematical thinking. He (ibid.) describes storytelling as a powerful tool which is a free and joint activity between teacher and children, employing language, a purposefulness of voice, facial expression and concrete story-related materials. He (ibid.) refers to van Oers (2002) and how participation (using tools of language, voice and concrete materials) contributes to a sociocultural activity and creates a ZPD where children construct meaningful mathematical ideas.

Carlsen's (ibid.) research scrutinises the subtleties of the interactions between teacher and children who engage with mathematical concepts through the story Goldilocks and the Three Bears, which as a fairy tale is a context through which mathematical concepts can be mediated. He finds that if educators are willing to wonder about mathematical possibilities in stories the creation of an oral mathematical storytelling experience invites an orchestration of concrete materials, facial expressions, voice, and actions or gestures, which, together with purposeful questioning, can playfully draw out imaginative story-bound

mathematical ideas (ibid.). The orchestration of story and mathematical ideas, language, voice, facial expressions and concrete materials makes it a potentially powerful way to encourage children's mathematical thinking.

Conclusion

The foregoing literature theorises several points: that oral story as a pedagogical choice creates the contextual track for mathematical knowledge to run on; meaning constructed by children as they listen to an oral mathematical story will be a function of the imaginative images created, associations made, and questions asked, which will give children a model to work with and allow their construction of mathematical ideas as they imitate stories heard; and that imitative activity will offer insight into children's mathematical capabilities, with the research which follows aiming to explore these possibilities. These ideas were set out as theoretical codes (Appendix 4) which constituted a framework for analysis and served as a starting point to inform the empirical work.

The aim of this research is to consider the possibilities for oral mathematical story as a pedagogical choice, and is approached through the overarching research question: how oral story as a pedagogical tool can encourage children's mathematical thinking in reception and year one classrooms? This theoretical analysis has raised the following related questions, which are responded to in later chapters:

- How will mathematical ideas be symbolised as part of oral mathematical storytelling?
- How will children translate between abstract and concrete representations of ideas and vice versa?

- How can oral story be facilitative of the transformation of ideas shared socially to individuals?

- What will characterise a quality 'intermental zone' and allow children access from a ZAD to a ZPD?

- How will the spoken language of these stories allow children to express their mathematical thinking?

- How will children and educators participate in this different form of pedagogy?

- How will mathematical learning happen as part of an oral story participatory framework?

- What will be legitimised as appropriate classroom practice for children and their teachers as part of these story experiences?

- How will educators respond to and manage interactions with children as part of the orchestration of these alternative mathematical experiences?

- How will differences between classroom practices impact on oral story experiences?

- Will there be any 'isomorphism' of mathematical ideas heard in story to other contexts such as play?

- How playful will children be with mathematical ideas and how will this be expressed?

Theorising thus far raises the question as to what will characterise a quality oral story experience, one which allows children access to a Zone of Mathematical Potential Development (ZMPD). Questions arose from theorising about what it means to teach and learn and the alignment of oral story as a pedagogical approach alongside the eight instructional principles which Eun (2010) devised, with the resulting framework informing what is important in the rest of the

research. These are questions to which the rest of the thesis now turns and which Chapters Six and Seven address empirically. In order to begin to explore these ideas and related questions, I start by considering the methodology for the project in Chapter Four.

Chapter Four Methodology and research design

Introduction

This chapter provides insight into the soundness of the research project by anchoring it to the four 'process elements' described by Crotty (1998) and it justifies the chosen methodologies and methods by discussing my theoretical assumptions and epistemological position so that the outcomes can be demonstrably robust and well considered. This is achieved by referring to a model proposed by Crotty (1998) which serves as a framework within which the research picture will be painted. Crotty's (ibid.) model allowed me to understand the research approach in greater depth as he identifies how epistemologies, theoretical perspectives, methodologies and methods inform and relate to each other and provide a way of explaining the research project under discussion.

The aim of this chapter is therefore to relate: constructionism; symbolic interactionism; ethnography; and the choice of methods, in the context of research concerning how oral story can encourage mathematical thinking in young children aged from four to seven. This research was shaped by ontological, epistemological and theoretical perspectives which I explain in this chapter. The viewpoints I held steered the choice of problem, the formulation of the research question, the characterisation of pupils and teachers, my methodological concerns, the kinds of data sought, and the way I treated these data (Cohen et al., 2011; 2000). Terms referred to in the chapter are defined next but later contextualised in relation to the research. Defining these words sets parameters within which I position project ideas. Crotty (1998, p.10) defines ontology as the study of being and explains that it is concerned with 'what is', with the nature of existence, and with the structure of reality. Crotty positions ontology alongside

epistemology and proposes that ontology informs theoretical perspective because '…each theoretical perspective embodies a certain way of understanding *what is* (ontology) as well as a certain way of understanding *what it means to know* (epistemology)' (Crotty, 1998, p.10, italics in the original). Epistemology is defined by Crotty (1998, p.3) as: 'the theory of knowledge embedded in the theoretical perspective and thereby in the methodology'. He (ibid., p.3) suggests that epistemology is a way of understanding and a way of explaining how we know what we know. What I regard as knowledge or evidence of mathematical understanding represents my epistemological position (Mason, 1996) and as such I hold the view that oral story is a way or medium through which children's mathematical understanding can be developed. As discussed in Chapter Two, the nature of mathematical understanding is that it can be both instrumental and relational, both of which are important (Skemp, 1976; Suggate et al., 2010, p.7). The research aims to explore the proposition that oral story can be used as a medium through which children think instrumentally and relationally about mathematical ideas, and that relational understanding can be modelled for and experienced by children as part of oral stories which allow flexibility as the words are interpreted and there are multiple meanings possible.

Theoretical perspective is defined by Crotty (1998, p.3) as the philosophical stance which informs the methodology and thus provides a context for the process. Methodology is defined (ibid., p.3) as the approach or strategy, plan of action, process or design lying behind the choice and use of particular methods as well as the connection between the choice and use of methods and the desired outcomes. He considers that ethnography is a methodology and represents a research design which determines choice of methods. Methods are defined (ibid.,

p.3) as the techniques used to gather and analyse data related to the research questions.

This chapter responds to the following questions:

- What methods were used?

- What methodology governed my choice and use of methods?

- What theoretical perspective was behind the methodology in question?

- What epistemology informs this theoretical perspective?

These relate to Crotty's model (1998) and what he refers to as the four process elements of research. An autobiographical account informs the role I take as researcher and offers insights into why I started with and rejected a positivist approach to this research. Who I am determines what I look at, how I look at it and how I interpret what I look at; what I am looking at will determine how I look at it. The challenges of this chapter are: first, to show my understanding about terms such as ontology, epistemology, theoretical perspective and methodology; and second, to explain how they fit together in the context of the choice of oral mathematical story as a pedagogical tool to encourage mathematical thinking, with Crotty's (ibid.) model supporting this two-fold challenge.

Crotty's (1998) model

I started with a research question and planned the project around this and in order to justify the chosen methods and methodology I developed an understanding about ontology, epistemology and theoretical perspective, relating these ideas to each other and to the project using Crotty's (ibid.) framework. Explaining the project using this model as a frame supports the research in three ways (ibid.): first, it sheds light on the theoretical assumptions on which the work is based;

second, it allows a penetrating analysis; third, it provides a status for the outcomes and, although his model is not the only way of understanding research, it provides coherence when explaining the project undertaken.

The four process elements

The four 'process elements' (ibid.) which shape the oral mathematical story project inform each other, and their relationships are contextualised in this chapter. The relationships between research purpose and each of the four elements are important to understand and articulate, as these connections support the research outcomes. The research question determines the choice of methodologies and methods; justification of these choices reveals assumptions about reality that we bring to our work (ibid., p.2). These assumptions draw on our theoretical perspective and our understanding about what knowledge is (ibid., p.2). I aim to draw out assumptions which prompted this research by describing my theoretical perspective and understanding of what knowledge is. The theme of Crotty's model is that terms such as symbolic interactionism, ethnography and constructionism need to be *related* to one another rather than positioned side by side as comparable, or competing, approaches or perspectives (ibid., p.3, italics in original); this chapter clarifies these relationships in the context of research about children thinking mathematically through oral story.

I brought assumptions to the research and I identify these to defend the project; setting out my assumptions serves to scaffold the research approach. These assumptions shaped the research aims, questions, methods and interpretations of data (Crotty, 1998; Mason, 1996; Thomas, 2013; 2009). They provide a context

from which the rest of the story is told and are evident in the autobiographical account which tells something of my epistemological stance.

Autobiographical details

This autobiographical account tells something of my view of the world and how I have come to hold this view in order to provide a context for the work. Though I may come across as cautious, on closer analysis I am a risk taker. An early memory from primary school is of hiding in a rowing boat, as a peer and I decide to skip an afterschool French lesson. The rush of excitement, the fear of misjudging the lesson timeframe (we were without a watch), and the relief of returning home and getting away with it, stay with me as an exciting experience of risk.

I took higher level mathematics, chemistry and physics in secondary school which at the time were subjects not many girls did, and in some schools were not even available options. I took Analytical Science at Dublin City University. I learnt methods of analysis such as High Performance Liquid Chromatography (HPLC), spending long hours in the laboratory. In the fourth year an option of specialising in analytical biology was introduced; initially I was the only student to take this up, though others followed once I made the transition. The decision to study higher level mathematics at secondary school paid off, as many students did not pass the second year of university, failing mathematics.

At the conclusion of my undergraduate course I left Dublin to find employment in London, facing the difficult challenge of seeking employment without an address and an address without employment. I had an Analytical Science degree which I did not want to pursue a career in, finding myself drawn more to interactions with

people rather than experiments in laboratories. A six-month laboratory work placement in the fourth year at university had confirmed this intuition. After nine months in a telephone sales position, I secured a driving licence and was offered employment as a medical representative in the pharmaceutical industry with GLAXO pharmaceuticals. This involved selling respiratory medicine to General Practitioners and Ear Nose and Throat hospital consultants in the South West of England. I was successful at this, and ambition drove me to promotion to a managerial role in a smaller company. Following a skiing accident, which prevented me from driving for six weeks, I took the decision to redirect my career and retrain as a teacher, gaining a PGCE (Early Years) from Oxford Brookes University and Qualified Teacher Status (QTS) a year later. I worked as a Reception and Nursery Teacher in England and later for the British Council in Spain.

The choice to teach young children on a much reduced salary reveal something of my personality: an ability to seek out and adapt to new challenges and a need to do something vocational rather than commercial. These changes in direction are an outcome of an attitude of alteration based on deep reflection. I have a natural tendency to analyse and interpret in order to arrive at a position of understanding before deciding to move on.

The early years training at Oxford Brookes established my belief in play as essential to children's learning. My motivation to leave primary teaching was due to dissatisfaction with and tension between an early years ethos not rooted in play and opposition from management in Schools where I worked. I diversified

into training early years practitioners, which allowed me to express my play-based ethos.

I worked in Further Education for over a decade and during this time I developed an interest in early mathematical development. I co-ordinated and lectured on a foundation degree in Early Childhood Studies, delivering Higher Education within a Further Education institution, working with students from what is referred to as a 'widening participation audience', which means they come from backgrounds where university education has not featured in their family. One of the modules I delivered, 'The Early Years Practitioner', relates closely to the workplace; I assessed learners in Nurseries, Children's Centres and Primary Schools and engaged in professional dialogue with practitioners supervising these learners. I have over a decade of experience of going into classrooms to observe and assess trainee practitioners' practice.

This brief autobiography is intended to illustrate my previous experiences, and offer a context as to why I am interested in pursuing research with an interpretivist approach. The account reveals a capacity to interact constructively with both adults and children from a range of backgrounds and disciplines. It also reveals something about my drive to take on challenges as a cautious risk taker and explains a shift in my epistemological assumption about mathematics as being about acquiring and storing mathematical concepts to being also about communicating and experiencing mathematics imaginatively through oral story.

Epistemology: the shift

My way of looking at the world and making sense of it constitutes a theoretical perspective and involves an understanding of what knowing is about. Burrell and Morgan (1979, cited in Cohen et al., 2000, p.6) state that epistemological assumptions concern the way knowledge can be acquired, and how it can be communicated to others. I see knowledge as personal and subjective (Burrell and Morgan 1979, cited in Cohen et al., 2000, p.6), constructed between, and thus requiring involvement with, participants.

At the outset I thought of the research in terms of a scientific approach where I would measure some aspect of children's mathematical understanding. For example, I could ask a child to count in twos before telling the story of 'Little Lumpty' (Imai, 1994), and again after subsequent storytelling. I thought this would tell something about the 'objective truth' of using oral storytelling to 'teach mathematics'. This approach reflected an objectivist epistemological or positivist stance associated with my experience as an analytical scientist, which involved laboratory experiments and quantifiable data, and which represents a view of knowledge as fixed and measurable. However, this objectivist epistemological position did not fit with the purpose of the oral mathematical story research. In fact, this approach was in conflict with the ethos of the project, which concerned encouraging children to make connections rather than recall mathematical information 'parrot fashion'. I realised that a 'true' measure was not possible; a child may develop an understanding of counting in multiples of twos independent of any intervention I put in place. Although quantifiable data could feature as part of the project, the main drive or research purpose resulted from a different epistemological position from that of my training as an analytical scientist.

Rejection of a positivist position

Two themes separate my epistemological position from that of a positivist position; first, I was not discovering something that existed; second, the behaviour of participants was not passive, in that they were actively participating and data were generated as an outcome of their actions. Therefore, I rejected the epistemological stance associated with my scientific training which held the belief that research was about discovering what exists 'out there' already, as captured in the following quote:

> Objectivist epistemology holds that meaning, and therefore meaningful reality, exists as such apart from the operation of any consciousness. That tree in the forest is a tree, regardless of whether anyone is aware of its existence or not. As an object of that kind ('objectively', therefore), it carries the intrinsic meaning of 'tree-ness'. When human beings recognise it as a tree, they are simply discovering a meaning that has been lying there in wait for them all along.
>
> (Crotty, 1998, p.8)

My research purpose was better represented by an interpretivist research paradigm; it was my thinking and that of others that constructed meaning. The meaning was not waiting to be discovered but came about as a result of careful consciousness (Cohen et al., 2000) and of what could be constructed meaningfully by children, using the theoretical constructs discussed in the previous chapter based on ideas of Vygotsky (1978) and Mercer (2000). There was no objective truth to discover; rather, this research was about uncertainty.

When contrasting positivist and interpretivist positions, Burrell and Morgan (1979, cited in Cohen et al., 2000, p.6; Cohen et al., 2011, p.6) identify assumptions about the relationship between human beings and their environment and two images of human beings emerge from these assumptions: first, as humans

responding mechanically to their environment; second, as humans initiating their own actions. This project required that participants initiate a different approach when encouraging children to think mathematically and encouraged interaction with the environment (Gergen, 1999); stories were adapted and created, puppets and props selected and made, words and actions chosen as part of interactive oral mathematical story experiences. There was an assumption that participants initiate creative action, which demanded a particular approach to the methodology or design of the project (Appendix 5).

Criticisms of interpretivism

A criticism of interpretivism is that the interpretative approach is restricted in that it is a narrow micro analysis reliant on a researcher's background, beliefs and circumstances, which influences the resulting interpretation and construction of meaning (Cohen et al., 2000). On the one hand, the interpretivist approach encourages the researcher to ignore external power and use their understanding, but on the other it limits power in the way it closes off what is external; there is a risk in interpretative approaches that the researcher becomes '…hermetically sealed from the world outside the participants' theatre of activity' (Cohen et al., 2000, p.27). Such a narrow closed analysis is a criticism of the interpretative approach and as such makes it difficult to generalise outcomes. Further, Cohen et al. (2011, p.21) acknowledge that how one interprets a situation is an outcome of circumstance and that power comes to play, in that the researcher takes on the powerful role of interpreting data. However, I argue that a strong interpretative analysis takes account of this and that the inherent positive qualities make it useful as an approach to certain kinds of research, particularly that which involves people and their responses to situations.

Constructionism: the making of meaning

Charmaz offers a definition of social constructionism as 'a theoretical perspective that assumes that people create social reality through individual and collective actions and that rather than seeing the world as given, constructionists question how it is accomplished' (2006, p.189). Crotty defines constructionism using themes and phrases associated with an interpretivist epistemological position:

> It is the view that *all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context.*
>
> (Crotty, 1998, p.42, italics in original)

Thus, from a constructionist viewpoint, meaning is constructed rather than discovered (ibid., p.42). I needed to be careful not to mistakenly use the word 'discover', as what I was doing was constructing meaning. Meaning was constructed as my consciousness engaged with the research process and data (ibid.; Cohen et al., 2011); those external to the work need to be persuaded of the quality of such engagement. Crotty (ibid., p.43) explains that what constructionism claims is that meanings are constructed by human beings as they engage with the world they are interpreting. I interpreted what I noted about oral mathematical story and represented this in ways that I consider appropriate and meaningful and as a constructionist I did not create meaning, I constructed meaning, about the way I worked with the children, educators, parents, stories and related materials.

Crotty (ibid., p.44) explains the word 'intentionality' as the way the mind becomes conscious of something and leans into this object; there was an intimate and active relationship between my consciousness and the oral mathematical story

project. On returning to the data gathered, I sensed, as Crotty (1998, p.47) advises, that construction of meaning is an 'on going accomplishment'; as with a well-layered story, poem or piece of music, I heard something different each time I returned to the data. Construction of meaning changed on each occasion revealing a new interaction or a 'continuous refashioning' (Gergen, 1999, p.146). I became aware of the potential for others to make sense of the data in different ways, which means there is no true or absolute interpretation (Crotty, 1998), but instead there are multiple interpretations. I provided useful interpretations framed by an explanation about associated assumptions I brought to the research.

Objectivity and truth

Ontologically, the term social constructionism refers to the way phenomena, our perceptions and experiences, are brought into existence and take the particular form that they do because of the language that we share in discourse (Burr, 2003). Each one of us looks at the world from a different perspective, expressing our own views through language with others, creating what we consider to be true at that moment in time. Social constructionism does not hold truth as central to its theoretical framework but instead considers truth as fluid and changing, created by people through discourse (Burr, 2003; Gergen, 1999). Rather than through our observations, it is through interaction with others that we establish 'truth'. Truth holds a currency relevant to the time within which it is socially constructed. What we consider as true may vary; 'therefore what we regard as truth, which of course varies historically and cross-culturally, may be thought of as our current accepted ways of understanding the world' (Burr, 2003, p.5). These 'truths' are an outcome of the social processes and interactions in which people are constantly engaged with each other rather than objective observation of the

world (ibid., p.5). This research involved interactions with educators to find a shared 'truth' concerning what happens when oral story is employed to teach mathematics.

In order to achieve objective understanding we would need to disconnect ourselves from our history and current context, which is not a possibility; in order to understand society and social life, we must identify and lay bare the discourses that are currently pulling our strings. However, if this is the case, how is such a task possible? How can we stand outside of and regard the very structures that are producing us? This point concerning objectivity combined with the earlier point about truth brings us to a position where truth and politics converge; if from a social constructionist perspective there can never be any objectively defined truth, which remains true regardless of the time or culture in which we live, then all claims to have discovered such truths must be regarded as what Burr (2003, p.153) refers to as 'political acts'. Thus, any claims made will not be based objectively, will be influenced by the politics of both researcher and participants and this calls for 'radical reading' (Clough and Nutbrown, 2012) or 'scepticism' (Robson, 2011) on the part of those who are one step removed from the work. Therefore, interpretative research is concerned with the socially constructed nature of reality and the situational constraints that impact on enquiry, along with an element of subjectivity brought about by the role of the researcher. Subjectivity as acknowledged by Burr (2003, p.204) is a term used by social constructionists to refer to the 'state of personhood or selfhood' and features as part of an interpretative approach. This research paradigm brings a number of implications: there are multiple realities; true objectivity is not possible; and I acknowledge that my personal values will influence the work (Burr, 2003).

Constructionism: consistent and problematic

Crotty (1998) aligns an objectivist epistemology with a positivist theoretical perspective, a constructionist epistemology with an interpretivist theoretical perspective, and advises that we are consistently objectivist or constructionist. I shed my earlier objectivist attitudes but needed to maintain a consistent position as a constructionist. I interpreted what I found rather than measured outcomes in a scientific or 'objectivist' way. Though an interpretivist theoretical position does not exclude methods which generate quantitative data, the main thrust of the project is determined by a research aim to explore what happens when oral story is played with to mediate mathematical thinking, using methods which generated qualitative data in order to construct meaning about the oral mathematical story phenomena.

This research project is based on a constructionist epistemology and sits comfortably with a belief about building meaning and understanding of an idea which is little understood, fraught with risk and uncertainty and which relied on others contributing their interpretations about what happened when they elected to use oral story. Although a constructionist epistemological position reflects and fits the purpose of the project, it is problematic; how I construct meaning will differ from how other people would, which challenges the outcomes of such an approach and raises the question as to whether readers of the thesis will construct meaning as I did. If the meaning of oral mathematical storytelling that I construct differs from someone else's, this potentially brings into question the worth of such a project. The reader of the thesis will need to be persuaded that these interpretations have been arrived at in a reasonable fashion; insights into

the theoretical perspective, methodology and methods which framed the project and led to the outcomes are provided to defend my position.

As a researcher I brought assumptions and these shaped the methodology. The context of the project is bound up with the assumptions I hold about Government policy, culture, and historical contexts, each of which is covered elsewhere in this thesis. A philosophical stance lies behind a chosen methodology and provides a context for the research process; my theoretical perspective outlined earlier provided the context for the research process, 'context' in terms of my personal assumptions and circumstances (ibid., p.7). Contrasting ontologies and epistemologies require different research methods and I favoured a more subjectivist, interpretivist or anti-positivist approach for this project, where I viewed the world as softer, personal and humanly created and selected from techniques which include: accounts, participant observations, personal constructs and interviews (Cohen et al., 2000, p.6). My concern was with understanding ways in which individuals created, modified and interpreted the facilitation of mathematical thinking through oral story. The research position is represented in the diagram taken from Crotty (1998, p.5).

Epistemology	Theoretical perspective	Methodology	Methods
Constructionism →	Interpretivism →	Ethnography	→ Observation
	(Symbolic interactionism)		Interview
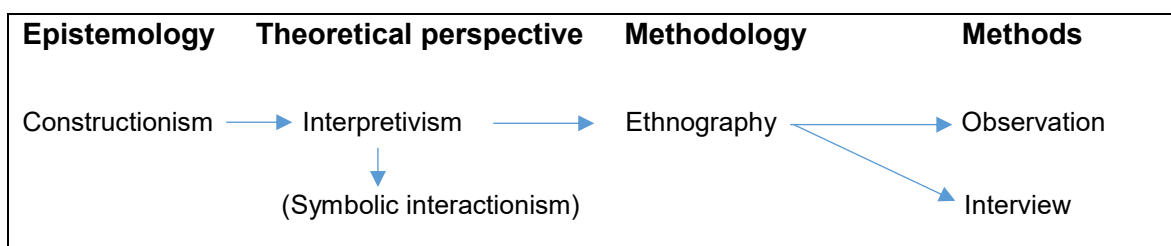
Figure 2: Research components represented using Crotty (1998)

Symbolic interactionism

Symbolic interactionism in the context of the mathematical story research was about interactions and use of symbols to represent abstract ideas. Crotty (ibid.,

p.8) describes symbolic interactionism as a term associated with language, communication, interrelationships and community, representing the epistemological and theoretical perspectives of this research into children's mathematical thinking through story. Of symbolic interactionism, Crotty (ibid.) describes a world of intersubjectivity, interaction, community and communication, in and out of which we come to be who we are. Putting oneself in the place of another is a central theme of symbolic interactionism and that which encompasses the research methodology, ethnography. Interestingly, there is a parallel between the world of a child's play and that of symbolic interactionism (ibid., p.75):

> The process begins in childhood…. It starts with early imitative acts and proceeds via play (in which children act out the role of others) and games (in which children have to put themselves in the place of others and think about how others think and act). Later this generalised other will be related to broader social institutions…

The phenomena studied as part of this research assumed that the researcher and participants constructed meaning about oral mathematical story through interactions on many levels: with published stories; between storyteller and story listener; and between symbols of language, props and actions. The research was concerned with the dynamic relationships between meaning about oral mathematical story experiences and actions which generated these creative mathematical exchanges – what can be viewed as an active process through which educators mediated meaning (Vygotsky, 1978). Charmaz (2006, p.189) offers a fuller definition of symbolic interactionism:

> …a theoretical perspective derived from pragmatism which assumes that people construct selves, society, and reality through interaction. Because this perspective focuses on dynamic relationships between meaning and actions, it addresses the active processes through which people create and mediate meanings. Meanings arise out of actions, and in turn

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influence actions. This perspective assumes that individuals are active, creative, and reflective and that social life consists of processes.

The research project sits comfortably within Charmaz's (ibid.) definition. Further, Woods (1979, cited in Cohen et al. 2000, p.25) identifies that humans '…act towards things on the basis of the meanings they have for them'. There is an active relationship between meaning and actions in that one influences the other (Woods 1979, cited in Cohen et al. 2000, p.25). Charmaz (2006, p.189) proposes that meaning is interpreted from the implemented actions which, when modified, evoke fresh constructions of meaning. Crotty (1998, p.72) identifies three basic interactionist assumptions: first, 'that human beings act toward things on the basis of the meanings that these things have for them', which is evident as children and adults utilise story-related materials; second, 'that the meaning of such things is derived from, and arises out of, the social interaction that one has with one's fellows', which is evident as children and adults construct mathematical ideas through interaction; and third, 'that these meanings are handled in and modified through, an interpretive process used by the person in dealing with the things he encounters', which is noted as children and adults partake in an oral story process.

Methodology

The distinction between objectivist or positivist research and constructionist or interpretive research occurs at the level of epistemology and theoretical perspective. The distinction between qualitative and quantitative research occurs at the level of methods (ibid.). The choice of method leads to distinctions between data; epistemological and theoretical perspectives drive the choice of methods. For some research a less exclusive approach can be taken (Crotty, 1998;

Thomas 2013); qualitative or quantitative research or a combination of both qualitative and quantitative methods sometimes can best serve a research purpose and for this project, methods which generated qualitative data best served the research purpose. Methodology frames choice of methods which are the servants to research and Crotty (1998) describes research methodology as a strategy or plan of action which influences the choice of methods. Throughout the project, I tuned into the need to direct and redirect the project with 'sensitivity' (ibid.); consequently, this research project had a unique methodology.

Ethnography

I was aware from the outset that the ethos of my approach was ethnographical but that I could not fully achieve this position; I moved between two educational institutional environments, School and College, and did not remain, as Gallas (1994) identifies, as a teacher who stays on to teach. Though I hold QTS and as part of the project stepped into the role of 'Teacher', this was transient. I was a teacher of Higher Education in a College context who moved temporarily into the world of School only for the purpose of the project. I cannot claim an ethnographical position, as I was temporarily part of the context I am studying, but I can draw on the principles of ethnography (Gallas, 1994).

Ethnography as a methodology is driven by the researcher's desire to see things from the perspective of participants (Crotty, 1998, p.7). Crotty explains that ethnography enquiry in the spirit of symbolic interactionism seeks to uncover meanings and perceptions on the part of those participating in the research, viewing these understandings against the backdrop of the people's overall worldview or 'culture' (ibid., p.7). This drive to see things from the participants'

perspective justified the choice of methods which were successful, which is discussed in Chapter Five.

I held assumptions as I engaged with this ethnographical form of enquiry and generated data via semi-structured interviews; these assumptions changed over the course of the project. In fact, my assumptions about the project being ethnographical changed; I realised that this research approach was only partly ethnographical. I was not a teacher-researcher; rather, a researcher-teacher, who came and went, though, an ethnographical ethos influenced the choice of unstructured or semi structured interviews and participant observations.

This research project took an interpretive approach with constructionism as the epistemological stance. The theoretical perspectives most closely drawn from are those of interpretivism and within this symbolic interactionism. The methodology is moulded from ethnography using constant comparison as an approach to analyse data, generated by using methods which include: use of an analytic memo to define theoretical constructs (an example included as Appendix 6); interviews (semi-structured interview schedule included as Appendix 7; transcript of semi-structured interview included as Appendix 8); observations of participant educators implementing oral story (examples of coded transcripts included as Appendices 9,10 and 11); researcher reflective accounts (an example included as Appendix 12); and participant written reflections (an example included as Appendix 13). The diagram (Figure 2) and associated discussion explains the four process elements which serve to inform the theoretical perspective of this work. The thesis next turns to considerations concerning data quality.

Data quality

Qualitative research abides by different principles of validity than do positivism and quantitative methods (Cohen et al., 2011, p.180). Maxwell (1992, cited in Cohen, 2011, p.180) proposes that understanding is a more appropriate term than validity. Maxwell (1992, cited in Cohen et al., 2011, p.181) argues for five kinds of validity in qualitative research methods to support the idea of 'understanding': descriptive validity, which means that the account is not made up; interpretive validity, or that the research catches the meaning; theoretical validity, or the theoretical constructs the researcher brings to the research; evaluative validity, which involves application of an evaluative judgemental stance about what is being researched; and generalisability, in the sense that the theory generated could be useful in understanding other similar situations within specific groups. Lincoln and Guba (1985, cited in Cohen 2011, p.181) offer several key criteria of validity in qualitative research that replace concepts associated with quantitative research: credibility replaces the internal validity; dependability replaces reliability; and confirmability replaces objectivity. Trustworthiness in qualitative research is addressed in the credibility, auditability and confirmability of the data (ibid., p.181). However, in practice the terms reliability and validity are still used to defend qualitative methods. Cohen et al. (ibid., p.182) offer a comprehensive set of ways of striving to ensure validity in qualitative research and these strategies were recognised as important in framing trustworthiness for this research, each of these approaches enhancing quality data and which are set out below in Table 4.1.

Prolonged engagement in the field to gather rich and sufficient data.	Data were generated over the course of a year.
Persistent observation to identify relevant issues and to separate these from irrelevancies.	Seventy two observations were undertaken and coded with a focus on highlighting most relevant data.
Use of triangulation techniques.	There was triangulation between data sources.
Leaving an audit trail including process notes on how the research is proceeding.	A research journal entry was made during and after each visit at the setting.
Member checks or informant feedback.	Discussions were held weekly with participants with copies of video recordings made to prompt their reflections.
Weighting the evidence giving correct attention to higher quality data.	The observations were colour coded to correspond with what were considered priority data. datum
Checking for representativeness ensuring that unsupported representativeness of findings is avoided.	Data were analysed several times to check for representativeness.
Checking for researcher effects and clarifying researcher bias.	Acknowledgement of some bias on the part of researcher provided.
Following data rather than leading data.	The design of the project allowed the data to lead the research to small group work.
Checking the meaning of negative cases.	Negative cases were analysed using Eun's (2010) instructional principles.
Replicating a finding or identifying how far the findings might apply to other groups.	There were replications of findings across data sources. (continued)
Following up surprises.	Some of the observational data presented surprises, which were reflected on by participants; for example, reception class teachers reflect on negative story experiences.
Structural relationships or looking for consistency among the findings with one another and with literature.	Data corresponded with codes derived from the literature review.
Rich and thick description providing detail to support and corroborate findings.	Detailed reflective accounts were made, which allowed deep thinking about the findings.

Confirmatory data analysis.	The opinions of participants and non-participants who viewed video recordings were sought.
Employing a reflexive journal.	Though participants were encouraged to keep a reflexive journal, this was not practical and one was kept by the researcher, who invited written reflections from participants at the end of the project.

Table 4.1 Approaches taken to ensure validity in this research

Data generated over a year were made up of: 14 semi-structured interviews with educators; 72 observations of educators/children implementing oral mathematical story; 18 informal discussions with educators; 20 reflexive accounts; 3 participant written reflective accounts; and weekly journal entries.

The inference process is about making sense of the results of data analysis and as a process starts early on: 'In other words, the inference process consists of a dynamic journey from ideas to data to results in an effort to make sense of data by connecting the dots' (Teddlie and Tashakkori, 2009, p.287). The quality of the inference is related to credibility and trustworthiness (ibid., p.287). In my view, inferences and interpretations are similar though arguably interpretations remain 'within' the data; inferences extrapolate 'outside' it and 'Inferences are conclusions and interpretations that are made on the basis of collected data in a study' and need to be distinguished from data from which they were derived (ibid., p.287); the term denotes both a process and an outcome (ibid.). Making inferences is both an art and a science and involves elements of creativity and intuition (ibid., p.289). The idea that an inference is valuable if it is credible is

supported by the statement that, '…credible inferences require a solid understanding of the culture of the investigation and the participants' (ibid., p.290). Knowing the culture and context of the research supports the process of making inferences and a deep cultural knowledge of the role of participants is required, which I had as an outcome of working as a reception class teacher.

Internal validity

With qualitative research, emphasis is on internal validity rather than external validity. Cohen et al. (2011, p.183) explain that 'internal validity endeavours to demonstrate that the explanation of a particular event or set of data resulting from a piece of research can be sustained by the data'. Internal validity is about the findings describing accurately the phenomena being researched (ibid., p.181). Thus internal validity relates to dependability and/or credibility of interpretations and conclusions. Internal validity in ethnographic research is addressed by having the 'researcher sample widely and remain in the situation for extended periods and by tracking and recording information clearly' (ibid., p.185). Rather than generalise, this work seeks to 'represent the phenomenon or situation being investigated fairly' (ibid., p.181), and is based on data interpreted over a year and weekly communication with participants.

In summary, in interpretivist research reliability can be replaced with terms such as credibility; and dependability and 'trustworthiness' replace more conventional views of reliability and validity (ibid., p.210). Credibility can be addressed by actions identified earlier such as: prolonged engagement; persistent observation; peer debriefing; negative case analysis; member checking; and triangulation, which I turn to next.

Triangulation

Triangulation is defined as 'the use of two or more methods of data collection in the study of some aspect of human behaviour' (Cohen et al., 2011, p.195); in its original application, 'triangulation was a technique of physical measurement using several markers to locate a point or objective set in advance' (ibid p.195). In this project, the points are not set in advance but are arrived at later, so triangulation in the original sense is not achieved. However, this research utilises two forms of triangulation: methodological and investigator. First, 'methodological triangulation as it uses the same method on different occasions' (ibid., p.196); observations of oral mathematical story experiences are carried out on different occasions; interviews are carried out on the same participants at intervals in the project. Triangulation was achieved through using different methods of data collection: methods such as observations, interviews, and reflective accounts were used to study oral mathematical storytelling. However, this is not triangulation in the original sense of the meaning; rather, I track common categories or themes generated by different methods, which is different from setting about mapping a point or objective using three different methods from the outset. Triangulation between methods is achieved circumspectly; methods lead to common outcomes, but these outcomes were not predetermined. Second, the work is characterised by investigator triangulation as it engaged more than one observer: the class teachers, teaching assistants, and the researcher, 'all of whom independently rated the same classroom phenomena' (ibid., p.197). There are two advantages of triangulation which are relevant to this work: first, confidence can be achieved when different methods of data collection yield substantially the same results. Contrasting methods such as interviews and observations and reflective accounts gave similar outcomes and meant that as a

researcher I could have confidence in the findings. The second advantage was that the use of more than one method overcame a heavy reliance on one method or what Cohen et al. (ibid., p.196) refer to as 'method-boundedness'.

Based on an established positive professional relationship I approached the head teacher to gauge her response to the possibility of carrying out the research project over the course of an academic year with children and staff at the state infant school of which she was leader. This school was an urban State Infant School two miles from the centre of a city. At the outset, the intention was that all teachers would partake, though in reality this did not happen. I was directed by the head to start with year one as the class teacher was to go on maternity leave partway through the academic year. Cohen et al. (2000) describe participants leaving research projects as 'mortality'; participant mortality impacted on the project as at some stages educators were unavailable because of maternity leave, mental health issues, or new employment opportunities. I secured agreement that the project could extend over an academic year though this was not under the continuous leadership of the same leader; her departure resulted in change, and meant I had to work hard to sustain the project.

The research artefacts were not predetermined and included stories, props and other related materials of an individual's choice, with educators free to choose stories and associated materials. Data sources included photographs, audio and video recordings, discussions, interviews, participant observations, reflective accounts typed up after each day spent at the setting, and field notes jotted down on the spot. The procedures I chose for exploring children's mathematical

thinking employed a deliberately flexible design and are further explained in Chapter Five.

Interviews

Interviews represent a research perspective that knowledge can be generated between humans and as such emphasises the 'situatedness' of research data (ibid., p.408). Indeed, Cohen et al. (2011, p.421) advise that the interviewer views the 'interview as a social, interpersonal encounter and not just data collection exercises, viewing interviews as powerful implements for researchers' (ibid., p.408). A key advantage of an interview is that it allows for 'greater depth than is the case with other methods of data collection and a disadvantage is that it is prone to subjectivity and bias on the part of the interviewer' (ibid., p.411). Interviews were useful methods in the interpretive enquiry about mathematical storytelling. Interviews are neither subjective nor objective but rather, intersubjective (Laing, 1967, cited in Cohen et al., 2000, p.267), and are not only about collecting data but are part of life (ibid., p.267). Charmaz (2009, p.25) identifies 'intensive interviewing' as a useful data-gathering method (ibid.). One-to-one and multiple, semi-structured, 'intensive interviews' (ibid.) were conducted with the head teacher, teachers, teaching assistants and trainee educators (see Table 4.2 for detail). Interviews were recorded using a Dictaphone to allow for greater eye contact and detail to be preserved, and annotated to help frame follow-up questions (ibid., p.32). Semi-structured interviews were useful because as the researcher, I required respondents to inform me (Lincoln and Cuba, 1985, cited in Cohen et al., 2000, p.270), which they did through this approach.

Participants	Semi-structured interviews	Observations of oral mathematical storytelling	Discussions	Reflective accounts
Head teacher (1)	1	n/a	1	n/a
Reception class teachers (2)	5	12	6	2
Teaching Assistants (2)	1	1	3	1
Year one teachers (2)	2	2	5	0
Year two teachers (2)	2	0	2	0
Professional storytellers (2)	1	8	1	0
Trainee teachers (2)	2	4	0	0
Children (170)*	n/a	10 (story) 9 (play)	n/a	n/a
Researcher(1)	n/a	26	n/a	20

Table 4.2 Detail of participant involvement

* Note: this represents the total number of children at the school from which, for the main part of the research, smaller groups were drawn. The whole school was involved at the start with a refocusing of the study on classes of thirty and smaller groups. The numbers here relate to child-initiated story and play narratives.

My aim as interviewer was to devise broad open-ended questions, ask these sensitively, and listen (see Appendix 7 for example of semi-structured interview schedule). On listening to audio recordings of interviews carried out in the initial phase, I was disappointed to hear my voice dominate. I had not achieved what O'Leary (2010) refers to as the right listening to talking balance or what Kvale (1996, cited in Cohen et al., 2000, p.280) refers to as knowing when the interviewer should be silent. I was conscious of the need to adjust this for future interviews and let the interviewee voice predominate. I also noticed that having checked with participants and acknowledged how much time was available, I then ignored this as I became too consumed. I needed to manage the interview process and respect the demands on professionals (O'Leary, 2010). When this was achieved, the interviews told a rich story, and required little extra in the way

of explanation; they were 'self-communicating' (Kvale 1996, cited in Cohen et al., 2000, p.281).

Interviews were audio recorded and transcribed by a third party to make best use of time available. Notes were taken during all semi-structured interviews, and reflective accounts made afterwards. On the one hand, transcriptions help to identify where a researcher has structured questions which lead to 'forced data' (ibid., p.32); on the other hand, audio recordings lack the non-verbal communication which contributes to the transaction; transcribing results in further loss of data from the original exchange and these transcripts are '*already interpreted data*' (ibid., 2000, p.281, italics in original). To address this issue I listened to and checked transcripts against audio recordings; the notes taken at the time of interviewing and reflective accounts helped to abstract ideas from these transcripts. Interviews complement other methods such as observations, which were key methods for this research (Charmaz, 2009; Cohen et al., 2000).

Reality is multi-layered, leading to the possibility of multiple interpretations of interview interactions. The main culprit in upsetting validity is bias, and researchers can minimise bias as much as possible and identify the sources of bias as: first, the characteristics of the interviewer; second, the characteristics of the respondent; third, the substantive content of the questions (Cohen et al., 2011, p.204). These concerns are contextualised in the context of this research project as follows: as an interviewer I held attitudes, opinions and expectations of the participants; I had a tendency to see the respondent in my own image; I had a tendency to seek answers that supported my preconceived ideas, which in some instances came about because of my participation as an educator creating

oral mathematical story experiences; I held misperceptions of what the respondent was saying and in some cases needed to seek further clarifications; there were misunderstandings on the part of respondents of what is being asked and sometimes I was challenged when participants asked about the direction of the project. These reflections give the reader an insight into the way the project was continually refocused and how it was flexible and responsive in nature.

Added to this are other factors, such as the way interviewers and interviewees 'bring experiential and biographical baggage' with them to the interview (Cohen et al., 2000, p.121). Interviews are about interactions between people and are therefore going to be difficult to meet the demands of validity and reliability in the sense associated with quantitative research. Silverman (1993, cited in, Cohen et al., 2000, p.121) suggests reliability can be assisted by 'careful piloting of interview questions, training of interviewers and employing inter-rater reliability in coding interview data and the use of closed questions', though this ran against the ethos of this project; open questions were used deliberately to encourage subjective responses. The semi-structured quality of the interviews challenged reliability and validity but elicited more meaningful participant responses than would closed or overly structured questions.

Bias in interviewing

Causes of bias in interviews are set out by Oppenheim (1992, cited in, Cohen et al. 2000., p.122; 2011, p.205) and are contextualised as follows: there was bias as I had established a relationship with the school and the head teacher through other projects; I had greater rapport with some interviewees than others; there were changes to question wording which meant that some interview questions

were not repeated for all interviewees; there was poorer prompting if as an interviewer I did not feel as comfortable with the interviewee, and biased probing if I had greater rapport or had related storytelling experience to draw from; for some interviews, I could have integrated and managed support material such as video recordings as I did in other cases; there were alterations to the sequence of questions asked; where supporting materials were used, these were selected and interpreted in advance and recordings of interview transcripts are open to a biased interpretation. These ideas concerning bias highlight the complexity of interviews as a choice of method for the research project, yet interviews allowed stories concerning the research to be told.

As a researcher my judgements were influenced by my close involvement, as I took the role of researcher-educator and participated in the research telling oral mathematical stories, which resulted in three concerns: first, as a researcher-educator I was not fully aware of the complexities of the School; second, my presence brought about different behaviours and expectations; third, I was active in the project and became attached to themes, not seeing them dispassionately (Cohen et al., 2000, p.129). This third concern resulted in a decision at the final phase of the project to minimise my influence by asking key participants to document their responses to the key questions referred to in Chapter Eight (see Appendix 13). My sensitivity to each of these issues, as illustrated through this discussion, allowed for them to be part of the research.

Observations

The distinctive feature of observation as a research process is that it provides the opportunity to gather 'live' data from naturally occurring social situations (Cohen

et al., 2011, p.456). However, what counts as evidence becomes cloudy because 'what is observed depends on when, where and for how long we look and how we look' (ibid., p.456). Observations allow the researcher to move beyond the perception-based data of interviews. My role as complete observer was typified in the video recording, the audio recording and the photographing of oral story experiences (ibid., p.457). In addition, notes were made when I was observing the practice of others. O' Leary (2010, p.209) highlights the value of observations, suggesting that an advantage over interviews is that it enables you to see it for yourself. Cohen et al. (2000) suggest that observations capture what is live and bring freshness, allowing one to enter the situation later. The observational records made meant that I saw the phenomena being studied for myself, and that I worked through the complexities of the mathematical storytelling interactions away from the immediate context of the School (O'Leary, 2010, p.209). Recordings of observations were two-fold in nature: first, raw data was preserved through video and audio recordings, which facilitated later searches for emergent patterns; second, notes were made in a research journal (O'Leary, 2010, p.217). Video recordings offer something different in terms of data collected compared with audio recordings, but potentially bring a threat to the environment. Video recordings allow collection of non-verbal data (ibid., p.211), which was relevant to this project as stories employed actions and story-related materials to support abstract mathematical ideas. This threat of video recording to the environment (O'Leary, 2010, p.217; Cohen et al., p.281) was noted; one participant experienced this threat as he willingly told a story when there was no video recorder but on subsequent occasions found reasons not to. For interviews and observations, rapport and trust needed to be established with participants; this trust was particularly relevant when recording practitioner practice.

As a participant observer I was part of the school community and because I told mathematical stories I was part of the teaching team, albeit in a limited way. I experienced the phenomenon of oral mathematical story from the perspective of the educators observed, which brought richness to the data and allowed educators to observe how the children they taught responded to this alternative pedagogical approach. This researcher participation extended to my telling oral mathematical stories to whole classes of thirty children and then to smaller groups, sharing class teacher observations and my reflective accounts with the teachers and teaching assistants.

The observations were conducted in an overt fashion; I offered full disclosure about the project by providing an ethics protocol (Appendix 2) and further summarised and verbalised explanations; I explained the purpose and role of the observations to participants (O'Leary, 2010, p.210) each time this method was employed. The observations were unstructured; as researcher I observed and recorded these mathematical story experiences without what O'Leary (2010, p.210) describes as 'predetermined criteria'. These unstructured observations are what Cohen et al. (2000, p.305; 2011, p.457) describe as 'hypothesis-generating'. Thus, overt unstructured participant observations were used as methods as part of this work.

Cohen et al. (2000, p.311) describe participant observational studies where 'the time the researcher spends with the group results in the reduction of researcher reactivity and the researcher records what is happening, and they take a role in that situation'. O'Leary (2010, p.210) identifies that the more immersed as

participant, the more difficult it is to maintain the role of researcher, but later acknowledges that the more intertwined as participant the richer the data (ibid., p.212). As a participant observer who worked with educators for a year and included video recordings of my participation, I gained a depth of data which otherwise might not have been achieved, but I inevitably brought impressions about these experiences to the interviews and to the process of data interpretation.

Observations carry the risk of bias which can be attributed to: selective attention of the observer; reactivity on the part of participants; attention deficit on the part of the researcher; decisions about what counts as valid evidence for a judgement; selective data entry where the interpretation rather than the phenomenon is recorded; selective memory; expectancy about outcomes; and shared understanding between observers about characteristics of behaviour (Cohen et al., 2011, p.473). These issues concern validity and reliability; for validity, it is necessary to have shared agreement about the characterising qualities of, for example, oral mathematical story. With regard to reliability, there needs to be no variation in interpretation with consistency within observations carried out by one observer and between observers (ibid., p.473). A further consideration included in the work was the importance of writing up the observations as soon after the event as possible (ibid., p.474).

Ethical considerations

As mentioned, the decision to approach this school was based on positive professional relationships established with the head teacher and on a belief that the staff would be willing to take what Naik (2013) calls a creative risk. After

gaining entry to the School, access to individuals was a further challenge. Informed consent needed to be obtained for staff, parents and children and this required different approaches. Children needed particular attention and sensitivity, as some were as young as four and five years old. I relied on the goodwill of educators and was aware that the project was expecting them to adjust their day-to-day practice and to be video recorded while they told stories to children of varying group sizes.

As recommended by Bell (1999, p.39) I gave time for participants to read and consider implications of their participation by providing a copy of the ethics protocol in advance of expecting signatures. Informed consent requires careful preparation, explanation and consultation (ibid., p.39), which was achieved by meeting several times with the head teacher and staff, collectively and individually, prior to starting the research. Informed consent is governed by four elements as highlighted by Cohen et al. (2000, p.51): competence; voluntarism; full information; and comprehension. All participants signed the ethics protocol (Appendix 2), which was approved by a panel at Plymouth University and by the head teacher of the school; names of participants were changed. Gaining entry to the school was different from achieving access to individuals and negotiation of access was a 'recurrent preoccupation', as identified by Hammersley and Atkinson (1983, cited in Cohen et al., 2000, p.67). Realising informed consent is central to ethical considerations and harder to achieve with children.

Informed consent from parents or carers of children was obtained before involving children by providing a letter and a summary of the ethics protocol. The project was explained to children and a child-friendly form devised to obtain their assent.

Where signed permission was not obtained, children were not included as research participants and particular effort was made to avoid video or photographs being taken of these children.

While observations and interviews were clearly identified as contributing to the methodology for the project, there were instances where less defined methods such as casual conversations found their way into the collection of data. Methodological and ethical issues are inextricably connected (Cohen et al., 2000, p.66) and whether alternative methods could be included ethically was questioned: where to draw the line as to whether a casual conversation can contribute to research is a question raised by Cohen et al. (ibid., p.66) and was relevant as many such discussions featured as part of this work. Casual or unplanned conversations often elicited what I considered to be valuable contributions and were either audio recorded or noted as soon after the discussion as possible. As researcher I worked at establishing good relations, rapport and trust with staff (Cohen et al., 2000; Bell, 1999). I was aware I relied on the co-operation of educators who were already challenged by their daily routines.

Research methods go beyond that of the interview or observation and include descriptions of how the data generated from these techniques was analysed (Crotty, 1998). The stages of the project are set out and explained in the next chapter, which identifies how data were analysed and what I mean by themes or categories. The next chapter explains how themes were identified and what was done with these themes to construct theory about oral mathematical storytelling.

Summary

Given my stance towards learning mathematics outlined in previous chapters, the challenges of this chapter were to express my understanding about terms such as ontology, epistemology, theoretical perspective, and methodology, and to explain how they fit together in the context of using oral mathematical storytelling to encourage mathematical thinking. Crotty's (1998) model supported this two-fold challenge with the theme that terms such as symbolic interactionism, ethnography and constructionism are related to one another; this chapter clarified these relationships in the context of the research.

The uniqueness of the research situation means this study could not be repeated; instead thematic outcomes could potentially be projected to other educational contexts. Reliability within the study is achieved in so far as what is generated is replicated in repeated oral mathematical story experiences. The literature review informed the codes used to analyse the video recordings of storytelling and replication of themes across data validates the constructs I make concerning oral mathematical story. Thus, I argue that as with validity, pursuing reliability further is imposing that which is more fitting for quantitative research and instead the interpretation is concerned with data quality which relies on trustworthiness and inference both of which are rationalised in this chapter. Though the outcomes from data cannot be generalised it is proposed they will resonate in similar situations; outcomes will be suggestive rather than conclusive and will be plausible but not definitive as there are potentially other ways of seeing what I found. I have set out the process and can defend this as an enquiry that can be taken seriously. The next chapter considers how the research methodology was implemented.

Chapter Five   Generating and analysing rich data

Introduction

This chapter aims to explain how I analysed the data I generated. The chosen analysis fits with an interpretivist approach discussed in Chapter Four. In this chapter I return to the initial research question and the theory provided by the literature reviewed in Chapters Two and Three. The chapter discusses categories derived from data in the context of previous research and in doing so provides a framework for analysis, aspects of which are explored in more detail in Chapters Six and Seven. The purpose of this study was to explore the potential of oral mathematical storytelling as a creative way of encouraging children's mathematical thinking. This project moved through three stages which were delineated by context: whole school (one hundred and seventy children); whole classes (thirty children); and small groups (three to eight children) away from the main classroom. At the start of each session, the project was explained and a diagram drawn of who was sitting where with cross reference made to a list of names of children for whom permission to partake had been granted. Children and educators were observed over the course of an academic year, listening to and retelling mathematical stories; this activity is set out in Table 5.1 below.

From September to December of the academic year 2012–2013, the project was located in larger group contexts with year one classes; post-December work was situated in an early years context where there was a greater emphasis on play. The reception classes were located away from the main school and each had an adjoining room with smaller spaces which were more or less dedicated imaginative play areas, used initially for story-related play following stories in the main classroom, and later as mathematical storytelling places. At the start of each

day I invested time in rearranging these rooms as storytelling spaces with cushions, carefully setting up audio, video and photographic equipment so that the experiences would be recorded from the perspectives of children and adults.

September	**Whole school activity** Professional storyteller telling stories with mathematical themes to Reception, year one, year two children as a whole school activity followed by workshops with year groups.	Interviews with head teacher and educators. Discussions with children and parents. Observations of children responding to large group storytelling experiences.
September – December	**Year one whole class activity** Researcher and class teachers telling oral mathematical stories to classes of thirty children.	Observations of children sitting on the carpet listening to adult at front of the class sitting on a chair using props to support the story ideas. Discussions with teachers about how children respond to this pedagogical approach.
December – July	**Reception class activity *** Class teachers telling oral mathematical stories to classes of thirty children.	Observations of children sitting on the carpet listening to adult at front of the class sitting on a chair using props to support the story ideas. Video recording provided for educators to reflect on.
	Class teachers and researcher telling oral mathematical stories to smaller groups of children in a dedicated side room.	Observations of children sitting on cushions arranged in an arc facing adult sitting on a storytelling cushion.
	Children taking the role of oral mathematical storyteller with adult taking the role as story listener.	Observations of children and adult sitting on cushions arranged in an arc facing a child sitting on a storytelling cushion.
August	**Reception class activity**	Educators document their experience as oral mathematical storytellers.

Table 5.1: Oral mathematical story activity over the academic year

*Note: weekly discussions and a semi-structured interview using video clips of children responding to oral mathematical stories contributed to the rich data gathered as part of the reception class activity.

The aim of this chapter is to explain how data were analysed in order to show how initial findings directed subsequent stages of the research and how reflective accounts associated with this data identified tensions that challenged the

direction of the project. Observations of oral story work with larger groups of children led to conflicts with the ethos of the project and an initial dissatisfaction that was satisfied with smaller group work where children could take the role as storyteller and play with story-related materials. The later stage was marked by reception teachers re-organising daily routines to facilitate taking small groups of children to these smaller physical spaces and allocating teaching assistant staff to supervise the main classrooms. The relocation of the project to an early years context led to re-positioning the educator as storyteller 'alongside' (Coles, 2013) children, and resulted in more creative story experiences. This shift from main classroom to smaller spaces resulted in notably different outcomes, which are discussed in the Chapters Six and Seven. These smaller spaces were more intimate and invited a story ritual as the younger children chose to take off their shoes and socks placing these behind their cushions. A typical smaller session was with six to eight children sitting on cushions in a semicircle facing the educator who sat on what children referred to as 'a storyteller cushion'. Story-related materials were set out in front of this cushion, often covered with a piece of fabric, which prompted suspense. The thesis now provides an overall context of the school before offering a short biography for the participants who contributed to the main body of the research.

Context

The school is a state infant school positioned alongside a junior school but retaining very much a separate identity. The school is smaller than most primary schools with approximately one hundred and seventy children registered. A large majority were of white British heritage with some children from minority ethnic backgrounds. The early years foundation stage consists of two reception classes;

key stage one consisted of two year one and two classes. There appeared to be a supportive environment and an ethos of creativity, or at least a willingness to try a different approach by the head teacher, who actively encouraged all the staff to participate in the project. Mary worked as a year one teacher alongside Sam, who was newly qualified. Sharon and Lorraine both worked as reception class teachers with full-time teaching assistants in a unit that was separate from the main school building. The thesis now offers short participant biographies.

Mary: relevant biography

Mary was a year one teacher who had qualified with a PGCE some years previously. She worked part time and was soon to go on maternity leave to have a second child. Mary was pragmatic and calm, taking things in her stride. She did not appear to allow her job to dominate her life and seemed to have a balance between work and home. She had arranged tables towards the back for writing work and there was a carpet area where children gathered in front of a white board. One of the challenges Mary faced was managing discussions on the carpet with a class of thirty children, some of whom had special educational needs; one boy showed characteristics of autism and was usually supported on a one-to-one basis, though in the absence of this support his behaviour was difficult to manage and then Mary's strategy was to allow him to walk around and cut paper into small pieces while she took the rest of the class. On one occasion she expressed anxiety as to what a parent who was helping in the class that day would think about this child wandering around.

Sharon: relevant biography

Sharon previously worked as a textile designer and used her artistic skills to run activities in youth clubs before working as a teaching assistant and then completing a PGCE. She described herself as 'a very creative person and enjoy[ed] learning about new ways to teach, using a variety of methods' [Extract from Sharon's documented reflection, August 2013]. Sharon expressed concern about the rigour of teaching and the pressure of an accountability culture on children at the age of four and five. The classroom where she was based was light and airy with a carpet area and tables for group work. There was an adjoining room set up as a home play area and which was used for assessment of children away from the busy context of the classroom. Sharon was supported by an experienced teaching assistant, Helen. Sharon was fond of the children speaking positively about their characters, encouraging them to express their views which she appeared to cherish. There was sometimes what seemed to be a more haphazard approach to her teaching; for example, on one occasion children were left waiting some ten minutes while she sorted out the interactive whiteboard. During the project she would suggest ideas with enthusiasm, though these would not necessarily be implemented; she frequently stated that she would observe my telling of a mathematical story and would not appear at the designated time. However, she did participate in the project, even though at times it appeared to be an additional pressure. She expressed a desire to be creative though was possibly constrained by a perceived responsibility to interpret the curriculum in a 'technician' way (Ball and Bowe, 1992). She confessed to sometimes feeling frustration with the dominance of report writing and other obligations, such as parents evenings. However, she nurtured imagination and encouraged children to express original thinking, as is evident in some of the data detailed later.

Lorraine: relevant biography

Lorraine was an experienced reception class teacher who held responsibility for early years in the school. Lorraine was interested in mathematics though confessed that as time had passed since her training she had moved away from her specialist subject, and noted how the project served to reawaken this interest. Her subject knowledge came across as stronger than her colleagues' and she held a certain air of authority that others did not have. Though she presented as aloof and silent at first, this shifted when she was in front of children, where she was notably skilled at questioning and prompting their thinking.

Lorraine was a reflective deep thinker who initially gave the impression that she would resist the project but who of all the participants contributed the richest insights. Her classroom environment was set out in a similar way to that of Sharon's and had an adjoining room used for play and assessment, and was a place where one child had daily physiotherapy. Her work as a reception class teacher was supported by Karen. A mutually respectful relationship was evident between Lorraine and the children. Lorraine on several occasions recounted children's learning moments and noted how they made imaginative connections.

Based on the literature review and the interpretation of data, a theoretical framework is constructed in response to the research question: How can oral mathematical story encourage children's mathematical thinking? Questions supporting this overarching research focus include: What characterises oral mathematical story experiences? What are the concerns educators have about this pedagogical approach?

By way of introducing and sustaining the project I constructed an oral mathematical story based on 'Little Lumpty' (Imai, 1994) with a year one class, while Mary the teacher observed how the children responded before taking on the role as oral mathematical storyteller herself. The benefit of my taking the role of teller was that it allowed insight into the research questions from a dual perspective, both as a researcher and as an educator with previous experience teaching young children. Further, as referred to in Chapter Four this approach provided educators with the opportunity to see how the children they taught responded to this alternative pedagogical approach and, in some instances, allowed children's mathematical thinking to be recorded, which otherwise may have gone unnoticed.

This chapter considers how data were coded and theorised about, with a particular focus on the early stage of the study; the two chapters which follow look in more detail at how findings integrate into the theoretical frames outlined in earlier chapters. The themes supporting categories discussed in this chapter are based on interviews, observations, reflective accounts and thick descriptions, generated over an academic year. The chapter focuses on the way the data were interpreted, discusses the emerging categories, and relates these to the review of literature covered in Chapters Two and Three.

Separating analysis and findings is difficult because presenting data involves analysis (Robert-Holmes, 2011; Thomas, 2013), and the content of this chapter slides between generating, interacting with and stating insights about data in an attempt to explain and analyse what went on. Analysis is itself a social

construction, as it takes its shape through language: 'There are always multiple interpretations of how a given form of discourse functions in social life, and there is no ultimate means of grounding a conclusion' (Gergen, 1999, p.63). However, I attempt to ground a conclusion by summarising what was generated, analysed and interpreted. First, I distinguish between data sources and methods particularly as the data sources changed over the course of the project.

Distinguishing between data sources and methods

Mason (2002) distinguishes between data sources and methods for generating data. Data sources were the places or phenomena from or through which data were generated, and the data generation methods were the techniques used to achieve this (ibid, p.51). Data sources for this project included the following:

- storytelling events with international and local professional storytellers

- people (children; teachers; teaching assistants; trainee educators; parents; and storytellers)

- the infant school

- the environments within the school (school assembly hall, main classrooms, smaller rooms and smaller play areas which I converted into storytelling areas); texts (books; research papers; articles in education journals; newspaper articles; and Government publications)

- objects and artefacts (which included storybooks and stories from which mathematical stories were adapted or created; puppets and props which were selected or made to support oral mathematical storytelling)

There are overlaps between these data source categories, but identifying them provides a way of visualising the project. Within the 'people' category, I was

interested in elaborating and exploring the following, based on Mason (2002, p.53): language; expression; gestures or actions; appearance; experiences; accounts; interpretations; memories; thoughts; ideas; opinions; understandings; emotions; feelings; perceptions; behaviour; practices; conversations and interactions with children; creations (story and related materials); and inner self (confidence). The range of methods which generated data included: interviews with participants; observations of mathematical storytelling experiences; discussions about oral story experiences; photographs; video and audio recordings of stories and discussions; thick descriptions; and participant documented responses to key research questions.

Richness of data

The richness of the data came about as a result of relationships I established with participants. Rapport and respect pervaded how I generated data and what data I came to have (Charmaz, 2009); my requests to create story-based mathematical experiences were responded to favourably because of the quality of the interactions I had with educators. Participants adapted and created original mathematical stories and story-related materials; for example, Lorraine, a Reception class teacher, practised telling 'Penguin' in front of a mirror at home, and prepared cut-out yellow and orange fish to support a number bond theme; Sharon prepared animated shapes and sourced a witch's hat, which she wore for 'The Greedy Triangle' (Burns, 1994) story; Karen carefully set out miniature people and artefacts for her telling of 'The Enormous Turnip' (Beck, 2004) (selecting suitably sized miniature turnips from a local vegetable shop) and wore a storytelling cloak. These three educators articulated their thoughts, documented ideas in notes and wrote detailed responses to key research

questions at the end of the project (an example is provided in Appendix 13). Actions such as these reflect the quality of the relationships established between researcher and participants and resulted in rich data.

Careful choice of language: gathering or generating data?

The use of language associated with data is worth noting: Charmaz (2009) uses the word 'gathering' of data, whereas Mason (2002) shows a greater sensitivity to the interpretivist feature of this stage of the research process and chooses 'generation' over words such as 'collection' or 'gather'. Mason's (ibid.) care with the choice of the word 'generation' rather than 'collection' is in keeping with an interpretivist research paradigm discussed in Chapter Four; the data are not out there waiting to be collected or gathered but can be generated depending on what approach the researcher takes. Further, methods chosen to generate data are more than techniques to apply; methods require intellectual, analytical and interpretive skills (ibid., p.52). I generated data using specifically chosen methods, posing questions about what I can interpret from these data about oral mathematical story experiences and what I can say in response to this interpretation of data.

Coding

Coding is a process which sits between generating data and creating a theoretical frame; data is generated, coding defines what is happening in the data, which leads to developing an emergent theory to explain these data. Coding represents the first step towards making analytic interpretations (Charmaz, 2009); it is categorising segments of data or units of meaning (Maykut and Morehouse, 1994) with a short phrase or label that simultaneously summarises and accounts for each datum (Charmaz, 2009, p.43). Codes act as analytic handles to develop

abstract ideas which are interpretations of data: they are the bones of analysis, and as such shape the analytic frame (Charmaz, 2009).

Theoretical statements were generalised in the project context and represented an analysis of the happenings within the research context, which are provided in Chapters Six and Seven along with a contextual analysis of the actions as part of oral mathematical story experiences.

Units of meaning

It is important to develop a discipline which ensures that each chunk or unit of meaning will need to be coded to its source. The process involves working from small units of meaning to generate categories which bring themes together: 'this search for meaning is accomplished by first identifying the smaller units of meaning in the data, which will later serve as the basis for defining larger categories of meaning' (Maykut and Morehouse, 1994, p.128). These units of meaning were identified by carefully reading through transcripts of interviews, video and audio recordings of storytelling, field notes and reflective accounts, with the essence of the meaning recorded on the transcript (ibid., p.129) (examples provided in Appendix 9,10 and 11). An alternative presentation of transcripts was designed to facilitate the coding of each unit of meaning, and an example of an excerpt from an interview with one of the professional storytellers is shown below (Interview 20.11.2012). The units of meaning are coded and represent the following themes: connecting curricula through story; balancing story and mathematics; playing with story-related materials; and playing with mathematical ideas creatively.

Time code	Label to capture essence of description	Speaker	Transcript
00:04:10	Connecting curricula through story Balancing story and maths	S2	Well, I think, I suppose, sort of independent of you having this project, kind of it was mulling in my mind before about not just maths but lots of other aspects of children's learning that can be drawn from stories. And obviously, that was always the case, you know, because the slaves in America weren't allowed to educate their children so they would tell them stories instead. There are all kinds of ways you can get moral messages and actual facts and history and all those kinds of things across. But I think certainly, in terms of traditional stories, there's lots of opportunity to bring mathematical things but I think there's quite a lot more than just numbers or kind of bigger…there are quite a lot of other things in stories. But the trick as we've talked about before is kind of making sure the story is still there and it's not been milked (laughter) by the maths to the point at which the story is now a limping along and kind of the children are going, 'Oh, this is just a maths lesson and you've pretended it's a story.' So I think keeping all the other parts of it and maybe just having one or two level focuses and trying not to kind of overdo it. It's definitely the way for it. But I think also talking about what my colleague said about, 'Well, it's too

| | Playing with story-related materials | | much talking and not enough playing.' And I think there's something in this idea of sort of a story that kind of maybe introduces a new idea or looks at an idea like capacities or something in a slightly different way. And then there are things that support those resources that the children can go and kind of play with those themselves. It's really important. And one of the stories that I'm working at the moment, Stone Soup, which I know because [refers to professional storyteller] uses as well, is kind of not necessarily about naming 3D shapes but kind of playing with the idea of kind of roundness just so that the children can use their own descriptions of those shapes. Before, you then hammer home (overlapping conversation) your name. So it's that kind of bi-numeracy. They have their own numeracy and then there's adult numeracy and the two are bobbing along together as they make up funny ways to describe those shapes and names. |
| | Playing with mathematical ideas creatively | | |

Table 5.2: Extract of interview with professional storyteller (coding)

When coding data, Thomas (2009; 2013) suggests reading through transcripts and as you read to underline, mark, label or highlight parts that you think are important. I established that it was not enough to code the transcript without going back to the video recording, an approach confirmed by Robert-Holmes (2014). I concluded that coding the transcripts while watching the video material generated

a deeper analysis. The coding of transcripts while viewing the video material allowed the coding of setting, scene, adult and children, as well as the words. Charmaz (2009, p.70) advises that observations of the setting, scene and participants are coded to generate more revealing data, which was achieved by returning to video material. I recorded who did what, when it occurred, and why it happened. I identified the conditions under which specific actions, intentions and processes emerged or were missed. I focused on specific words and phrases to which participants seem to attribute particular meaning. The contexts of storytelling were carefully recorded to delineate situations: whole school; whole class; and small groups. The position of storyteller in relation to story listeners was noted as part of this contextualised data. Coding of video recordings of oral mathematical story experiences and play scenarios was different from coding transcripts of interviews where re-listening to the original audio recordings relied on reading field notes to code contextual detail.

One of the methods referred to in Chapter Four was video and for this research, video recordings were made from two perspectives: one of the children listening to mathematical stories and the other of adults telling mathematical stories, which provided two perspectives for analysis. Recording from both perspectives offered a greater opportunity to observe behaviours and physical responses which might have remained hidden in the data if both perspectives had not been captured. In line with the ethical considerations discussed in Chapter Four, the class teacher and I worked together referring to a list of names for children whose parents had provided signed permission that they could participate. As mentioned earlier those children for whom there was no ethical clearance were kept outside of the lens view. In addition to two video perspectives, field notes were made at the

time; in one or two cases where video or audio recordings failed, these notes were relied on.

Language to code

The language used to code confers meaning and is representative of my ontological and epistemological assumptions as outlined in Chapter Four. Burr (2003) expresses the view that language provides the basis for our thought and that through the use of language we construct rather than represent our thoughts. She describes how researchers identify variability and repetition as belonging to repertoires:

> Researchers look for the metaphors, grammatical constructions, and figures of speech and so on that people use in constructing their accounts. By examining the talk of different people about a topic, it is possible to see patterns in the way that some figures of speech, metaphors and so on recur. By collating such usage across different speakers, the researcher identifies them as belonging to a particular repertoire. Therefore both variability and repetition are features which such analysts are looking for in their material.
>
> (Burr, 2003, p.186)

I paid attention to language when data was coded and in particular to 'in vivo codes', which are expressions participants use as 'insider shorthand', or which are innovative terms or expressions regarded as common currency, or what everyone knows (Charmaz, 2009, p.55). I used vivid terms without being assumptive in doing so. Coding data as actions prevented me from making conceptual leaps (ibid., p.48). Charmaz's (2009) guidance directed the words I chose to code as I endeavoured to represent the action of the data. An example of this attention to in vivo codes is evident in the coding of the interview with one of the year two teachers (Interview 12.10.2012) who referred to 'engage with', 'adapted to learning', and 'accessible'. The words 'accessible' and 'engage' correspond with words used by other participants and were codes deduced from

the literature review (see Appendix 4), contributing to an initial repertoire which captured a description of oral story.

Phases of coding

Broadly there are two main stages to coding: ' 1) an initial phase involving naming each word, line, or segment of data, followed by 2) a focused, selective phase that uses the most significant or frequent initial codes to sort, synthesize, integrate, and organise large amounts of data' (Charmaz, 2009, p.46). Focused coding follows initial coding and '…pinpoints and develops the most salient categories in large batches of data' (Charmaz, 2009, p.46). Though themes such as 'engage with' and 'accessible' correlated with the literature, they were not subsumed into categories because they were not central to the project focus; other themes such as 'making mathematical connections' were considered more of a priority in providing insight into how oral mathematical story could encourage children's mathematical thinking.

Initial coding

Charmaz (2009, p.47) advises that we see actions rather than apply pre-existing categories, that we choose words that reflect actions, that we code datum as actions. A question posed of initial codes was which initial codes make the most sense to categorise data? (ibid., p.58). Thomas refers to initial impressions about what is important in the data as '*temporary constructs*' (italics in original, 2013, p.236). I looked for general themes which emerged from the data: I remained open; stayed close to the data; kept codes simple and precise; constructed short codes; preserved action; compared data with data; moved quickly through the data (Charmaz, 2009, p.49).

Focused coding

Focused codes should be active, brief, reflect what people are doing or what is happening, and lead to potential categories (ibid., p.92). Charmaz (ibid., p.92) suggests that 'Processes gain visibility when you keep codes active. Succinct, focused codes lead to sharp, clear categories'. I compared observations of oral mathematical stories at different times and places; I moved across interviews, observations, comparing expressions, actions, interpretations; I compared data with data which helped to develop focused codes and comparing data with these codes helped to refine them. What began as a code became a category. The comparing of data with data formed focused codes using the codes created through initial coding. I questioned which codes made the most analytic sense to categorise data. Focused coding prompted me to see relationships and patterns between categories (ibid., p.94; Thomas, 2011, p.235).

Categories

A category is a 'conceptual element in a theory' (Glaser and Strauss, 1967, cited in Charmaz, 2009, p.91). Categories explain ideas, events or processes in the data and subsume common themes and patterns (ibid., p.91). Categories should be as conceptual as possible, have abstract power, have precise wording, and drive analytic direction (ibid., p.91). Categories were based on in vivo codes taken directly from respondents and were representations of my theoretical definition of what happened (ibid., p.92). As with codes, Charmaz (ibid.) advises that action categories involve the reader more, a consideration which influenced my choice of language when defining categories.

Raising a code to a category

When coding I asked the following questions of the data (Maykut and Morehouse, 1994, p.133): What are the recurring words, phrases and topics in the data? What are the concepts that the interviewees used to capture what they said or did? Could I identify any emerging themes in the data, expressed as a phrase, proposition or question? Did I see any patterns? Responses to these questions generated recurring concepts, phrases, topics, patterns and themes grounded in interviews, field notes and observations (ibid., p.133). Once these themes were identified I returned to extract quotations from the data that best represented these themes.

Building categories

Codes resulted in building categories concerned with the process of oral mathematical experiences. Coding is about making a smaller statement with different words, or extracting exact words with a high level of relevance; it captures the essence of what it serves to represent: 'Coding consists of this initial, shorthand defining and labelling; it results from a grounded theorist's actions and understandings' (Charmaz, 2009, p.47). Entire interviews, play scenarios, oral mathematical story experiences and mathematical discussions were transcribed. These full transcriptions allowed me to return to the data and reread and recode the data. These transcripts along with the video recordings, which preserved details, led to development of ideas about the phenomena associated with oral mathematical stories. There are examples of some of the transcribed data with codes provided for the reader in the Appendices (9, 10 and 11). Each line of the transcript was coded and some of these codes were subsumed into categories

that correlated with codes derived from the literature review and are tabulated below.

The coding of interview data provided insights into educator epistemological perspectives as to how they saw the teaching and learning of mathematics. In the majority of cases responses were that of 'technicians' rather than 'professionals' (Ball and Bowe, 1992) with educators planning from objectives set out in the curriculum rather than planning from a story, which was the approach Lorraine took and which is returned to in Chapter Seven. This challenged the premise that oral story would allow educators to be playful with mathematics and enable them to take a creative risk in interpreting and implementing the curriculum.

Initial codes led to focused codes and then to two main categories: characterisation of the oral mathematical story experience; and challenges which this experience presents. Analysis of interviews and some early observations led to the creation of categories which describe what educators perceived as characteristic (six identified of which four, in italics, are discussed here) and challenging about oral mathematical storytelling; this is summarised in Tables 5.3 and 5.4, which follow.

Characterisation of oral mathematical story	Related sub categories
Differentiating between reading and telling a story	• Building relationships. • Removing barriers. • Flexibility with telling.
Inclusive quality	• Children acquiring English. • Children categorised as lower ability. • Children with autistic characteristics.
A connective quality (Integrative instruction)	• Connecting curricula disciplines e.g. literacy and mathematics. • Connecting within mathematics as a curriculum discipline: between mathematical ideas or themes. • Children using story context to explain mathematical patterns.
Playfulness	• Playful relationship between story and mathematics: playing with the plot 'what if?' • Playful telling: open to possibilities. • Playing with story-related materials to translate between abstract ideas in concrete ways and/or to solve problems posed by actions.
Mathematics	• Story providing imaginative ways of seeing numbers: different ways of seeing 10 as a crab's legs (Sayre and Sayre, 2003). • Exploring mathematical algorithms through actions of story character. • Extending and developing mathematical ideas through story.
Documenting mathematical thinking in qualitative ways	• Oral story as a qualitative assessment of children's mathematical thinking using the proposed observational tool (Appendix 3).

Table 5.3: Characterisation of oral mathematical story

Characterisation of oral mathematical story experiences

The characterisation of oral mathematical story experiences as a theoretical frame was constructed with categories derived from the process of coding described above. Each of these categories is considered in more detail below and related where appropriate to codes derived from the literature review.

Differentiating between telling and reading

The differentiation between telling and reading a story led to three subcategories: building relationships; removing barriers thus allowing eye contact; and flexibility associated with storytelling. Oral storytelling brings a unique experience to educator and child; reading is interpreting text in a shared way, but telling a story is a personal performance (Grugeon and Gardner, 2000, p.2). Parkinson (2011, p.12) acknowledges that storytelling rather than story reading retains advantages of flexibility and adjustment, and Grugeon and Gardner (2000, p.2) propose that telling sets you free from the written text and allows the story to be altered and adapted to the needs of the audience; it is this flexibility which potentially facilitates mathematical thinking as part of oral story experiences.

A theme interpreted from several data sources is that oral story is a way of building relationships. Several participants refer to the removal of the barrier of a book and note how 'eye contact' is more pronounced. However, though year one teacher Mary puts forward a positive perspective about oral story, she positions it as 'a gap-fill thing' and considers that it had 'nothing to do with the curriculum' (Interview 12.10.2012). One of the professional storytellers confirmed that some educators see oral story as something for later in the day rather than at the core of routine, which constrains possibilities for oral mathematical story. Thus, though

participants' comments characterise oral story as an active experience which allows educators to build relationships with children, responses to questions about the possibilities of oral story as a pedagogical approach have a notable inherent tension; oral story supports building relationships with children but was given lower status than other teaching activities by some educators, which is potentially problematic for this research as it challenges where oral storytelling will fit with day-to-day pedagogical practice.

Inclusive

A theme concerning inclusion recurred in interview and observational data and displaced an early misplaced preconception I held that oral story might exclude some children. The 'inclusive' category encompasses 'children categorised as lower ability'; 'children acquiring English as a second language'; and 'a child with autistic characteristics'. Though the project did not have specific groups of children as a focus, outcomes early on in the research indicated that contrary to initial concerns, all children responded favourably and those with the specific needs were included in the experiences alongside their peers.

A connective quality

The connective quality of oral story relates to the way story provides a context for children to think about mathematical ideas and this category derived from the data corresponded to the literature code 'story context'. Research findings that support the use of children's literature for improving the disposition to pursue mathematical learning and mathematical thinking (Keat and Wilburne, 2009; Van den Heuvel-Panhuizen and Van den Boogaard, 2008; Hong, 1996) suggest this is because story provides a context for mathematical ideas. This pedagogical

approach potentially integrates mathematics, literacy and social skills through the thoughts and actions of story characters (Keat and Wilburne, 2009; Casey et al., 2004; Hong, 1996). Story is connective in the way it links curricula areas and allows connections to mathematics and between mathematical ideas aligning with the horizontal and vertical model to support the integrative feature of oral mathematical story proposed in Chapter Three. Year one teacher Jon's telling of the 'Three Little Pigs', for example, can be viewed as connecting literacy, mathematics, science, music and social skills during snack time. A professional storyteller, when interviewed, places particular emphasis on the connections between story, mathematics, and Personal, Social and Emotional curricula.

Thus, a story context offers the possibility to contextualise mathematical ideas and for children to make imaginative suggestions. If curricula areas were tabulated, the connective quality of story could be imagined as extending horizontally across curricula, vertically up and down mathematics, and diagonally interconnecting many areas and ideas. However, application of this connective or integrative facility of oral story depends on how educators view teaching and learning and more particularly whether they see understanding mathematics as 'relational' as well as 'instrumental' (Skemp, 1976), which is discussed in more detail in Chapter Seven.

Participants suggested that story contextualises mathematical ideas and in doing so helps children remember. One of the professional storytellers relates the contextualising of mathematics in story to memory: 'Because it just serves to make it all more memorable I think and it fixes in their minds more' (interview 20.11.2012). The context of a story can support children in how they think about

mathematical ideas. 'One is a Snail, Ten is a Crab' (Sayre and Sayre, 2003) is a picture book that allows children to imagine ten as crab's legs, which reception class teacher Lorraine refers to when explaining how story context can offer an alternative to that of Numicon, which is a commercial mathematical support, in that a story can allow children to see ten in imaginative ways. This theme plays out later in the project when children see the difference between even and odd numbers with shoes as part of 'The Elves and the Shoe Maker' (1995) where it was notable how children used story context to explain mathematical patterns of evenness. The story context is as it were the binding ingredient between curriculum disciplines and within mathematics.

The category termed 'connective quality' had three subcategories: first, story connects curricula, for example literacy and mathematics; second, story can connect aspects of the mathematics curriculum; and third, story context offers scope for children to explain mathematical patterns and make connections to mathematical themes beyond those of the story told.

Playfulness

This category is a key area of the research since it represents how story can change the way children experience mathematics, in ways that differ from other classroom practices which focus on isolated learning objectives, explaining and practising often through provision of worksheets. Playfulness is subcategorised into three areas: a playful relationship between story and mathematics; playful telling of an oral story; and playing with story-related materials following an oral mathematical story. In the introduction to workshops, the second professional storyteller makes explicit her intention: 'So we can think about how we play with

maths to help us play with stories' (workshop 12.10.2012). This relationship can be considered in another way: playing with story to play with mathematics. Further, there is potential to play with the relationship between story and mathematics. The professional storyteller (interview 20.11.2012) makes the idea of naming shapes and considers that it is '…not necessarily about naming 3D shapes but kind of playing with the idea of kind of roundness so that the children can use their own descriptions of those shapes;' and that children '… play with those ideas'. She adds 'And then as time passes, all those ideas fit and the shared language fits rather than just saying, this is a cuboid, this is a cone…' (interview 20.11.2012; see also Table 5.2), which suggests a deeper more interconnected learning experience. However, it is the sub category I turn to next that is central to the tenet of the research and that presents both the greatest opportunity and challenge to this alternative pedagogical approach.

Playful telling

Whether an educator tells a story playfully depends on their epistemological view of what it means to teach and to learn. A quality of oral story orchestration noted by Carlsen (2013) is the way the educator playfully dealt with mathematical ideas which he considers came about because of familiarity with the story and the way props were used purposefully to support the story. Year one teacher Jon playfully tells 'The Three Little Pigs' with his guitar and in doing so prompts a child's suggestion to count bricks in multiples of hundreds, leading to an imaginative representation of a large number with the word 'one quintron'. This playful telling of 'The Three Little Pigs' encouraged children to make suggestions beyond those more obviously associated with the story. An outcome of playful telling was that children posed playful mathematical problems, for example a suggestion by a child after listening to 'Little Lumpty' (a description of which is included in Chapter

Six), which had counting in multiples of 2 to 24 as its mathematical theme, was to count in multiples of 10 to 300, presenting an opportunity to connect the idea of counting in multiples to other numbers. Notably, there was one educator who told stories playfully, saw the opportunity to think about mathematics in a problem solving way, and contributed the richest data, an analysis of which is included in Chapters Six and Seven.

Playing with supporting materials

It is necessary to view this category in two ways: first, from the perspective of the adult using story-related materials in a playful way to enhance the story experience and allow the more abstract mathematical ideas to be represented in concrete ways; second, allowing children to play with these materials and observing what they do in terms of translating ideas heard and modelled by the adult storyteller and representing these as concrete ideas in their play or story narratives. Egan (1988) proposes that not all learning needs to move from concrete to abstract, as is generally considered the case for young children. There is potential for young children to learn in a different way: moving from abstract to concrete with the abstract mathematical ideas of stories made concrete by playing with story-related materials. Children can listen to the mathematical ideas of a story and play with story-related props, expressing ideas in a concrete way. As noted in the literature review, Haylock and Cockburn (2013) advise that children need to work with concrete materials before they can articulate number relationships, highlighting the need for story-related materials.

Challenges of oral mathematical story

There were several categories generated concerning what were perceived at the start of the research as the challenges of oral mathematical story which are

tabulated below. Some of these challenges are referred to again in Chapter Seven, where educators reflect on their moment-to-moment practice of oral mathematical story.

Challenges of oral mathematical story as a pedagogical approach	Related sub categories
Children reconstructing mathematical ideas as part of other contexts (adapted Isomorphism)	• Reconstructing mathematical ideas as part of play and story narratives.
Managing relationships	• Preserving a balance between story and mathematics. • Managing story and props. • Managing story language, actions, props and mathematical themes.
Confidence and competence as a storyteller and as a mathematician	• Confidence mathematically: a story can go in many directions as ideas interconnect. • Confidence in storytelling. • Making mathematical errors. • Challenging and correcting errors. • Overlooking errors. • Missing opportunities to make connections or develop mathematical themes.

Table 5.4: Initial challenges and concerns about oral mathematical story

Children reconstructing mathematical ideas as part of other contexts

A challenge identified by participants was whether children will use mathematical ideas in other contexts. A year two teacher commented regarding mathematical learning: 'Yeah, yeah, it might get lost...', and questioned whether learning would be transposed to paper: 'I don't know how it [will] …transpose onto paper' (Discussion 30.11. 2012). Mary shared this concern and questioned whether

children who hear about capacity through story would use what they know in other

contexts:

> Mary: …Um the one thing I thought would be…it would be interesting to see if those skills…if that knowledge, like we talked about in the staff meeting really, the knowledge that we're trying to sort of impart on them will they then be able to transfer those…that…that knowledge into mathematical skills in another way…
>
> CMcG: Mmm…
>
> Mary :   In another area or situation if you like.
>
> CMcG: Mmm, yes.
>
> Mary :   So I think that's one thing I'll be interested. If I tell a story about you know…a capacity or something.
>
> CMcG: Mmm…
>
> Mary :   And then if I let them go in the sand and water, will they transfer that…that into their own…
>
> CMcG: Yes, yes…
>
> Mary :   …play or learning?

(Interview 12.10.2012)

It is worth noting Mary's choice of language here as it is representative of her

view of 'knowledge' and her mathematical epistemology. This concern

demonstrated the teacher's belief in knowledge as objective is central to the

question of whether oral story can change teachers' understanding of what

mathematics is all about, seeing mathematics in a 'relational' as well as

'instrumental' way (Skemp, 1976), as an interconnected discipline as well as

about acquisition of facts. This concern about children using mathematical ideas

in other contexts is addressed in more detail when the practice of oral

mathematical storytelling is considered in Chapter Seven.

However, more in keeping with the ethos of the project is the adapted idea of

isomorphism (Casey, 2011), discussed in Chapter Three, which is taken to be

about children reconstructing mathematical ideas as part of other contexts such

as play or storytelling. This research proposes that mathematical learning

contextualised or situated in a story context encouraged children to reconstruct

what they knew from this story context in other specific contexts such as play or story narratives. As noted earlier, Boaler (2002, p.2, referring to Lave, 1988) argues that theories need to consider the communities in which children operate, and that knowledge is shaped or constituted by the oral story situation or context in which it is developed and used.

The views educators held about teaching and learning and about mathematics combined with their response to explicit and implicit pressures influenced how they interpreted the curriculum and implemented mathematical activity-orientated goals in practice. The pressure of accountability reflected in shared concern among participants about whether children would apply their mathematical learning to other contexts, raised by several participants, reflected a certain epistemological stance about what it means to know. The research advocates that because oral mathematical story experiences allow children to think flexibly about mathematical ideas they can reconstruct these themes in play or story narratives in a way which is conceptualised by 'isomorphism'.

Managing relationships

There were three aspects of this category that could be identified from the data: first, preserving a balance between story and mathematics; second, managing story and props; and third, managing story language, actions, props and mathematical themes.

Preserving balance: story and maths

A challenge to oral mathematical storytelling included achieving the correct balance between story and mathematics. I failed to achieve a balance in the second and third telling of 'Little Lumpty' and recorded how the story became the

servant to mathematics, which a professional storyteller cautions against (Appendix 12). This concern about losing the balance between story and mathematics was central to refocusing the project as it resulted in the project changing the context from which data was sourced; smaller groups with play-based learning opportunities presented less in the way of behaviour management and more in the way of flexible storytelling. The context of year one, whole-class situated learning brought tensions as there was less in the way of dialogue and creative exchange or play opportunities. Conversations become creative when children think beyond what they already know: 'a dialogue becomes creative when it allows for playful and divergent ideas' (Fisher, 2009, p.8). Dialogue is creative when it is about improvising and making connections between ideas and concepts that you have not thought of connecting before (Pound and Lee, 2011; Fisher, 2009). These connections may or may not be something adults have considered; children can make fresh connections which as adults we need to adjust our thinking to. This playful quality of creative dialogue can be part of oral storytelling; story can be played with, diverging to new ideas and this understandably presents a creative risk.

Confidence and competence: as mathematical storytellers

Confidence in mathematics is highlighted by Haylock and Cockburn (2013) as key to success when teaching young children. Carlsen (2013) identifies how mathematical and pedagogical competence contributed to the positive orchestration of the oral mathematical story he observed. Perceptively, year one teacher Jon (interview 12.10.2012) identifies the need for '…confidence in storytelling and in maths'. A lack of confidence in mathematical abilities can result in educators over-formalising and failing to optimise informal opportunities to

develop mathematical understanding (Pound, 2006, p.125). Pound (ibid., p.152) highlights the importance of early years practitioners being confident about their mathematical abilities as insecurities can result in educators teaching the way they were taught, which, though familiar, may not work well. Reliance on the competence of the educator as a storyteller and their confidence with mathematics was identified by year two teacher Charles:

> So other challenges would be...I mean not.... I think potentially, teacher's competence in storytelling. I like stories and [inaudible 00:09:10] I don't think it would be a massive challenge for me but my challenge might be getting the Maths out of everything
>
> (Interview Charles 12.10.2012)

Haylock and Cockburn (2013, p.7) recommend that educators must understand mathematical concepts themselves and acknowledge that engaging with the structure of mathematical ideas and how children come to understand these is a way that adults enhance their competence. The realisation of the need for mathematical competence as an educator, highlighted by a year two teacher participant, has implications for oral mathematical story work if mathematical ideas are to be managed in a flexible and potentially fluid way. Educators were aware of the demands made by this approach in terms of subject understanding and the skills involved in orchestrating oral mathematical story.

A theme which emerged from the series of stories about Little Lumpty identified the challenge of seeing unplanned connections; these were coded as 'missing opportunities' and prompted thinking about my own competence as a 'flexible' mathematical storyteller. Such sensitivity to responding to unplanned mathematical opportunities depends on the approach the educator takes, which ,as discussed in Chapter Three, can be influenced by the policy context they find

themselves in (Ball and Bowe, 1992) and on their mathematical competency, which, in light of the empirical research, is discussed in Chapter Seven.

The correlation between codes derived from data and literature

The coding of data shows that participants saw oral story as providing a different experience from that of reading a story, and subcategories which positioned oral story as a way of building relationships and removing barriers concur with literature findings that suggest an inherent freedom in telling story. Thus oral storytelling allows teachers to personalise mathematics and connect it to their own creativity (Schiro, 2004). The story context offers the opportunity to interconnect different areas of the curricula and to think about mathematical ideas in a different way from that offered by other pedagogical approaches such as worksheets. Reading literature containing mathematical concepts is a strategy that educators can employ to engage children's enthusiasm and interest in mathematics (Keat and Wilburne, 2009). Schiro (2004, p.46) develops this idea further and describes the intention behind oral storytelling as an attempt to personalise and contextualise mathematics with story and oral story placing mathematical ideas in meaningful contexts for young children.

Participants described their competence and confidence as storytellers and as mathematicians as challenges to facilitating children's mathematical thinking through oral story. As well as working the story, the educator needs to work the mathematics. Oral mathematical story is promoted as a potential way of building mathematical connections with Haylock and Cockburn (2013, p.11) advising that the more connections children make, the more secure and the more useful will be their mathematical understanding. The development of understanding

involves building up connections in the mind of the listener; seeing mathematics in this way depends on the epistemological view of the educator. Carlsen (2013) advises that educators have an enquiry and problem-solving mathematical epistemology when embarking on oral mathematical story work which was the epistemology expressed by the head teacher and Lorraine, one of the reception class teachers.

Summary

The analytic direction of this theoretical framework was a result of how I interacted and interpreted comparisons between data generated from interviews, observations, field notes and reflective accounts. I worked inductively to generate theories from the data (O'Leary, 2014, p.117) and am aware that this theoretical framework would no doubt change if I were to revisit the data again. However, making connections between categories and between methods was something I was alert to. The convergence of these patterns between literature and data was exciting and gave credibility to claims made. Maykut and Morehouse (1994, p.133) describe how 'convergence of a major theme or pattern in the data from interviews, observations and documents lends strong credibility to the findings', which I searched and strived for. I found similar patterns through the use of different ways of generating data from interviews and observations, which make claims more credible.

This discussion suggests that oral story:

- Brings playful opportunities in that there is the possibility of playing with story to change the mathematical ideas

- Is potentially a more intimate, active and imaginative experience compared with reading a book; in the absence of a picture book there is greater reliance on imagination and 'eye contact'

- Has connective or integrative qualities, which can be imagined as stretching horizontally and vertically over curricula domains with potential to connect story to mathematical ideas and for mathematical ideas to connect within a story

- Allows imaginative mathematical suggestions as story contextualises mathematical ideas and supports children's mathematical thinking

- Is inclusive of children labelled as 'lower ability', with autistic characteristics, and acquiring English.

The challenges of oral story are considered again after educators have implemented this approach in practice, as part of discussions in Chapter Seven. Thus far, challenges to this approach include:

- Preserving a balance between story and mathematics so that it does not become an over-stylised mathematical experience

- Educator confidence and competence both as storytellers and mathematically

- Educators being responsive and seeing mathematical opportunities

- Communicating with words, actions and resources contribute to the challenge of the orchestration of oral story

This idea about children reconstructing mathematical ideas in alternative contexts prompted a focus on play and observations of how children might use story-related materials in their play to express mathematical thinking. This brings an important implication for the project; how children navigate between abstract

and concrete and vice versa, and the role of story-related materials in enabling this, which is considered in Chapter Six.

Implications and discussions

In response to the research questions posed at the start of this chapter, the categories outlined serve to characterise some of the aspects concerning the orchestration of oral mathematical story experiences and the challenges this pedagogical approach presents. These categories suggest that there is potential for children to think mathematically as part of oral mathematical story experiences, though how they do this requires further discussion and responses to the following questions:

- How will children think mathematically as part of oral mathematical story experiences?

- How might oral story as an alternative pedagogical approach open the possibility for thinking about mathematics in a different way?

Conclusion

Charmaz (2009) identifies a fine line between interpreting data and imposing a pre-existing frame on it. In order to stay on the right side of this line, I endeavoured to avoid coding at too general a level; I identified actions and processes rather than topics; I carefully looked at how participants constructed actions and processes (watching video material from two perspectives); I attended to participant concerns; I coded in context using video rather than audio recordings where possible, research notes, analytic memos and reflective journal entries (Moon, 1999); I avoided using codes to summarise, instead I kept the focus on actions contributing to the orchestration of mathematical stories.

This chapter serves as an overview describing what I did with the data using the methods referred to in Chapter Four. I explain how I constructed meaning from the data, through the analysis of words using the constant comparison method. In the next chapter, I explore in more depth how oral story can support children's mathematical thinking.

Chapter Six

How oral story supports children's mathematical thinking

Introduction

Oral mathematical story and related props are proposed as mathematical mediating tools that can work together to satisfy Vygotsky's (1978) view of what instruction of young children should entail from a sociocultural perspective. This overarching Vygotskian framework supports various mathematical models such as horizontal and vertical mathematisation proposed by Treffers and Beishuizen (1999), the proceptual thinking idea of Gray and Tall (1994), and Hughes's (1996) concern about translation of abstract ideas to concrete representations. These mathematical models encompass both the process and product dimensions of mathematical understanding, which are represented by the two pentagons of Casey's (2011) model (see Chapter Two). In this chapter a sociocultural perspective about instruction and about mathematical learning in particular are brought together through the synthesis of these theoretical ideas and the analysis of observational data using the constant comparative method discussed in Chapter Four. This approach serves to respond to the question as to how oral mathematical story as a pedagogical tool can encourage children's mathematical thinking.

The research questions posed in Chapter Three are responded to in this and the next chapter. There is some overlap in that where the question relates to the experience of children and teachers they are referred to in both chapters, for example the question:

- What will be legitimised as appropriate classroom practice for children and their teachers as part of these story experiences?

The questions which relate to discussions in this chapter include:

- How will mathematical ideas be symbolised as part of oral mathematical storytelling?

- How will children translate between abstract and concrete representations of ideas and vice versa?

- How can oral story be facilitative of the transformation of ideas shared socially to individuals?

- What will characterise a quality 'intermental zone' and allow children access from a ZAD to a ZPD?

- How will the spoken language of these stories allow children to express their mathematical thinking?

- How will mathematical learning happen as part of an oral story participatory framework?

- Will there be any 'isomorphism' of mathematical ideas heard in story to other contexts such as play?

- How playful will children be with mathematical ideas and how will this be expressed?

- How will children and educators participate in this different form of pedagogy?

Chapter Two outlined a social-historic-cultural perspective on mathematics and proposed a framework through which mathematics can be conceptualised based on Casey's model (2011). Central to this perspective on mathematics is the idea that it is the making of connections between ideas that creates mathematics (Haylock and Cockburn, 2013; Hersh, 1998), and that collective agreement about ideas secures these as mathematical concepts. In Chapter Two, the difficulty defining mathematics from a sociocultural perspective was attributed to its

complexity, involving knowledge, skills, processes and emotional dispositions, which opens the way to view mathematical instruction through Casey's (2011) model and which corresponds with a Vygotskian approach to teaching and learning mathematics. In order to explore the questions, the thesis now considers how oral mathematical story as a pedagogical approach fits with the pentagonal points of Casey's (ibid.) model, which supports a Vygotskian sociocultural perspective about teaching and learning mathematics. First, the reader is reminded how this model was interpreted for the research project.

Casey's (2011) model supported the conceptualisation of mathematics from a sociocultural perspective and was used in the project to interpret children's mathematical behaviour when they listened to stories, played with story-related materials, and took the role of mathematical storytellers, each of which is analysed in this chapter. Casey's model was represented as ten points arranged as inner and outer five-sided pentagonal shapes (Chapter Two, Figure 1). The five inner pentagon points include: acquisition of *facts* and *skills*, *fluency*, *curiosity*, *creativity*; and the outer pentagon concerns key mathematical processes: *algorithm, conjecture*, *generalisation*, *isomorphism,* and *proof* (2011, italics in original). For the purpose of this discussion particular attention is given to three of the ten features located at the points of the outer pentagon: conjecture, generalisation, and isomorphism, which contribute to the process aspects of mathematical learning and which were identified as absent from or less obvious in the curriculum policy texts for mathematics (DfE, 2014a; DfE, 2013), an analysis of which was included in Chapter Two.

Conjecture

The interpretation of Casey's (2011;1999) model in Chapter Two viewed 'conjecture' as part of a child's mathematical disposition; the question 'what if?' was positioned as central to connecting mathematics and story in a playful problem-posing or possibility thinking way. This question was central to playing with the relationship between story and mathematics; by changing something about the story, this prompted a change to the mathematical relationships contextualised as part of the story and vice versa. An example of this playful relationship was evident in the story 'Jack-O-Saurus', where the story context and the related dinosaur eggs mediated mathematical ideas about number complements for 8 and the commutative property of addition. The story is based on a dinosaur called Jack-o-Saurus who one day was trying to catch a dragonfly when he knocked over two nests of eggs which belonged to a scary larger dinosaur. Lorraine, the class teacher, provided the start of the story and then worked with children to construct different possibilities giving children ownership as to what these might be. The children placed the eggs back in the nests in different ways trying to guess at and match the arrangement that was knocked over. As part of the storytelling Lorraine summarised the ideas proposed by the children before prompting them to think of other possible combinations for the 8 eggs. Analysis of the transcribed story show explicit examples where Lorraine used the question 'what if?':

> All of a sudden he tripped over. Oh my goodness, he didn't see the two dinosaur nests and he tripped over and knocked all of the eggs out of the nest! "Oh no!" he said. *What if* a really scary big dinosaur comes back and I've knocked over the nest and he might eat me. So he just thought…What do you think he needs to do?

> …Jack-o-Saurus looked at the four eggs in one basket…in one nest. And the four eggs in the other nest and he thought to himself "Oh but

what if this isn't right? *What if* this isn't …*what if* one dinosaur had more eggs in their nest than the other one?"

So, Jack-O-Saurus is still very worried and …*what if* there are more ways?'

<p align="center">(emphasis added, Jack-O-Saurus 21.3.2013)</p>

Children modelled their class teacher Lorraine's use of the question 'what if?' as part of the story construction some of their utterances included:

'Oh but *what if* this isn't right?'

'*What if* it's not the same problem?'

'*What if* it's not the same dinosaur?'

<p align="center">(emphasis added, Jack-O-Saurus 21.3. 2013)</p>

A clear differentiation was made earlier in the thesis between language and speech with speech identified as central to Vygotsky's (1978) view of the human activity of thinking and communicating. The question 'what if?' prompted flexibility of story speech and of mathematical ideas. It is because of the nature of spoken words that oral story 'speech' afforded flexible conjecturing about mathematical ideas. In this way, oral story as a pedagogical choice allowed the conjectural feature of Casey's mathematical model. Thus conjectural thinking, or the disposition to think 'what if?' at the heart of problem solving (Pound and Lee, 2011, p.9), connected mathematics and the playful quality of oral story and allowed children to think flexibly about complements of 8 as they constructed the Jack-O-Saurus story with Lorraine.

As part of one of these story experiences, children worked through the following combinations of 8 eggs in 2 baskets in this order: 3+5=8; 4+4=8; 5+3=8; 2+6=8; 6+2=8. Through interaction with this story context and the props, children thought

through possible ways of combining numbers to make 8, and explored the commutative property of addition through the examples 3+5=8; 5+3=8; and 2+6=8; 6+2=8. Children explored possibilities of number complements and connected some of these to thinking about the commutative property of addition. Thus, the flexible way of working through possibilities encouraged by Lorraine led to connections between two mathematical themes, number complements and the commutative property of addition, which was symbolised by the word 'swap':

> Lorraine: We've got three in this one and five in that one.
>
> Child: Because last time there was five with that one and …three in that one.
>
> Lorraine: Oh so you *swapped* it over.
>
> > (emphasis added, Jack-O-Saurus 21.3. 2013)
>
> Child: What if … if it's the wrong way around, so I have to *swap* it…
>
> Lorraine: You mean, so when we've tried these in this one and these in this one then we need to *swap* them because it might be the wrong way around…
>
> > (emphasis added, Jack-O-Saurus 21.3. 2013)
>
> Lorraine: *Swap* them around, go on then because, as well as six and two you can have…
>
> Child: Two and six.
>
> > (emphasis added Jack-O-Saurus 21.3.2013)

The question 'what if?' was central to playing with mathematical ideas and story, and allowed the posing and solving of problems, which featured as part of these oral story interactions facilitated by Lorraine. 'Conjecture' can be viewed as part of a child's mathematical disposition to be curious and seek possibilities and for this work is aligned with the question 'what if?', which facilitates thinking about mathematics in a playful way as part of oral story experiences.

Generalisation

Chapter Two highlighted how in mathematics it is important that children see patterns, make general statements that articulate pattern and that they can explain why this is so. Haylock and Cockburn (2013, p.297) describe how generalisations are statements in which there is reference to something that is *always* the case and that when children use such words in their speech to explain their observations they are generalising. Children responding to the 'Jack-O-Saurus' story were starting to generalise about the commutative property of addition. However, there are more explicit examples of children generalising or reasoning about mathematical ideas as part of a 'Ladybird on a Leaf'. First, a summary of the story:

A ladybird, too proud to share a secret that her spots are artificial and need to be stuck on each morning, is under pressure to get ready as a friend, who always arrives early, will call so that they can go on a trip to Ladybird London. Just before the doorbell rings, a rain cloud washes some spots off and an ant, who watches from a higher leaf, replaces them.

The mathematical idea of this story is that a number, say 'N', will always remain unchanged if a number added to it and then subtracted from it is the same, or if a number subtracted from it and then added to it is the same. A specific example which Haylock and Cockburn (2013, p.297) offer from which a generalisation can be made is as follows; 'if you add 6 to a number and then subtract 6 from the answer you always get back to the number you started with'. The story idea of the rain and the ant connected with this mathematical idea, which can be mapped generally as: $N+n-n=N$ and $N-n+n=N$ or more specifically as $N+6-6=N$ and $N-6+6=N$. Children articulated these number

patterns in imaginative ways using the words of the story to explain the pattern

with the rain and sun characters representing subtraction and addition:

> He [rain] washed one spot away.
>
> He's [rain] washing all of the spots off.
>
> The Ladybird didn't realise that the spots were coming off.
>
> And the ant kept putting them up.
>
> And it was sunny and rainy, sunny and rainy, sunny, rainy,
>
> sunny.
>
> (Ladybird on a Leaf 23.5.2013)

Children used story words to explain the mathematical pattern and the word

'keeps' was resonant of the word 'always', which Haylock and Cockburn (2013)

consider a sign of a child's tendency to generalise:

> Child: It was…when the rain cloud wash it off. And then, the ant puts it on. And, the rain cloud *keeps* washing it off. The ant *keeps* putting it back on.
>
> (Ladybird on a Leaf 11.5.2013, emphasis added)

Children explained the algebraic pattern about the null effect of identical addition

and subtraction, using story-related words to describe the actions of story

characters. They used story words as part of their observations to explain number

patterns and as such they were generalising and reasoning in a way that is

characteristic of thinking mathematically (Haylock and Cockburn, 2013, p.297).

The idea that children can generalise about mathematical ideas is proposed

tentatively and framed carefully as a possible outcome of the way children

articulate mathematical ideas using a story context. The words of the story

facilitated children's explanations of mathematical ideas and, thus, oral story as

a pedagogical choice enabled the generalisation feature of Casey's (2011)

mathematical model in that children were generalising and reasoning about

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mathematical patterns using the spoken words of these stories to access and mediate their mathematical thinking.

Isomorphism

Isomorphism is about recognising that the same solution works for two different situations or contextualised problems (Casey, 2011). Isomorphism for the project related to the taking of mathematical ideas heard in a story to other contexts rather than recognising similar solutions in different situations as proposed by Casey (ibid.). Such isomorphism was observed following the story 'Teremok! Teremok!' adapted from a Russian tale (Arnold, 1994; Ransome, 2003). This story about a little hut in a wood is paraphrased for the reader as follows:

A small cat arrives at the clearing. The cat looks in front of the hut, behind the hut, on top, next to the hut, and under the hut and then wonders what's inside the hut? He begins to knock: 'knock, knock, knock, Tere-teremok, who will answer when I knock?' No one answers and so he climbs inside and falls asleep. A bee arrives to the clearing and is curious about the hut and decides to knock: 'knock, knock, knock, Tere-teremok, who will answer when I knock?' The cat answers and the bee goes inside to sleep. Other animals arrive and each time there is a knock the last animal in opens the door to the latest arrival. Then there is the sound of big, booming steps. The bear looks in front, behind, on top of, next to and under the hut curious to know what is inside the little hut. The bear can tell he won't fit in and can be heard deciding to sit on top of the hut. The animals inside panic and run from the hut one by one in the order of last in first out. The bear decides against sitting on top of the little hut in the wood which is empty.

The story is deceptively simple, challenging children to think about positional language, capacity and to recall the order or sequence in which the animals arrive

and then leave the hut. One of the professional storytellers told 'Teremok! Teremok!' (Arnold, 1994; Ransome, 2003) to a group of thirty reception class children, who provided the positional language (DfE, 2014a) which features as part of this story and recalled which animal was inside the hut and needed to remember which animal went in last, as it is this animal who would respond to the next knock. Children were invited to consider the capacity of the hut and whether there was room for another animal:

> Storyteller: Vulture. I think you're there. Let's have a look. Vulture, seahorse, monster, squirrel, under there somewhere is a fish. They're so squashed up. And a bee. Now, bear said, 'Oh, it looks lovely in there. Is there room in there for me?'
> Child: No.
>
>   (Teremok! Teremok! 5.1.2013)

Following this story reception class children expressed story-related mathematical ideas in their play narratives. Providing story-related play opportunities prompted children's mathematical thinking and it was notable how children took the ideas of this story to their play; for example, Anne referred to the need to recall the sequence of animals: 'We've got to remember'; and she thought about capacity: 'He won't fit in' (Teremok! Teremok! 1.2.2013).

The ideas of the original 'Teremok! Teremok!' story are evident when Carey and Olive played, though their narrative soon becomes about pirate ships and less about a hut in a forest. Mathematical language about capacity and position (DfE 2014a) heard in the oral mathematical story was recorded in this play:

> Olive: Ooh! He fits in there.
> Carey: Shall we squeeze him in?
> Olive: The little ones go underneath. The little ones go underneath and the big ones go on top. And then, he's

asking if he can sit in. Only the little ones can come in
because it's going to be a ship.
Carey: And then fit more in. And that's the tiny one, not a big
one.

<div align="right">(Teremok! Teremok!', 1.2.2013)</div>

Anne and Carey (both four years of age) used ideas relating to capacity heard in 'Teremok! Teremok!' in the construction of their play. Though it could be contested that this could have happened regardless of the oral story, there are other examples of children reconstructing mathematical ideas from a story heard to an alternative play context, an example of which is Sean's play narrative about 'Ladybird on a Leaf', an account of which is detailed next. A transcription of Sean's play is mapped to the features of Casey's (2011) mathematical model using the observational format referred to in Chapter Two (see Appendix 3).

Sean's construction of a mathematical play narrative

Sean (4 years and 5 months) played with story-related materials after listening to 'Ladybird on a Leaf'. Sean carefully arranged 12 spots as a 6 and a 6 on each wing and represented the pattern N-n+n=N through four number relationship patterns: 12 remove 4 and then replace 4, make 12; 12 remove 7 and replace 7, make12; 12 remove 12 and replace 12, make 12; 12 remove 10, replace 10, makes 12. He used story language to support his expression of mathematical ideas: 'the sneaky rain takes spots away and the ant adds spots back on', articulating mathematical patterns in imaginative ways. Sean chose a larger number (12) than that of the story he heard (10) and constructed his own number relationships (e.g. 12-7=5) as he played with story-related materials. Sean's physical action of removing spots posed the question 'what if?', as he had to work out the outcomes of his actions. Sean expressed ideas of the original story heard

i.e. you start with a number N, then subtract a number n, then replace the same number n, to arrive back to the original number N. Sean used the ladybird body and spots to support an abstract idea in visual, physical and verbal ways. His play was related to the story though he constructed his own mathematical number relationships that were different from those of the story heard. He used the props thoughtfully in a way that supported his actions: he used the spots to work out how many he had taken away and how many were left. The sequences relating to the original story of $N–n + n = N$ which featured as part of Sean's play narrative were: $12–4 + 4 = 12$; $12–7 + 7 = 12$; $12–10+10 = 12$; and $12–12+12=12$, where the action of placing and then removing the ladybird spots are represented as the adding and subtracting symbols in these expressions. He started with twelve spots and repeated the pattern of removing a number and adding back on the same number, four times. Sean played with the props in a way which preserved the original mathematical idea of the story he listened to, using the props to support his mathematical thinking.

That Casey's (2011) ideas of isomorphism, generalisation and conjecture were what seemed like natural outcomes of these oral story experiences is posited as a possible interpretation of the data generated from observations of children constructing mathematical ideas as part of their interaction with these story experiences and in their play narratives which followed. Further, children made connections between mathematical concepts as the story and the related materials acted as mediums for their mathematical thinking, for example connections were made between number complements such as $3+5=8$ and the commutative property of addition $3+5= 8$ and $5+3=8$ as part of their interaction with the blue eggs and the two nests for 'Jack-O-Saurus'.

The thesis asserts that oral mathematical story experiences can align favourably with Casey's (ibid.) model and that they do so because of the playful quality of oral story which uses the conjectural question 'what if?' Children used story words in their mathematical speech to explain or in some cases generalise and reason about mathematical ideas and took mathematical ideas heard in story to alternative play structures. Thus in a Vygotskian sense, oral mathematical story and related props, aligned with Casey's (ibid.) mathematical ideas about conjecture, generalisation and isomorphism.

Oral story encouraging children's mathematical thinking

The thesis now considers how oral story encouraged children's mathematical thinking, translating between abstract and concrete representation of ideas, in ways which allowed access to ZPDs, by analysing 'Penguin', a story constructed between Lorraine and a small group of reception class children. This analysis considers the mathematical concepts that can be conceptualised as part of such story experiences. First, a summary of the story which has at its heart the idea of number complements to 10:

Once upon a time there was a little penguin. His mum said to him 'Go to the magical pond and catch ten fish for our tea.' He walked a bit, and he walked a bit, and he walked a bit, and he walked a bit, until he got to the magical pond that glistens and shines. 'Today we have orange and lemon flavoured fish', the pond says. Penguin fished, and fished and fished until he caught ten delicious fish for tea. But on bringing the catch home, the family eats the fish and is still hungry

and so Penguin has to return to the pond with the lemon and orange flavours and find different ways to catch ten fish …

Lorraine prompted children (aged 4 and 5) to rebuild the story of Penguin: There are a few different ways of getting ten fish from the pond ('Penguin', 10.7.2015). Through their actions of not placing all the same coloured fish together, children created another mathematical idea about pattern. It was difficult for children to realise when they repeated number complement patterns as they did not group all the same colours of fish together. Because of how the fish on the carpet were arranged they needed to see a pattern within a pattern and to add similar coloured fish to see if the number complement was repeated. For example, Adam was guided to see different arrangements for 7 and 3 as he carefully set out (in this order) 5 lemon, 2 orange, 2 lemon and 1 orange fish, to make 10. He had to work hard to answer the question about how many lemon and how many orange make 10 fish and realised that his pattern could be interpreted in the same way as a previously arranged pattern. Adam's pattern of fish on the carpet was set out as: 5 lemon +2 orange +2 lemon +1orange or 7 lemon +3 orange which equals 10. Adam's 7 lemon and 3 orange were the same as another child's but different in how the coloured fish were set out. His 7 lemon fish was made up of a 5 and a 2; his 3 orange was made up of a 2 and a 1. Adam and other children started to make connections between the different pattern arrangements which represented the same number complements.

Connections to other mathematical ideas such as conservation of number were part of this oral mathematical story experience. In a mathematical way Lorraine took the opportunity to ask children about this principle:

> Lorraine: Do you think that's more because it's a longer line there?
> Child: Yes
> Lorraine: Do you think it's more?
> Child: Shall I count Erin's ones?
> Lorraine: What do you think? Do you think there is more in that line because it's longer?
>
> ('Penguin', 16.7.2013)

The idea of larger fish being introduced and that a lower number would be required to feed the hungry family evolved:

> Child: Only one.
> Child: He would only need two.
>
> ('Penguin', 16.7.2013)

This developed to the idea of cutting the large fish up into pieces as a way of solving the problem with a child providing the following explanation:

> Maybe we can cut the tail in half and then we can cut the fish into eight bits and then we serve. Easy. So this bit into two, that would be two bits and then this bit into eight bits and then would that be…?Because they've got…that's how I [inaudible 00:18:20] because it says on my board, 2 add 8 equals 10.
>
> ('Penguin', 16.7.2013)

Children responded to Lorraine's prompt that a larger fish would last longer:

> Lorraine: That's a huge fish. That would keep his family going for a while, wouldn't it? I wonder how many days it could it....
> Child: Eighteen
> Lorraine: Eighteen days do you think? (Overlapping Conversation) That would keep his family for a very long time.
>
> ('Penguin', 16.7.2013)

This led on to the idea of exploring the reverse of cutting:

> Lorraine: The lines are there to help me, aren't they? And then it would make it a bit like a jigsaw puzzle. I could almost fit it back…try and fit it back together, couldn't I?

The idea of cutting progressed to tessellation:

> Lorraine: Do you think you'll have enough to fill your whole piece of paper?
> Child: Maybe if I cut the head off. Rafi. Rafi, I think you should put the thin ones in that really thin gaps. That'll be great.
> Child: That looks like I've cut a rectangle and stuck them together.

In summary, the colour combinations of fish suggested by children were random and are rearranged to offer order for the reader as follows: 10+0=10; 0+10=10; 9+1=10; 1+9=10; 8+2=10; 2+8=10; 7+3=10; 3+7=10; 6+4=10; 4+6=10; 5+5=10. The commutative property of addition was made visible by using different coloured fish and can be represented by the following example: 4 strawberry + 6 blueberry =10 and 6 strawberry + 4 blueberry = 10, though because children did not group colours together they had to see a pattern within a pattern before making this connection about commutativity. Number complements for 10 were articulated and visualised as part of the mathematical dialogue contributing to this story experience, with these number relationships set out on the carpet by children using the coloured fish.

Ensuring there was a well-stocked supply of fish meant children could keep the number complements they thought of on the carpet while building new ones, which allowed connections to be made to previous examples and prompted new possibilities. The extracts above show how children thought about mathematical ideas through their interaction with the story context and the simple cut-out fish props and how they used the original frame provided by Lorraine to structure their own mathematical ideas.

Oral mathematical story and relational understanding (Skemp, 1976)

Chapter Two discussed Skemp's (1976) proposal that because instrumental and relational understandings are so different, potentially there are two kinds of mathematics. Relational understanding was delineated by Skemp (1976) as knowing what to do and understanding why, and instrumental understanding as using rules without understanding the reasons, with both types of understanding playing a role in children's mathematical thinking. Skemp (1976) attributes richer advantages to relational mathematical understanding highlighting that relational schemas are organic in quality, a description which fits well with the observations of 'Penguin', as one idea led to another for example, number relationships, conservation of number, time and tessellation. Children who listened to 'Jack-O-Saurus' and 'Penguin' travelled on a number of journey routes about number complements, forming cognitive maps of these mathematical concepts (Skemp, 1976) as they interacted with the story, the props and their teacher Lorraine, who posed questions to prompt more possibilities or different ways. As part of the 'Penguin' story experience, children thought about: eleven possible number complements for the number 10; size and possibilities of dividing a larger fish to share; time and how a larger fish would feed the family for longer; and tessellation as cut-up pieces of fish were reunited to cover a page. These story experiences encouraged children to build conceptual structures or schemas about mathematical ideas as they playfully thought about mathematics as part of their interaction with their teacher as storyteller, the story and the cut-out coloured fish as well as with each other.

Skemp (1976) differentiates between instrumental and relational understanding in the way children are predisposed to manage making an error; with instrumental understanding the child will remain lost as he is not able to retrace his steps whereas with relational understanding he will be able to correct his mistake and re-orientate himself. Sean intended to represent 12-10+10=12 but made an error thinking there were 9 rather than 10 spots. Thus, oral mathematical story allows children to build conceptual structures or schemas for mathematical ideas and find their way back from errors as Sean does.

Oral mathematical story and the vertical and horizontal model for thinking mathematically (Treffers and Beishuizen, 1999)

Oral story was a mediating pedagogical tool for the horizontal and vertical model for mathematical thinking proposed by Treffers and Beishuizen (1999). The horizontal and vertical model for mathematics encourages a two-pronged approach to mathematical thinking: to mathematise 'horizontally' by moving between abstract and concrete and vice versa; and to mathematise 'vertically' by extending the mathematical ideas (ibid.) as outlined in Chapter Two. Simple story-related materials like the coloured cut-out fish that Lorraine selected for the 'Penguin' story, assisted horizontal mathematisation, by mediating the abstract mathematical theme of 'different ways of making 8' as concrete visual representations which children set out on the carpet, for example, 2 orange and 8 lemon coloured cut-out fish represented a number complement arrangement for the number 10.

Educators mathematised horizontally and vertically as oral mathematical storytellers; for example, Lorraine mathematised 'horizontally' when she used two baskets with the blue eggs for 'Jack-o-Saurus' and the cut-out fish for 'Penguin',

to communicate abstract ideas about different complements for the numbers 8 and 10, in concrete ways; and she encouraged vertical mathematisation by using questioning to extend children's thinking by prompting more possibilities. Thus the horizontal line of Treffers and Beishuizen's (.)ibid. model was represented by concrete representation of abstract ideas using story-related materials; and the 'vertical' line of this model was represented by seeking more possibilities beyond the initial ideas of the story by posing the question 'what if?' and allowing children to take the ideas in different directions.

Oral story and related materials aligned with the horizontal and vertical model for mathematical thinking proposed by Treffers and Beishuizen (ibid.). This process encouraged a two-pronged approach to mathematical thinking; the props were mediators of horizontal mathematisation by allowing abstract mathematical ideas to be represented in concrete ways; and they were mediators of vertical mathematisation when children's physical manipulation of these props extended the ideas beyond those of the original story heard, their physical action of setting out the fish or ladybird spots, posing problems for them to solve: Sean used the props to work through and respond to the silent question posed by his actions. The manipulation of supporting materials negated the need for children to rely on words. Lorraine observed how children posed problems through their physical actions with props, without asking a question:

> The props, were giving her the chance to be engaged in a way that if they hadn't been there, she wouldn't have done because she wouldn't have said it. So she found another way of arranging the eggs by sort of getting up because she was prepared to do some maths action but didn't really want to say. I thought that was very, very interesting.

> (Interview Sharon and Lorraine, 21.6.2013)

Sean's physical action resulted in his mathematising 'horizontally' moving between abstract and concrete and back again; and mathematising 'vertically' by extending the ideas which challenged his thinking:

> [The Ladybird] decided to take more than two, more than four. She decided to take three more than four. Three more makes…Hey, how many does it makes? 1, 2, 3, 4, 5, 6, 7. She took seven away. The rain took seven away. She only had five spots left.
>
> ('Ladybird on a Leaf', 26.4.2013)

The scaffolding of Treffers and Beishuizen's (1999) model by educators like Lorraine encouraged children to play with the materials and explore mathematical ideas themselves in play and story narratives. Children used these simple props to symbolise their mathematical thinking as part of flexible story and play narratives.

Symbolism and the power of flexible thinking: 'proceptual thinking' (Gray and Tall, 1994)

That symbolic representation of mathematical ideas using story-related materials was a central characteristic of the oral mathematical story experiences and was outlined above. The story-related props symbolised either process or concept (ibid.) or both; for example, the cut-out fish for 'Penguin' evoked the process of addition of two numbers such as 2 and 8 and/or the concept of sum or complements to make 10. As a mathematician, Sean used symbols such as ladybird spots or cut-out fish to encompass both process and product of number complement ideas.

That the process and concept were cognitively combined by children as they used story-related materials is a central tenet of this work. Gray and Tall (ibid.) characterise 'proceptual thinking' as the ability to manipulate symbolism flexibly

as process or concept. This notion of thinking flexibly about notation or symbolism is relevant here in that I propose that children can think 'proceptually' (ibid.) about mathematical ideas as they use related materials or props as part of their interaction with stories. This thesis asserts that oral story with props as symbols brings an ease to mathematical thinking and that children can use these to symbolise mathematical products and processes (ibid.) in a way that facilitates relational mathematical understanding (Skemp, 1976).

Oral story combined with physical actions and story-related materials, which can symbolise mathematical ideas, connected four models about what it means to think mathematically: Casey's (2011) inner and outer pentagons; Skemp's (1976) two types of mathematical understanding; Treffers and Beishuizen's (1999) horizontal and vertical mathematising; and Gray and Tall's (1994) 'proceptual' thinking; and in doing so responds to the related questions about how oral story and related materials encourage children's mathematical thinking.

Oral story is positioned as a cultural tool which encompasses each of the features of Casey's model and encourages children's mathematical thinking when combined with simple supporting materials that can be used by children to work through ideas. The interactions between story, children and teacher as part of 'Penguin' led to the development of several mathematical themes such as number complements, conservation of number, and tessellation, which fits with a Vygotskian integrative perspective on instruction (Eun, 2010).

Children responding to oral mathematical stories in playful ways

Children responding to oral mathematical story can be categorised in three ways: as listeners in large and small groups; in their construction of play using story-related materials; as mathematical storytellers themselves. This chapter has already considered what can happen when children listen to an oral mathematical story and are given the opportunity to play with story-related materials afterwards, and now considers the way they take the role as storytellers. In Chapter Three, alignment of oral story with Eun's (2010) model concerning the eight principles of instruction based on the work of Vygotsky questioned how playful children would be with mathematical ideas and how these would be expressed. The data analysed next provide insight into how playful children were with ideas and how they used story and the props together to represent their mathematical thinking.

Children constructed mathematical ideas and participated in mathematical activity which can be understood from the perspective of social constructionism. Constructing mathematical understanding as part of these oral mathematical stories was about interactions – interactions with the cultural tools which were the story and the story-related materials but also between the children and the story, the children themselves and with the storyteller. An example of this followed a story titled 'The Greedy Triangle' (Burns, 1994), paraphrased as follows:

A triangle becomes dissatisfied with life. The triangle goes to a shape witch and asks for 'one more side and one more corner'. The triangle is happy being a square until dissatisfaction sets in and it asks the shape witch for 'one more side and one more corner' turning into a pentagon. This is fine until the pentagon feels dissatisfied and asks for 'one more side and one more corner' turning into a hexagon. It is then that the Hexagon shape realises that actually it was happy as

it was and returns to the shape witch to become a pentagon, then a square, and finally a triangle.

Children (aged 4 to 5 years) proposed imaginative mathematical possibilities as an outcome of interactions with their class teacher, Sharon. One example of what was noted as a 'meaningful mathematical moment' was when a child imagined a 2D square shape becoming a 3D cube shape:

> Sharon: You think he should turn back into a square? If a square turned into a 3D shape, and it kept growing and growing and growing, can you think what he'd turn into if he was a 3D shape? If he was a square and he kept growing outwards and he kept getting bigger and bigger…
> Child: Triangle.
> Sharon: He turned into a 3D shape. Can you think what he would be? It's a bit like…
> Child: Triangle?
> Sharon: It's a bit like one of these. Imagine if he kept on growing, growing, and growing, and he came all the way out…
> Child: Ice cube.
> Sharon: And he grew into one of these.
> Child: Ice cube.
> Sharon: A cube, Mikey, well done. It's a cube, isn't it?
> Child: If he were that tiny, he will be a tiny cube.

> ('The Greedy Triangle', 10.5.2013)

There was something about combining mathematical ideas with story ideas which allowed imaginative responses like this of a square growing outwards in all directions to become a cube which happened naturally as part of these story exchanges. The story experience encourages teacher and pupils to re-orientate their goal from one which is about finding the answer to one which is about imagining possible answers which happened naturally in this exchange. This dialogue extended to a child proposing the idea of a shape becoming 4D, which challenged the class teacher's mathematical knowledge:

> Child: Miss [refers to teacher], imagine there was a 4D.
> Sharon: That would be interesting, isn't it?
> Child: What's a 4D?

Sharon: Well, we've got 2D and 3D. But I'm not sure there's anything that's 4D. But we can make our own shape up.

('The Greedy Triangle', 10.5.2013)

Playfulness

The children constructed meaning by interacting with peers through discussions in which they used various symbolic representations, to share meanings, clarify thought, and test the mathematical ideas related to the story. The extracts which follow illuminate how children constructed their own individual meanings in a playful way. First a summary of 'Little Lumpty':

In the town where Humpty Dumpty fell lives Little Lumpty. The children of the town sing the traditional nursery rhyme: 'Humpty Dumpty sat on a wall, Humpty Dumpty had a great fall, All the King's horses and the entire King's men, Couldn't put Humpty together again.' Little Lumpty gets an idea into his head. He wants to climb the wall and see what the town of Dumpty is like from the top. He secretly searches out a suitable ladder looking in garden sheds. He finds one he likes the look of. He sees that each rung of the ladder is roughly the width of two bricks of the wall and that the ladder is twelve rungs long. He thinks he can manage to carry this long, hooked ladder over his shoulder. When the rest of the town are asleep he creeps out into the night, takes this ladder from a nearby shed and hooshes it up to hook to the top of the wall. To steady his nerves he counts in twos: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24. 'Wow' he says aloud, 'the wall is twenty four bricks high'. He pulls himself up and sits on top of the wall and looks at the moon, the stars and the sleeping town. He turns around and looks over the other side of the wall. He sees animals asleep and the hills. He turns back around looking down on the town of Dumpty. Suddenly he becomes frightened, cold and hungry. He moves back along the wall to the ladder. He knows he must come

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down now. He counts down in twos until the last rung brings him safely to the ground: 24, 22, 20, 18, 16, 14, 12, 10, 8, 6, 4, 2. He brings the ladder back to the shed like a burglar in the thick of the night. He gets back into bed. He won't tell anyone that he's been where Humpty Dumpty's been. He wonders if Humpty looked over the other side of the wall before his fall. He is pleased he knows the height of the wall in case he wants to build a wall in another town: twenty four bricks. He dreams of the pattern of the bricks in the wall…. 'short, long; long, short; short, long…..'

Anne (4 to 5 years old) counted in ones forwards and in reverse, before inventing 'Zooming numbers' which imaginatively overcame the need to count down in multiples of any number:

> And then, he went back to the ladder his next night. He climbed. He climbed and then he thought, 'I'm going to count up twos.' [inaudible 00:16:16] (Overlapping Conversation) 40, 60, 80, 20, 22, 24. And then he swooshed down and said, 'Whee!' He climbed (overlapping conversation) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 40 No, he's going to count [inaudible 00:17:34] zooming numbers. So we woosh! And he found something. And then he nearly fell off because he was so far but somebody got the sheet from the ladder. And then put it down and then Lumpty fell on and he didn't even [inaudible 00:18:03]. He was so fat, [inaudible 00:18:06]. The end. (Clapping)
>
> ('Little Lumpty', 23.7.2013)

Taren (4 to 5 years old) took the role as storyteller and adjusted the mathematical idea of 'Little Lumpty' which was based on counting in multiples of twos to counting in ones:

> Ooh! And he was playing hide and seek with his next door neighbour. And I don't know where he's gone. So I look in the shed and he didn't find him but he did find something. He found a ladder. Hmm...I wonder what I could do with this ladder. Climb up that wall. Or climb up this wall. But my mother said I could do…

> So he climbed up in ones 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. There are 12 steps. This is 12 steps long. And he wanted to climb down. So he did.
>
> ('Little Lumpty', 16.7.2013)

This playful feature of oral story was evident again through Taren's work with a story paraphrased earlier, 'The Greedy Triangle' (Burns, 1994) when Taren played with the story and suggested 'six more sides' which if added to a four-sided shape would give a decagon. Taren demonstrated a flexible way of playing with a story which changed the mathematical ideas. Another example of Taren playing with story is when, rather than animals arriving and leaving in ones to fill and empty the hut in 'Teremok! Teremok!', Taren changed the story which altered the mathematical ideas relating to the rate the hut reached capacity. Taren playfully retold the story with the idea of the animals arriving at the hut in twos using two toy rabbits who arrive and leave together, which changed the rate the hut filled and emptied. Taren developed the mathematical idea of the original story by playing with the plot again when he suggested that animals leave the hut in twos and threes:

> 'Maybe two more goes'
>
> 'Then three will go'.
>
> ('Teremok! Teremok!', 1.2.2015)

Three examples of Taren's playful narratives based on 'Little Lumpty', 'The Greedy Triangle' and 'Teremok! Teremok!' make explicit the possibility of playfulness and the possibility of changing a story so that the mathematical ideas change. The idea of playing with the story in a way which changes the relationship with the mathematical ideas represents a unique quality of oral story as an approach to encouraging mathematical thinking. Imaginative thinking was very much part of the stories children told, which were remarkable in how they were

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mathematical, well-structured with plots and twists at the end and which they told naturally in a similar way to how they play.

Children as oral mathematical storytellers

Children in the project listened to and told stories, translating between abstract and concrete and vice versa, through physical manipulation of story-related materials or props in line with the horizontal and vertical model (Treffers and Beishuizen, 1999) discussed earlier in this chapter. There were examples which support a response to the question asking how children will translate between abstract and concrete representations of ideas and vice versa. Story-related materials as tools enabled children to translate between abstract and concrete representations of ideas in ways which gave insight into their mathematical capabilities (Hughes, 1986). This was the case with Sean as he played with the spots and with Sarah who imitated her teacher Lorraine's telling of 'Penguin'.

Sarah retells 'Penguin' with *precision* and *imagination*

After hearing 'Penguin', Sarah (5 years and 11 months) retold the story using the coloured fish with remarkable precision. There was a notable hush as children cut fish and listened as Sarah told her story over seven minutes. Sarah developed her version of the story using two soft toys, 'duck' and 'goose', which she picked out of a nearby box. She creatively adapted the story to fit with different characters, extended the story to try the number complement idea for 11 rather than 10, and created an imaginative end. Below is a transcript of Sarah retelling 'Penguin' using cut-out coloured fish. Sarah's words are in italics and the non-italic comment is to guide the reader when she repeats her count or supports the storytelling with actions.

Once upon a time there was a duck
And this Duck said to a seal 'My Mum wants you to go and get some fish from the pond, the magical pond which shines and glistens.'
So he went to the pond and he jumped into the pond
And he caught two yellow fish
(Repeats this phrase)
Two yellow fish, and three pink fish, and four orange fish and one blue fish
So he counted them one, two, three, four, five, six, seven, eight, nine, ten
He had ten altogether
And then he picked them up
And he went back home to Goose
Here's your ten lovely fish
But I'm still hungry
So he went back to the pond
And he caught one pink fish and four blue fish and he caught three yellow fish and he caught two orange fish
And he counted them one, two, three, four, five, six, seven, eight, nine, ten
And he picked them up counting them in his head
And he took them back to Goose
'But I'm still hungry' said Goose
So he went back to the glistening and shining pond
And he caught two orange fish and took them back and counted them and took them back to goose
'I'm still hungry'
So he went back to the pond
And he went back to Goose
And he said 'I want eleven fish this time'
So he went back to the glistening and shining pond
And he caught five orange fish and four yellow fish …..
(Adds another yellow fish changing this from four to five)
And five yellow fish and one blue fish
So he counted them one, two, three, four, five, six, seven, eight, nine, ten, eleven
And he picked them up counting them
And he took them back to Goose
And they had a big meal
Then when Goose was full after they all had those fish
She thought 'I'm too full up. Maybe I should have said I wanted two more fish.'
The End.

Sarah worked through number relationships, using the coloured fish to support her thinking about these number relationships. She worked out a combination of 5 orange and 5 yellow and 1 blue to make 11 fish, extending the idea of number

complements to a more challenging number than 10. A summary of mathematical ideas expressed in Sarah's 'Penguin' story is as follows:

Numbers making ten: 2+3+4+1=10

Counting accurately 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Total quantity: 'he had 10 altogether'

Numbers making ten: 1+4+3+2=10

Numbers making eleven: 5+ 5 +1=11

Counting accurately 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Sarah used her knowledge of counting and adding to build up her story, which mirrored the story heard but which she adapted to allow new ideas. She used the cut-out coloured fish to work through her mathematical thinking. Sarah's story carried much of the original story but also showed evidence of applying the idea of number complements to a different number. This abstract experience, which was supported with props, was remodelled but with her own choice of number and number relationships. Sarah internalised the idea of using different coloured fish to work out different number complements. She connected this mathematical idea of the story heard to her own retelling using coloured fish in a visually supportive way. The cut-out fish as story props allowed her to mathematise horizontally and vertically (Treffers and Beishuizen, 1999): horizontally, as they allowed her to translate between abstract and concrete representations of number complements; and vertically, by encouraging her to explore possibilities and extend the idea to eleven. There was remarkable precision in how she retold the story of 'Penguin', testing a different number complement, combining story and mathematical ideas imaginatively, and offering a twist at the end.

The work of Piaget was referred to earlier in the thesis and acknowledged as important when theorising about the role of language as a symbolic mediator. At this point in the thesis, the importance of understanding the relationship between assimilation, accommodation and equilibration is recognised as central to appreciating Piaget's work (1951, p.5) and important in interpreting the way children in this research interacted with storytelling situations. Piaget (1955, p.351) explains how 'in its beginnings, assimilation is essentially the utilization of the external environment by the subject to nourish his hereditary or acquired schemata.' Piaget (1955, p.380) describes how assimilation and accommodation at first pull in opposite directions and gradually become 'differentiated and complementary'. This pulling in opposite directions represents a state of disequilibrium as it were, which matures to a state of equilibrium. Children experiencing oral mathematical stories will experience assimilation and accommodation as they interact with story situations, and there may well be some tension until assimilation and accommodation reach a state of equilibrium.

Piaget (1951, p.5) explains how 'sensory-motor intelligence is…the development of an assimilating activity which tends to incorporate external objects in its schemas while at the same time accommodating the schemas to the external world. A stable equilibrium between assimilation and accommodation results in properly intelligent adaptation'. This suggests the relationship between the child and the external objects of the mathematical story and how these might be accommodated as mathematical schemas. Piaget (1947, p.7) describes how 'taking the term in its broadest sense, "assimilation" may be used to describe the action of the organism on surrounding objects, in so far as this action depends on previous behaviour involving the same or similar objects'. Piaget (1947, p.7)

explains that 'in fact every relation between a living being and its environment has this particular characteristic: the former, instead of submitting passively to the latter, modifies it by imposing on it a certain structure of its own'.

Sarah who told the story of 'Penguin' as a four-year-old child is beyond the first two years of her life which Piaget associates with the development of sensorimotor intelligence. Piaget (1955, p.xii) explains how '…at the moment when sensorimotor intelligence has sufficiently elaborated understanding to make language and reflective thought possible, the universe is, on the contrary, formed into a structure at once substantial and spatial, causal and temporal'. Sarah is using language and other symbols which make her mathematical thinking accessible to those listening. This research refers to another example, where Jake is reflectively thinking about the mathematical ideas of his play narrative with his mother: 'Hey Mum, not only 6+6 makes 12 spots! 5+7 and 4+8 also make 12!' His mother documents her reflection as, 'He noticed that there could be several combinations of numbers to make the same total' (Appendix 3). These children are using language to express their reflective thinking.

Children's imitative activity: Zones of Proximal Capabilities

Chapter Three highlighted how Vygotsky (1978) positioned learning ahead of development, valuing children imitating adults to achieve a ZPC, arguing that diagnostic tests of development should include assessment of imitative activity in order to be conclusive. Vygotsky (1978, p.87) proposes 'a re-evaluation of the role of imitation in learning': for these children to imitate the oral stories they listened to, 'it is necessary to possess the means of stepping from something one knows to something new' (Vygotsky, 1986, p.187) as oral mathematical

storytellers. Adult or peer demonstration of oral mathematical storytelling led to children's imitative activity, which provided insight into their capabilities; in this way the theoretical idea of a ZPC proposed by Vygotsky (1978) was supported by oral mathematical story. Children's imitative oral mathematical story activity provided meaningful insight into their capabilities (ibid.), which is relevant because children's response to the medium of oral story told a different story about their mathematical capabilities in ways which surprised their teacher. In line with a Vygotskian perspective about the value of imitative activity, Sarah imitated the storytelling of her class teacher Lorraine:

> Lorraine: I'm amazed as well that the children who have been…children like Sarah who's really quiet in class, May who's really quiet in class, is very animated in this group. Austin isn't somebody to come forward in a larger group. I mean Jess would normally anyway. It is quite interesting seeing who really wants to do it and who actually takes a lead. Because they're not the children who would in the whole class.
> CMcG: Mm. That is interesting.
> Lorraine: And Sarah isn't somebody who's kind of mathematically has stood out this year. And yet, she's the one who's drawn out more maths in the story than other children, really.
>
> (Interview, Lorraine, 16.7.2013)

Lorraine's assumptions about children's capabilities were disturbed:

> I have also realised that I have underestimated some children – being surprised by storytelling confidence displayed by children such as Liam and Sarah who are very quiet in whole class storytelling.
>
> (Reflective account, Lorraine, August 2013)

Children categorised as 'lower ability' surprise their teacher

It might be that children are categorised as lower ability because they are different and it could be that some children find that they are round pegs in square holes.

There is a certain school culture that some children learn and even embrace but others do not (Boaler, 2002). Layla (4 to 5 years old), a child considered as lower ability, responded to the oral mathematical story 'Little Lumpty' about counting in multiples of two in a way which surprised her class teacher. When the group of children were asked to think about the mathematics of the story, Layla perceptively described the mathematical idea:

> CMcG: 'What do you think about the mathematics?'
> Layla: 'When you counted in twos you missed one out, so it's like a pattern'
>
> ('Little Lumpty', 23.11.2012)

Mary, the year one class teacher, expressed her surprise at Layla's response:

> You always miss one, she said. It's very… especially for her, the level she's operating at in maths, I would never have thought she would come up with that sentence. I would have expected some other children to put their hands up and they didn't but she did.
>
> (Discussion following oral story 23.11.2012)

As one of thirty listening children, this child articulated the mathematical idea contextualised in this story in an enlightening way. This child's thinking fits with a creative classroom experience combining mathematics and story and this mathematical experience disturbed the assumption made by the class teacher about Layla. These educators reflected on how oral story elicited responses from children that surprised them and in doing so provided insight into their mathematical capabilities that otherwise may not have been noted.

One of the questions raised at the start of this chapter was about what will be legitimised as appropriate classroom practice for children and their teachers as part of these story experiences? The thesis responds to this question before offering a summary response to other questions.

Legitimising a different expectation about mathematical behaviour

Freedom and flexibility of thinking about mathematical ideas were legitimised as part of classroom discourses for children and their teachers as part of these story experiences. Sharon (9.11.2012) described a freedom to change the story:

> Well, not having an actual text to go by, so I think it's open for more...we can change things that are going on and it's being more flexible than having an actual book in front of you. So when you've got a book, you kind of stick to what's happening whereas with oral storytelling, it changes all the time.

The idea of oral story being flexible was evident in participant responses and was captured by a year two teacher who described this 'flexibility' using a metaphor:

> And yes, it's something that's sort of not very fixed in stone, but actually, it's very adaptable something which is, has a flow which can be adapted to learning… Something which can be moulded and has a very smooth feeling, sort of. Yeah.
>
> (Interview, 12.10.2012)

Flexibility is relevant to oral mathematical story experiences in that it supports the making of connections between mathematical ideas, a key feature of supporting children's mathematical thinking (Haylock and Cockburn, 2013) as discussed in Chapter Two. The unique quality of oral story as interpretative, combined with the way educators model thinking, enables children's flexible or relational mathematical understanding (Skemp, 1976).

One of the resources which featured as part of Lorraine's storytelling were clipboards and rather than presenting a distraction which detracted from the oral experience these encouraged participation:

> CMcG: And all the others are listening. And the clipboards came in handy because they were drawing. So strangely enough, though I think, I'm not so keen or interested, it's not about them recording. The recording seems to help them be an audience.
> Lorraine: Yeah. It's almost like adults who like to doodle while they're listening and it helps their listening or….

> CMcG: Yes.
> Lorraine: And yet in schools we would frown on that, wouldn't we?
> CMcG: Yes.
> Lorraine: Children are supposed to be listening. We wouldn't normally in a normal class or group situation, we wouldn't let them draw. Because they're not concentrating. But actually, these children are really concentrating, aren't they?

(Discussion with Lorraine, 16.7.2013)

Oral story appeared to allow teachers to change something about the mathematical happenings of classrooms. Children and teachers thought flexibly about mathematical ideas legitimately with this different form of pedagogy. The practice of oral story appeared to legitimise a more creative mathematical classroom discourse and expectation about behaviour; for example, the children drew on clipboards and cut out fish while they listened to 'Penguin', as noted by Lorraine whose decision to allow drawing legitimised a different classroom culture. Lorraine's sociocultural perspective about how children learn was represented in her approach to teaching and enhanced the mathematical story experiences she created for children. For example, as part of both the 'Penguin' and 'Jack-O-Saurus' stories, children represented ideas using mathematical graphics:

> …you know children finding their own ways of representing…mathematics
> …we were recording so we don't forget what we've done
> The recording it has a purpose…

(Interview Sharon and Lorraine, 21.6.2013)

Lorraine suggested that children recorded the different ways of combining eight eggs in two baskets so that alternatives could be more easily discovered:

> Lorraine: Before we had four in one nest and four in the other, can you remember what we had before that?
> Child: Fives. No.

Child: Five and three.
Child: Three of the other.
Lorraine: Ah maybe we should note that way down as well.

('Jack-O-Saurus', Lorraine' 2.3.2013)

Lorraine: So we've got two different ways then. I'm going to find it hard to remember all of these ways that we're finding of putting eggs in the nest. Could anybody just note them down for me…

('Jack-O-Saurus', Lorraine, 2.3.2013)

Lorraine encouraged children to record their discoveries in an open way on clipboards, which supported recall of what had been found and prompted children to think of possibilities. Indeed as part of the story about 'Penguin', one child proposed: '*We could write them on the clipboard'*.

The discussion as part of oral mathematical story can be less dominated by the teacher and take on a multiplicity of directions as was the case when Lorraine told 'Jack-o-Saurus' and 'Penguin'**.** Educators can change the way they teach mathematics which opens up or legitimises a different way of thinking about the business of teaching and learning mathematics; rather than having a fixed goal, ideas can be thought about in evolving and flexible ways. Epistemological and ontological views of the nature of what it means to know reflected in data associated with Lorraine's work suggest that this approach can change what is acceptable about how children participate as part of mathematical learning experiences in ways that are surprising. Oral mathematical story legitimised a different classroom practice or classroom behaviour for children and their teachers as part of these story experiences, which was about thinking flexibly about mathematical ideas.

When children were given the opportunity to play with story-related materials they verbally expressed and physically represented mathematical ideas creatively, often going beyond the mathematical ideas of the stories told by their teacher. What happened can be delineated in two ways: children like Sean created mathematical play narratives; children like Sarah orchestrated oral mathematical stories. Therefore, children can use oral story and props as artefacts to express their mathematical thinking and, in doing so, surprise their teachers about their 'true mathematical capabilities', which otherwise could be overlooked, as long as oral story allows playfulness and avoids becoming rigid like worksheets.

There were close parallels between Sean's play and Sarah's storytelling, though they differed as narratives; playing with story-related props and orchestrating story as an oral mathematical storyteller. Sean's play and Sarah's story narrative correlated with the horizontal and vertical model for mathematical thinking proposed by Treffers and Beishuizen (1999), which encourages a two-pronged approach to mathematical thinking; both scenarios show how children can mathematise 'horizontally' by abstracting the situation (moving between abstract and concrete and back again) using story-related props to translate between the two; and how through oral story narrative they mathematise 'vertically' by extending the ideas. For Sean, mathematising horizontally and vertically happened when mathematical ideas of the 'Ladybird' story were restructured in a play situation, with the sugar paper ladybird shapes and spots representing abstract ideas of story in concrete ways. Sean did not know the answers to the questions he posed through his physical actions and used these simple materials to explore these outcomes and to extend his thinking. Sarah mathematised

horizontally and vertically as she skilfully orchestrated a story which expressed mathematical ideas which required working through using the cut-out fish.

Sean and Sarah chose numbers beyond that of the original story they heard and used supporting props to think through mathematical relationships that resulted from their actions. In both cases, there was an orchestration of mathematical ideas, words and actions, though in Sarah's case there was a further orchestration of a story sequence. This analysis of data asserts that oral story provides possibilities for horizontal mathematising (Treffers and Beishuizen, 1999), abstracting mathematical ideas from a story context to concrete representations and vice versa using story-related props, and vertical mathematising (ibid.) by allowing children to play with and extend mathematical ideas. The problem-posing quality of these oral story experiences did not lie exclusively with the words of the story or with the words 'what if?', rather as highlighted above the manipulation of story-related materials allowed educators and children to mathematise horizontally and vertically and it was these props or symbols combined with words and actions that encouraged children's flexible mathematical thinking.

Sean and Sarah both exemplified a 'what if?' disposition towards mathematics as they worked through each possibility created by their actions with the ladybird spots and the coloured fish. The question 'what if?' was central to connecting mathematics and story in a playful way. Sarah and Sean restructured mathematical ideas of stories they listened to in play and story situations aligning these experiences with Casey's (2011) idea of 'isomorphism'. Sarah's oral

mathematical story narrative represents reconstruction of the mathematical ideas she heard in Lorraine's.

Returning to questions raised at the start, this discussion provided examples of how children: symbolised mathematical ideas as part of oral storytelling using simple props; and translated between abstract story and concrete representations of mathematical ideas and vice versa. The examples discussed show how oral story can be facilitative of the transformation of ideas shared socially to individuals like Sean and Sarah. However, the question posed about characterisation of an 'intermental zone' is beyond the scope of this work. Instead, a claim asserted is that oral story allowed children access to a Zone of Proximal Mathematical Development in that the experiences enabled them to go beyond what they knew and told something of their mathematical capabilities. There were example from 'Ladybird on a Leaf' showing how children used the action of story characters and story language to express their mathematical thinking. As part of these oral story participatory frameworks aspects of mathematical learning possibly included generalising and conjecturing along with specific examples of number-related ideas. There were examples of 'isomorphism' of mathematical ideas as children reconstructed mathematical ideas heard as play narratives. Children like Sarah were playful with mathematical ideas through physical action with the props, for example by setting out eleven fish and then working out the pattern of fish which represented the number complement combination. Sarah and her teacher Lorraine participated in this alternative form of mathematical pedagogy in playful ways.

Implications

These orchestrated oral mathematical story experiences promoted flexible thinking about mathematical ideas and enabled children to combine skills or procedures with concepts to facilitate 'proceptual thinking' (Tall and Gray, 1994), allowing qualitatively different kinds of knowing (Boaler, 2002). Mathematical thinking models proposed by Casey (2011; 1999), Treffers and Beishuizen's (1999), Skemp (1976) and Tall and Gray (1994), are united by the playful question 'what if?' of oral storytelling. This question can be posed through words and/or through the physical action of children playing with story-related artefacts. An implication of this theoretical construct rests with the provision of simple but sufficient story-related materials which children can use to represent both the process and concept of mathematical ideas themed in story, in playful ways.

Oral story as a pedagogical approach may require a shift in educator perspective about what is important about teaching and learning mathematics as it encompasses the ten pentagonal points of Casey's model (2011). Consequently, changing the way mathematics is taught opens up a new dialogue which potentially allows or legitimatises a different way of thinking of mathematics, what it means to work mathematically in a school context, and points towards documenting mathematical thinking constructed by children like Sean in qualitative ways (Appendix 3). Documenting mathematics in qualitative ways will require a different perspective about what it means to think mathematically and where this fits in classroom practice, which is part of a wider political arena. This raises the question of whether educators can change the way they approach mathematics which potentially allows or legitimatises a different way of thinking about the business of teaching and learning mathematics in line with the eight

instructional principles based on a Vygotskian sociocultural perspective of teaching (Eun, 2010), considered in more detail in the following chapter.

Rather than separating the outer and inner pentagons of Casey's (2011) model, when combined they bring together what Skemp (1976) refers to as 'instrumental' and 'relational' mathematical understanding. A more representative diagram of these features might be circles which spiral like a record disc with the needle moving from the outside to the centre intersecting each cut or feature of these pentagons. Casey's (2011) model could be rearranged with 'possibility thinking' at its heart and with 'symbolising' (Gray and Tall, 1994) framing this changed model. 'Possibility thinking' is at the centre of thinking mathematically; the needle which travels from outer to the inner grooves of the track, making oral mathematical story music.

Conclusion

This research project is based on a socio-cultural perspective on mathematics which encompasses understanding mathematics in instrumental and relational ways (Skemp, 1976). Casey's (2011) model brings together what could be considered as instrumental and relational characteristics of mathematics many of which were observed in the oral mathematical stories analysed. Oral mathematical story as a pedagogical choice aligns favourably with the conceptualisation of mathematics based on Casey's (ibid.) model in that each of the ten features can be part of oral mathematical story experiences. That these oral story experiences supported relationships between mathematical themes (Gray and Tall, 1994) facilitated by the flexible thinking of ideas and the manipulation of symbolic mediators, is a claim asserted in this chapter.

The question 'what if?' is key in turning over relationships between story and mathematical ideas, and interactions between storytellers, listeners and the story-related materials. This question facilitates mathematical thinking as part of oral story experiences. Further, oral story offers a flexibility of thinking mathematically because the meaning of words are interpreted; flexible mathematical thinking is legitimatised as part of these interactions and it is the flexibility of oral story which facilitates interconnections between mathematical ideas. In this way, the practice of oral story legitimises a more creative mathematical classroom approach and expectation about behaviour, for example the children drawing on clipboards and cutting fish while they listen to mathematical stories, as noted by Lorraine. The teaching can be less dominated by the teacher and take on a multiplicity of directions as was the case when Lorraine told 'Jack-O-Saurus'. Further, oral mathematical story as a pedagogical approach legitimised children's flexibility of thinking mathematically and symbolising mathematical ideas in ways which surprised educators. However, it should be acknowledged that not all oral story experiences did this and that it appeared to depend on the way the teacher implemented this alternative pedagogical approach.

This chapter examined how the use of oral stories and related props, as cultural artefacts, mediated classroom activity in the sense of the instructional model based on the work of Eun (2010). Although I hold a sociocultural perspective about mathematics, I acknowledge that educators may hold different views from mine and that the political context they work within will influence how they teach this subject in practice (Maguire et al., 2014; Hersh, 1998, p.41; Ball and Bowe,

1992). The next chapter considers the practice of oral mathematical story within the context of the eight Vygotskian instructional principles proposed by Eun (2010) and the policy arena or micro-political world within which policy text is re-contextualised by educators who participated in the research, highlighting how a culture of top-down performance management beyond that of the school brings conflicts and tensions to the educator in the classroom, threatening the possibilities for oral mathematical story in practice. It is the way in which these oral mathematical stories are constructed through human interaction with mediating artefacts as part of goal-orientated teacher activity that is important and warrants further discussion in Chapter Seven.

Chapter Seven

The practice of oral mathematical story: policy-in-use

Introduction

The theoretical framework used for the analysis of the data generated in this research is based on the work of Vygotsky and views oral story as a cultural tool that encourages children's construction of mathematical ideas. The eight instructional principles proposed by Eun (2010) based on a Vygotskian sociocultural theoretical perspective on teaching and learning provides the framework against which oral story as a pedagogical approach is considered. This chapter explores how the alignment of oral mathematical story with a Vygotskian theoretical stance fared in practice, using data generated as a result of interviewing and observing oral mathematical story experiences involving children and their teachers, analysed using the constant comparative method discussed in Chapter Four. Thus, the focus of this chapter is how the use of oral stories and related materials, as cultural artefacts, acted as mediators of educator goal-orientated activity to make it 'more mathematical' in the sense of Casey's (2011) conceptualisation model, using the eight Vygotskian instructional principles (Eun, 2010) set out in Chapter Three as a lens through which the data are viewed.

The previous chapter considered some of the questions raised in Chapter Three and those pertaining to discussions in this chapter include:

- How will children and educators participate in this different form of pedagogy?

- How will mathematical learning happen as part of an oral story participatory framework?

- How will educators respond to and manage interactions with children as part of the orchestration of these alternative mathematical experiences?

- How will differences between classroom practices impact on oral story experiences?

In order to respond to the questions, this chapter first considers the possible mathematical epistemologies of educators within the policy context of a state infant school. A sociocultural perspective on teaching and learning based on the work of Vygotsky is used as a frame through which participant epistemological views about teaching and learning and about mathematics are analysed. The views educators held about teaching and learning impacted on their interpretation of the curriculum (Ball and Bowe, 1992; Maguire et al., 2014) and how they implemented oral story as an alternative pedagogical approach for mathematical activity. Data generated through interviews were theorised in relation to: Eun's (2010) eight instructional principles; Alexander's (1997) competing imperatives; the ideas of Ball and Bowe (1992) and Maguire et al. (2014) about implementing policy in practice. The practical application of oral mathematical story by two educators with what could be interpreted as different approaches to teaching mathematics is explored. Satisfactions and shifts in educator mathematical epistemological stances are examined as part of this discussion along with the challenges of implementing this alternative pedagogical approach in a culture of accountability. This chapter makes connections between what was practised by educators 'policy enactment' (Maguire, 2014) or 'policy-in-use' (Ball and Bowe, 1992) and the actual policy texts or curricula that were analysed in Chapter Three.

In a culture of accountability educators are under pressure to deliver what is considered 'good practice', which Alexander (1997) asserts is problematic because it is judged by a poorly defined criterion with associated competing imperatives which include: politics; pragmatics; a causal relationship between teaching methods and outcomes; and a consistency with the teacher's values and beliefs about the purpose of education. Alexander's (ibid.) framework of competing imperatives places values as central to judgement of educational practice which are influenced by: individual personal philosophies of education; practice which works for teachers; the implementation of practice which educators can prove effective for learning; and practice expected and related to institutional and national policy. How educators responded to the opportunity to use oral story and related materials for mathematical activity depended on their values and views about teaching and learning generally, and their epistemological perspectives about mathematics.

Policy process is fraught with complexity

Chapter Two characterised the policy process distinguishing between: intended policy or what the political party prescribes in terms of education policy; actual policy; and policy-in-use (Ball and Bowe, 1992; Maguire et al., 2014). Actual policy for early years education includes statutory curricula (DfE, 2014a; DfE, 2013), and 'policy-in-use' is the representation in practice by educators of such policies combined with educator mathematical epistemologies. Educators' implementation of curriculum policy texts can result in outcomes characterised as technician and professional (Ball and Bowe, 1992) or indeed a mixture of the two.

In schools, policy is re-contextualised, and within each school there are variables which stretch and strain with and against each other. In each classroom there is

a highly specific, subjective and situated construction of policy enactment (Maguire et al., 2014), which changes moment to moment.

The ways in which educators interpreted policy and how they responded to the demands of top-down performance management beyond the classroom or school influenced whether and how oral story was used as a pedagogical approach to facilitate children's mathematical thinking. Maguire et al. (ibid.) describe how educators can have different orientations towards practice in schools, with some teachers less influenced by particular policy shifts than others. Policy enactments as Maguire et al. (ibid.) propose depend on the perspectives, values and positions of different types of policy actors and different types of policies, as well as factors of time and place and consequently enactments are contingent and fragile social constructions. In the process of enacting oral mathematical story, there were tensions resulting from the different orientations and understandings of educators; for example, individual teachers in the school held contrasting beliefs and values about their approach to the planning of teaching mathematics, which the thesis turns to next.

Planning from a story or from the curriculum

Chapter Five explained something about the culture of accountability and educator epistemologies when it referred to concern about whether children would apply mathematical ideas heard in story to other contexts. Later in the research project, educator mathematical epistemologies were apparent in their approach to planning mathematics. Mary outlined curriculum planning as part of her teaching practice and referred to mathematics as a set of objectives that a story needed to match:

> Mary: Because I can imagine sitting down at a planning meeting and we plan numerous sessions in and we

know what the objectives or the areas are for that week so it would be quite easy for us in the planning meeting to say, 'right, we'll use a story for this'.

CMcG: Okay.

Mary: I think…the thing will be which story…

(Interview, 12.10.2012)

Mary revealed a pressure to deliver the curriculum: '…*obviously, we've got this that we have to cover and we know the areas that we have to cover…*' She described a 'fixed' approach to planning where what has to be covered is predetermined:

Mary: And we generally…we do tweak ideas from year to year but what we generally do in year one…is we look at what we did this time last year…

CMcG: Yes.

Mary: And say, 'Right we did money because it links with our research projects,' then we did measurements…so we've done measuring this term because it links to our research project of vehicles.

CMcG: Yes.

Mary: Um so actually, we've got it mapped out term to term.

CMcG: Okay…

Mary: And we usually go with what we did last year because it usually works and if didn't work, we do…we do change a little bit (Overlapping background Noise) Um we know that…that is all of this. So we know that we've got the coverage and the breadth of knowledge covered…

(Interview, 12.10.2012)

Reception class teacher Sharon explained how she would plan from the curriculum first:

Well, I mean if I was planning numeracy, I would plan what I want to do in numeracy first and then find something that would link in with that because the main focus is the numeracy.

(Interview, 9.11. 2012)

Lorraine took a different approach to planning and emphasised seeing possibilities in story '…*the choice of story*' rather than the curriculum dictating the mathematical stance taken. For Lorraine it was about finding mathematical links in any story. She saw oral story as a way of connecting story and mathematics,

seeing possibilities, opening opportunities for children to make easier links, and children visualising ideas in their heads. Further, she placed emphasis on how familiarity with a story makes it easier for mathematical links to be made:

> So I mean we didn't take a particular mathematical stance with any learning linked to it but there'll be a lot of possibilities there about up and down, and high and low, and measuring, and making different height, hills, and acting as how to.
>
> With 'Little Red Hen', there are lots of opportunities for sorting different seeds and grains, and obviously, with the baking, there are loads of mathematical opportunities in there.
>
> ...we'd find the mathematical links in any story. It's the same with oral storytelling really. I just think it's so liberating for children to know the story so well, that those links become, it becomes a little bit easier for them and for adults, or an audience.

(Interview, 9.11.2012)

The perceived challenges around planning reveal differing approaches towards mathematical instruction in the quest for 'good practice' and reveal something of Alexander's, 1997) competing imperatives: interconnected ideas which can be planned from a story as favoured by Lorraine; or a set of objectives with a focus on numeracy and planning from the curriculum as referred to by Sharon and other teachers. These educators responded to policy in the two ways identified by Ball and Bowe (1992), as technicians and as professionals, in their approach to implementing curriculum policy. Participants saw oral story as a way of teaching a set of objectives that formed part of a planned sequence of work for the teacher to teach and that were set out in a fixed format. Sharon and other teachers relied on this planned sequence considerably, with only Lorraine expressing the view of starting with the story to consider its mathematical possibilities, projecting a more holistic perspective relating to children's development of mathematics, and a broader view of the curriculum than her colleagues. These patterns of response, 'professional' or 'technician', influenced the 'interactional patterns of teachers and

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students' (Eun, 2010, p.415) as part of oral mathematical story experiences which constitute the theoretical idea of the ZPD.

In addition to two voices of the expert or educator and the novice or child, there is what Eun (2010, p.415) refers to as a 'third voice which exerts an overarching influence within the zone by shaping by shaping the dialogic interactions between the two participants'. This third voice Eun (.)ibid. refers to as 'the larger social, cultural, historical, and institutional forces that shape that the developmental course within the zone by defining valued goals and outcomes of development' which for example can be mandatory high-stake testing.

The interpretation of data showed that within the same school individuals responded as 'technicians' and as 'professionals' despite the head teacher encouraging what could be described as a 'bottom-up' micro-culture where staff were given licence to embrace oral story as an approach to their teaching and take a 'professional response' (Ball and Bowe, 1992) to the implementation of mathematical curriculum policy or 'policy enactment' (Maguire et al., 2014). Further, how educators respond within the micro-culture of their classroom varies from day to day and moment to moment along a spectrum, with complex factors influencing their goal-orientated activity of teaching mathematics. Educator mathematical epistemologies were found to be complex and sometimes contradictory.

'Policy enactments' (Maguire et al., 2014)

The outcomes of the mathematical stories depended on whether educators could themselves mathematise horizontally and vertically (Treffers and Beishuizen, 1999) based on their individual mathematical epistemology and understanding as well as the pressures they perceived within and beyond the policy context they worked in. Lorraine stood out in that the stories she created satisfied many of the

pentagonal points which feature as part of Casey's (2011) mathematical model described in Chapter Two. Cognitive maps about mathematical ideas (Skemp, 1976) were constructed as children worked through possibilities in response to Lorraine's high order questioning where children searched out possibilities in a relational way which arguably brought Casey's (2011) model and Skemp's (1976) relational understanding together.

The interactive, collaborative, dynamic and dialogical nature of teaching and learning characteristic of the sociocultural perspective proposed by Vygotsky (1978) were part of Lorraine's oral story instruction. That sociocultural instruction is characterised by recognising teaching and learning as a 'process rather than a product', with knowledge co-created between teacher and child (Eun, 2010, p.404); these were notable characteristics of her work. Lorraine's teaching and learning were representative of a sociocultural perspective in that they prompted dialogue, supported diverse mathematical learning activities, and encouraged children to participate as 'active constructors of knowledge rather than as passive receptors of premade knowledge' (Eun, 2010,p.403). Lorraine's practice of teaching and learning corresponded with a view of dialogue as a way of constantly negotiating learning goals (ibid.), for example, the following exchange illustrated the possibility of children thinking about a complex idea through a story context which Lorraine facilitated rather than avoided. As part of a story titled 'Two of Everything' (Toy Hong, 1993), the concept of replicating Mr and Mrs Haktak and their houses was discussed and found to be problematic as only one house had the magic pot, which prompted children to think about the idea of finding a way to create a magic pot for the second house:

> Child: They can't put a brass pot in another …because it won't fit.

Lorraine: No. that's true. It wouldn't.
Child: Just because they're that way.
Lorraine: If you put another one inside, you mean?
Child: Or if she tried to put that in the same pot, it would be very, very tricky.
Lorraine: Uhm, yes.

('Two of Everything', Lorraine, 22.2.2013)

This example of Lorraine's work illustrates several features that repeatedly stood out: her skill at posing questions that allowed children to problematise; and her willingness to follow their lead even when this resulted in errors. She placed emphasis on following through and searching out the child's explicit understanding of why they arrived at a possibility. She was on the lookout for opportunities to develop new thinking and recognised the limitation of the child's answer or the possibility to extend their thinking. She found a subsequent question which matched the idea that needed further exploration. She showed a willingness and ability to hear what children were saying and to utilise this as part of the story dialogue. Her approach to oral mathematical storytelling may be explained by her view about learning in the early years: 'It's kind of like I sort of see it like …you're on a journey together and the thing is you don't know where it's going, do you?' (Interview, Lorraine, 21.6.2013). Lorraine's skill at questioning, examples of which are discussed in Chapter Six, where learning was about possibility thinking and where mathematical ideas were socially constructed and context driven are examined later.

An extract from 'The Greedy Triangle', 10.5.2013:

Child: Miss, I know I'm going to change the square into a diamond.
Sharon: Shall we draw a square. But do you know what we need to think about? What bit are we going to change in the story? What do you think we should change in our story to make it even better?

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Child: We should do a door [inaudible 00:15:39] writing.
Sharon: We could do some writing but remember we said we could change part of the story so it could be…
Child: Do you know…?
Sharon: Oh, Doris, what did you say earlier? It could change into a…?
Child: I couldn't remember.
Sharon: You said the shape could turn into a…? Circle. What other shape he could turn into?
Child: I know.
Sharon: It doesn't have to be a TV shape, Margaret.

The opportunity to discuss how a triangle could be turned by the shape witch into a circle was overlooked possibly because of a lack of subject knowledge on behalf of this teacher. Lorraine probed for alternatives to the correct answer and in doing so prompted a deeper level of mathematical thinking. The correct answer was acknowledged and the expectation that there may be alternatives encouraged further exploration. This request for more created the sense of a genuine deep dialogue about mathematical ideas; Gifford (2005, p.55) highlights how open-ended questions are associated with better 'cognitive achievement'. Further, adults who model curious, questioning behaviour encourage this in children (Curtis, 1998, cited in Gifford, 2003). Lorraine had the professional confidence to allow the discussion to proceed into unchartered or at least unplanned water and asked questions which allowed children to explore connections which were new to them. Rather than provide explanations as her colleagues tended to do, Lorraine relied on children to theorise about the response to her questions and allowed time for them to explore possibilities using story-related materials to formulate answers. Thus, quality of questioning was a distinguishing feature between the professional and technician implementation (Ball and Bowe, 1992) of these mathematical story experiences.

An analysis of the interviews highlighted how Lorraine took a different approach to planning her mathematical activity as highlighted earlier and potentially explains the differences between these educator mathematical epistemologies.

Chapter Three conceptualised the idea of learning supporting development with a caveat that '…the only "good learning" is that which is in advance of development' (Vygotsky, 1978, p.89) proposing that it is the quality of learning which influences the possibility of the ZPD. Though it is difficult to qualify teaching' (Alexander, 1997), this skill can be characterised by the type of questions educators ask. This was one of the characteristics which differentiated the oral mathematical story experiences in this research. The thesis now turns to what constitutes 'good instruction' and how oral mathematical story as a pedagogical approach aligns with the eight instructional principles proposed by Eun (2010). Such contrasting 'policy enactments' (Maguire et al., 2014) highlight how policy-in-use emerges from the oral mathematical story work of teachers; Lorraine and Sharon were working with the same policy texts (DfE, 2014a; DfE, 2013) and what differed was 'policy-in-use' or their oral mathematical story in action which was influenced by a complex array of factors, some of which included their perspective about planning and teaching mathematics and their competence as mathematical educators. Ideas about educator epistemologies are tabulated below.

Educator epistemology : teaching and learning and mathematics	Related sub categories
Managing children	• Teacher talk, for example 'Remember your lightbulbs'; and 'don't call out because it might be the wrong answer' or more open inviting of response. • Sticking to learning goal or allowing children to be creative and extending to other areas of learning.
Planning	• Planning from curriculum policy texts 'technician' or passive response; and from a story: 'professional' response. • Possibility thinking: see what happens. • Teaching one idea or teaching many connected ideas in a 'relational' way.
Interconnecting ideas: exploratory rather than fixed	• Taking opportunities to extend or connect to other mathematical ideas by making connections between mathematical ideas. • Accepting children's suggestions. • Prompting other possibilities. • Skilful questioning: posing questions/problems.
Positionality	• Directing from the front. • Being alongside children.
Assessing children's mathematical thinking qualitatively	• Viewing oral story as qualitative assessment of children's mathematical thinking. • Documenting children thinking mathematically through story. • Educators noting children solving problems through actions associated with story.

Table 7.1: Educator epistemology: policy-in-use

Alignment of educator practice of oral mathematical storytelling alongside a sociocultural-based instructional model

From a sociocultural perspective, acquisition of knowledge and understanding stems from exploration, mediated learning experiences and discursive communication (Eun, 2010; May et al., 2006; Rogoff, 2003; Vygotsky, 1978), which were incorporated into oral mathematical experiences as part of a professional response (Ball and Bowe, 1992; Maguire et al., 2014) to implementing this pedagogical approach. Based on the eight instructional principles set out by Eun (2010) in order that oral mathematical instruction as a pedagogical approach to teaching is 'effective', it needs to be: mediated; discursive; collaborative; responsive; contextualised; activity-orientated; developmental; and integrated. Each of these will be taken in turn and analysed to illuminate examples in practice.

Mediated instruction

Vygotsky (1978) considered the process of mediation as a central mechanism through which all higher psychological functions develop. Three major categories of mediation constitute his theory: tools, which as part of this research included story-related materials and story maps; symbolic systems, which included story and mathematical spoken language; and teachers like Lorraine who supported children's mathematical ZPD.

Chapter Three theorised that through oral story experiences there would be an interplay between symbolic systems: story and mathematical spoken language; tools (which included story-related materials and story maps); and the educator. These three domains can be imagined as points on a triangle: words, tools (story-related materials and maps) and educators, which together mediated

mathematical instruction. Each of these three processes of mediation featured as part of the oral mathematical stories observed and are considered next.

Mediating role of the teacher

The most important role of the teacher in mediating mathematical learning was creating a social environment, a context or culture conducive to learning (Eun 2010), one where the educator became engaged in the learning process constructing mathematical understanding in partnership with children, acting as enquirers themselves rather than as transmitters or key holders of knowledge, which some educators appeared to do more than others. Lorraine adopted an open 'enquiry' stance and saw herself on a journey of learning with children and as a mediator enabled children to challenge their mathematical thinking without waiting for development to happen. She fostered mathematical thinking by deepening children's current mathematical understanding so that new mathematical connections were generated. As a mediator of learning, Lorraine co-constructed mathematical ideas, modelling and scaffolding oral mathematical stories which children like Sarah imitated. Lorraine, as an enquirer herself, modelled the process of learning and, from a sociocultural perspective, was both a participant and observer, operating as a mediator of learning (Eun, 2010). When a child took the role of storyteller, Lorraine thought carefully about where she sat and saw value in being alongside the children, physically relocating to sit on the cushion which a child taking the role of storyteller left vacant, actively partaking as a story listener, which was not noted with the practice of her colleagues:

> Lorraine: You know, that kind of…. And I feel like when a child has been a storyteller, to take up the adult's position and the adult sit where they were, and that whole ritualised behaviour around storytelling feels really important. If I just came and sat

over here with you while a child was storytelling, it wouldn't be right, would it?

CMcG: No, no. No. There is something in that. It's us respecting them as (overlapping conversation)

Lorraine: And as much as they enter into the storyteller role, we have to enter into the listener role, don't we?

(Discussion with Lorraine, 16.7.2013)

Mediating role of tools

Through the thesis the focus has arguably been more on the nature of interactions, and social rather than cultural factors: the opportunity is now taken to redress the balance and acknowledge the role of culture, that of mediating cultural artefacts/tools. The effect of cultural mediation on the data of this research is considered, with specific examples of the mediating role of mathematical artefacts/tools highlighted. Referring to the work of Kozulin (1998), Daniels (2016) highlights how Vygotsky envisaged a theoretical perspective which accounted for three classes of mediators: material tools, psychological tools and other human beings. Thus there are three types or classes of mediational means which are each relevant to this research about oral mathematical story: material tools such as props; words and story language or text; and other human beings participating as listeners or tellers of stories. Chapter Three referred to cultural psychology and the mediational process. Cole (1997) refers to 'practical activity', which is interpreted here as the practical activity of telling oral stories, where cultural-historical tools mediate mathematical thinking. Elsewhere in this thesis the three classes of mediational means are set out as a triangular arrangement: material tools; psychological tools; and other human beings. In this section, the theoretical ideas concerning the mediational role of cultural artefacts/tools relating to mathematics are set out.

Daniels (2016) proposes the mediational properties of artefacts, such as texts, in the social formation of ideas, which is relevant to the work concerning story as a mediator of mathematical ideas. Further, the mediational properties of mathematical artefacts, including children's books which prompted oral mathematical stories, are central to this thesis. The following three examples of story books, provided frameworks, for teachers to base oral mathematical stories on: 'The Greedy Triangle'; 'Little Lumpty'; 'Two of Everything'.

Daniels places emphasis on 'mediation through the activities of and with other people in sociocultural settings' (2016, p.18). Daniels states 'People just as objects may act as mediating artefacts' (ibid, p.17): this attributes value to the role of another individual as a mediator of meaning – for example, the role of the educator in mediating mathematical thinking. The idea of the educator as a mediational tool was proposed in Chapter Three, and in the case of all of the story experiences described in Chapter Six and Seven, these were first told by educators; for example, 'Penguin' was told several times by Lorraine. Sarah will have listened to her teacher tell the story using the simple mediational cut-out fish as tools to convey number bonds to 10. This shows how the teachers worked with the children on developing mathematical understanding and were themselves mediators of mathematical thinking through the activity of teaching.

Mathematical meanings are represented by the stories children created, for example Sarah expresses the mathematical idea of combining different coloured fish to make 10. She uses the number words of her culture: 'So he counted them one, two, three, four, five, six, seven, eight, nine, ten, eleven'. The number bond idea was mediated by having yellow and orange coloured fish. This mediated the

possibility of finding different ways of making 10. In this way these cultural tools mediated mathematical thinking about counting and possible ways of constituting 10 by combining numbers. This 'Penguin' storytelling experience is an example of cultural tools which mediated mathematical thinking which had been thought about and communicated by the class teacher. Such mathematical experiences are influenced by cultural experiences of children, peers and teachers. Children like Sarah utilised mediational tools to construct their narratives. The teacher decides: the mathematical idea at the heart of the story; choice of mathematical artefacts to represent these ideas; and the words used to communicate imaginative mathematical narrative.

There were several mediating cultural artefacts contributing to these oral story experiences as follows: the role of the mathematical idea within the story context; the role of supporting artefacts; and the constraint of mathematical artefacts. Relationships between children, culture and mathematical ideas show up in the way these children engaged with the mathematical narrative of, for example, 'The Greedy Triangle'. An example of culturally specific materials being used as part of mathematical story narratives include pictures of the shapes cut out and attached to mini sticks. Children utilised such mediational tools as part of their mathematical story narratives. An implication of these cultural mediational artefacts is that though they could be used by children in making their personal narrative, the mathematical meaning was associated with the story prop.

Cultural constraints on freedom

Mathematical ideas were reconstructed by children in ways which teachers and researcher considered culturally appropriate. Indeed, arguably the examples of oral stories chosen to represent the data, reflect those that are particularly valued by teachers and researcher. Though on the one hand these experiences offered children a greater freedom than a whole class teacher directed mathematics lesson, it is acknowledged here that artefacts are constrained by cultural meanings imposed on them, which is theorised about in Chapter Three.

Educators presented a clearly defined way of thinking about mathematics: within a cultural context, children were given freedom to think mathematically; however, they were drawing on mediational artefacts from school and classroom cultures. They referred to a western number-based system, framed by the language of this culture. These mathematical artefacts communicated a socially framed 'correct' answer. Thus, children mediated story prompts in culturally meaningful ways. Further, these mathematical story practices were associated with teachers as mediators of mathematical thinking and school traditions. Thus, children's mathematical knowledge was constructed through cultural participation and mediational tools, which on the one hand offered freedom and on the other purposefully mediated mathematical thinking.

Vygotsky developed a theory within which social, cultural and historical forces play a part in development: 'The social/cultural/linguistic mediation of meaning serves to create a range of individual possibilities for understanding' (Daniels, 2016, p.10). There are three implications of this theory for this research: first, what was notable was the intertwining of imagination and culturally related

mathematical artefacts as children expressed their narratives; second, there was a converging of mediational tools in the construction of these mathematical stories as children incorporated cultural beliefs and practices into their mathematical narratives; third, children's interpretations of these materials were mediated by their cultural experiences both within and beyond the classroom. Classroom culture provided children with materials for the content of their stories and with artefacts/tools to communicate the mathematical narratives. The interplay between culture and learning is highlighted by Daniels (2016), who considers that culture is created and recreated through teaching and learning. The analysis of these oral narratives indicated that a culture of oral mathematical storytelling along with a ritual emerged. Like three strands to make one stretch of string, social, cultural and historical factors intertwined. Children drew on social, cultural and historical representations as they expressed their imaginative mathematical ideas. The social and cultural contexts provided a framework for children's imaginary mathematical narratives; this framework mediates the accepted mathematical ideas of the home and school culture to which the child belongs.

Educators orchestrated mathematical thinking using words, artefacts and actions to symbolise mathematical ideas. The importance of material artefacts in the development of mathematical thinking as part of these oral mathematical stories was apparent in the contribution made by story-related materials and maps. Lorraine considered that oral story was a way of mediating imaginative mathematical thinking. The idea of oral story relying more on imagination was developed by Lorraine and implicit in her view is how through these experiences

children create mathematical pictures in their heads. First she described how with

a book children do not create images themselves:

> But I think there are certain books you know, that [you] really
> want to just learn off by heart, so the book can go to one side
> because as soon as the pictures are there, the children don't
> create their own pictures in their head, do they?
>
> (Interview, 9.11.2012)

Lorraine asserted that reliance on imagination allows children to create

mathematical mental pictures:

> … in terms of children's mental images of number, I think
> stories really help with that. Because with all the storytelling,
> they are conjuring up their own you know, pictures in their
> mind, and I think if we're exploring Maths through oral
> storytelling, then that gives them those sort of mental pictures
>
> (Interview, 9.11.2012)

Lorraine referred to a book titled 'One is a Snail, Ten is a Crab' (Sayre and Sayre,

2004) and how children used their imaginations to visualise representations of

the number 10:

> …they haven't got that picture in their head of what ten looked
> like but to think ten as a crab, they then suddenly have a
> picture of the crab's legs and pincers, five on each side and
> lots and lots of mathematical thinking and pictures in their
> heads….
>
> (Interview 9.11.2012)

Lorraine's insight into how familiarity with a storybook such as 'One is a Snail,

Ten is a Crab' (Sayre and Sayre, 2004) can be utilised as the book can be 'put to

one side' so that children imaginatively '… think ten as a crab' is a key theme

relevant to the research question about how mathematical thinking is encouraged

through oral story. Oral story facilitated children's visualisation of mathematical

ideas imaginatively and contributes to the characterisation of oral mathematical

story experiences. Tools are referred to several times as part of the principle of

mediated instruction (Eun, 2010; Vygotsky, 1998) by participants in their

response to interview questions. Props and story maps readily featured as part

of descriptions by educators of what oral story experiences entail and the importance of these mediating tools was represented by a year two teacher who comments: '…resources and gestures and other non-verbal forms of communication which I think [are] so important in storytelling….' (Interview, 12.10.2012).

However, two opposing views were found concerning the possibilities of children playing with story tools. Year one teacher Mary hypothesised that children would use props for storytelling but not for mathematics. She did not see the possibility of props being used by children to support mathematical thinking in play: 'I think they would…my guess is, they'll naturally use the props as a storytelling rather than the maths…' (Interview, 12.10.2012). On the other hand, storyteller Paula asserted that after listening to the story, children would play with the props in ways that support mathematical thinking: 'So, I think those kind of opportunities, when they can still be playful with it within a story and then play with the resources and… it's quite a nice early years sort of approach I think' (Interview, 20.11.2012).

Chapter Six highlighted how children used props to support and extend their mathematical thinking. As part of oral mathematical stories such as 'The Greedy Triangle', a story map was used as a graphic representation with visual props such as the dressed up shapes on sticks which together mediated mathematical ideas. Children sketched out a story map as a visual model to depict the mathematical ideas of the story. In this way, mathematical ideas were represented visually using graphics such as story maps and visual models such as the blue dinosaur eggs for 'Jack-O-Saurus', the ladybird spots for 'Ladybird on a Leaf', and the cut-out coloured fish for 'Penguin'. Thus the supporting props were symbols which mediated children's mathematical thinking and the

manipulation of the simple ladybird spots, for example, presented new problems

for Sean to solve, as noted in Chapter Six.

The value of story-related props and language working together to encourage

mathematical ideas was highlighted by Lorraine in the following exchange with

her colleague:

> Sharon: They love the actions and the repetitive bits in stories
> that's kept them engaged.
> Lorraine: But I think you have to have the visuals so they
> understand…they've got to have some sort of visual prompt
> because…because they're not understanding all the
> language, I think.
> (Interview, Sharon and Lorraine, 1.6.2013)

Lorraine used story props like the eggs for 'Jack-O-Saurus' and cut-out fish for

'Penguin' to prompt children's mathematical thinking processes about number

complements, which were later used by children like Sarah who constructed her

own mathematical story. Lorraine saw the need for a balance to be struck

between a story and the use of supporting props and saw story-related materials

as a way children would mathematise horizontally about mathematics (Treffers

and Beishuizen, 1999) as storytellers:

> Yes. Yes, I think you can have too many props. And what I've
> noticed is, if the props are the props that were used by the
> storyteller, then there seems to be a closer match with the
> child's…. They become the storyteller using the props to work
> out their mathematical thoughts, rather than a different type of
> play, like a narrative – a play narrative.
> (Discussion with Lorraine, 16.7.2013)

Memory

Oral story experiences built around mediation developed higher psychological functions one of which includes memory. Memory may be supported for adults and children with the help of story maps, story-related materials, gestures and language which support the meaning of mathematical ideas communicated through story context allowing children to '*think ten as a crab*' as proposed by Lorraine. Intellectual functions in oral story include the building of memory as children recall the plot sequence, associated phrases and actions. One professional storyteller spoke of sequencing being a natural feature of story: '*…*Well, obviously, sequencing and order, kind of naturally falls out of storytelling anyway' (Interview, 20.11.2012). She comments on how story supports memory: 'because it just serves to make it all more memorable I think and it fixes in their minds more' (20.11.2012). A year two teacher described how he used a story about a robot to facilitate children's thinking about grid references and how children: '…could recall everything and tied it in to what the robot was doing' (Interview, 30.11. 2012)*.* As part of these oral mathematical experiences, story-related tools supported children's memory of the mathematical themes which they later recalled in play and story. For example with 'Teremok! Teremok!', the children recalled who was inside the hut and remembered which animal went in last as it is this animal who would respond to the next knock:

> Storyteller: Knock, knock, knock, knock, knock, tere-teremok. Who will answer when I knock? Who do you think is inside? Who's going to answer this time?
> Child: Bee! Bee!
> Storyteller: The bee?
> Child: And the squirrel?
> Storyteller: Bee and squirrel. Just two. Do you think there's room for fish?
> Child: Fish.
> Storyteller: …Harry, what is inside?
> Child: Fish and bee and squirrel.

Oral story as a form of instruction utilised the three categories of mediation identified by Vygotsky (1978): story artefacts, maps and actions; symbolic systems such as story and mathematical words; educators and children who orchestrated these stories. Oral mathematical story as mediated instruction developed children's mathematical thinking and led to imitation where children orchestrated and reflected on their own mathematical story creations. Mathematical ideas such as the number complements for 8 and 10 were symbolised through the use of blue eggs as part of 'Jack-O-Saurus' and yellow and orange fish as part of 'Penguin'. A further example was how the mathematical ideas relating to shape as part of 'The Greedy Triangle' were remembered using a story map, dressed-up shapes, actions, and mathematical and story words. Dressed as a witch, Sharon as class teacher was a mediator of the mathematical themes of this shape story.

Language as a symbolic mediator

Language as a symbolic mediator played a crucial role in these mathematical exchanges. Spoken language was constituted of story and mathematical words that combined contextualised mathematical ideas in story. The interpretative quality of story, discussed in Chapter Six, allowed for playfulness with the mathematical ideas. Lorraine reflected on oral mathematical story language as a mediating tool:

> And I suppose the other thing that struck me was the mathematical language, the chance to introduce language and build on what they already know is so much stronger in the storytelling
> (Interview, Sharon and Lorraine, 21.6.2013)

> …and because it's a language-based activity somehow the language then becomes really high-profile, doesn't it?

As part of these oral mathematical story experiences, the mediating role of the teacher was about how they created the social environment within which children discussed mathematical ideas which contributed to mathematical learning and instruction and is a principle considered next.

Discursive instruction

A social constructionist epistemological stance is based on a belief that knowledge is constructed through conversation and that spoken language used collectively allows a common understanding which may not otherwise be realised if children could not partake in discursive instruction. Spoken communication is central to Vygotsky's theory of language and the idea that individual thinking is derived from social communicative processes (Eun, 2010). Individual mathematical thinking was based on communication that occurred between two or more individuals; Sean and Sarah were part of small groups of children who communicated with their teachers Lorraine and Sharon and with other children. The individual thinking of children like Sarah and Sean as oral mathematical storytellers arose from the social oral mathematical story processes created by their teachers. Within these sociocultural oral mathematical story frameworks, generative knowledge was an important goal which was derived from narratives facilitated by educators. These collaborative dialogues were possibly internalised to serve individual children's cognitive function which included problem solving, logical thinking, and reasoning about mathematical ideas with the internalisation of mathematical themes evident when children like Sarah retold oral

mathematical stories like 'Penguin' or when Sean played in a way which provided insight about his mathematical thinking. That talk is important as a pedagogical approach to facilitate children's thinking about mathematics has been documented in literature and was raised by the head teacher:

> …we looked at the language of mathematics in quite a lot of detail and how exploring and talking through mathematics helps children, young children to understand and to understand tricky concepts.
> (Interview, 28.2.2013)

Story and mathematical spoken language were powerful tools on which these social story discussions were based. Oral story as an instructional tool for mathematical development incorporated spoken language as part of the mathematical dialogues between educators and children. In the story narratives with Lorraine, children engaged in extended dialogues with their teacher who prompted and guided them to take their reasoning abilities to the next level by building on their already existing mathematical knowledge. Based on these funds of mathematical knowledge, Lorraine asked children to predict what might happen in the story, to explain their reasoning, to evaluate others' predictions and explanations, to seek out other mathematical possibilities. The shared talk facilitated by this classroom teacher was one way that mathematical knowledge was co-constructed as part of story experiences such as 'Penguin' and 'Jack-O-Saurus'. Through this cumulative talk, children built on each other's contributions, added information, and constructed shared knowledge and understanding (Mercer, 2000, p.31). Lorraine encouraged substantive discussions among children as part of her mathematical story experiences.

Spoken language differentiated educational instruction practice through the words chosen and the questions constructed by educators to prompt children's

thinking, a point which was raised earlier in this chapter. Lorraine's oral mathematical storytelling was characterised by instructional conversations (Eun, 2010) rich with higher order questioning and, as a consequence, her oral mathematical stories facilitated discursive instruction in ways which allowed for children's negotiation and generation of mathematical understanding. Lorraine's practice arguably encompassed more than that documented in policy texts (DfE, 2014a; DfE, 2013), which were scrutinised in Chapter Three. Instead, the social nature of her oral mathematical story work satisfied Casey's (2011) and Skemp's (1976) ideas about mathematics as well as the mediated instruction principle proposed by Vygotsky (1978; Eun, 2010). These collaborative dialogues were internalised by children to serve their problem solving, reasoning and other features of mathematical thinking which they later articulated as story and play narratives.

Internalisation

Children's internalisation of mathematical thinking is complex, mediated externally by signs and internally by word meanings. Mediated instruction as an instructional principle proposes that thought is mediated by signs externally, but thought is also mediated internally by word meanings (Vygotsky, 1978, p.252). Although children's internalisation of mathematical ideas was inaccessible, some of their thinking was externalised in oral story-related discussions, play and storytelling narratives. Oral story facilitated the transformation of mathematical ideas shared socially to become internalised by children like Sean, Taren and Sarah, each of whom expressed this internalisation as play and as story narratives.

It is beyond the scope of this work to make any claims as to what extent mathematical ideas were internalised; however, the stories children told, clearly communicated the way in which memory was supported with the help of story maps, story-related materials, gestures and story language, and words which together mediated the meaning of mathematical ideas. Sean's reflections indicate that he internalised ideas about the number complements he constructed. For example, Sean commented on his mathematical narrative after watching a DVD of him retelling 'Ladybird on a Leaf' at home: 'Hey Mum, not only 6+6 makes 12 spots! 5+7 and 4+8 also make 12!'

Sean had previously used the ladybird spots to construct visual models for depicting theoretical knowledge about number complements and later restated these ideas in his play narrative. This opportunity in Sean's case to watch a recording of his play narrative at a later stage and reflect on his learning was a feature of the research design which mediated further learning processes (Eun, 2010). Oral mathematical story instruction drove mathematical development, supporting relationships between instruction, development and communicative processes, each of which contributes to collaborative instruction.

Collaborative instruction

The emphasis on educators as mediators and on communication in development presupposes that teaching and learning are collaborative processes (Eun, 2010). The principle of collaborative instruction encompasses the ZPD based on the premise that children are capable of solving problems in collaboration that they might not otherwise tackle. The outcomes of this research supported the ideas of Vygotsky (1978), and acknowledged that teachers can guide collective thinking activities (Mercer, 2000, p.117) as part of collaborative instruction through use of

careful questioning which was observed in the work of Lorraine when, for example, she told 'Penguin'. When a child repeated a fish pattern made previously, Lorraine questioned this and challenged them to look more closely at how the fish were arranged, and see what the pattern represented in terms of number complements:

> Six. So you've got four strawberry fish and six blueberry fish. Does anybody notice anything? Four strawberry fish and six blueberry fish [inaudible 00:11:43].
>
> Four strawberry fish and six blueberry fish. Is that a different way of [inaudible 00:11:56]? (Overlapping Conversation) one over here. Four strawberries and six blueberries. Is that (overlapping conversation)? It is in a different pattern. But we still got four strawberries and six blueberries (overlapping conversation).
> Child: I can change it.
>
> <div align="right">('Penguin' 10.7.2015)</div>

Through skilful questioning Lorraine encouraged children to explore possibilities:

> Now Jack-o-Saurus is feeling a little bit worried because he said "Well yeah, it could be three in one nest and five in another. But it might be a different way."
>
> But he's really worried because he found two ways but he's just wondering if…they are the only two ways of putting these eggs back into the nest?
>
> …What if there are more ways?
>
> …What if one dinosaur had more eggs in their nest than the other one?
>
> <div align="right">('Jack-O-Saurus', 21.3.2013)</div>

Mercer (2000, p.141) emphasised the relationship between the teacher and learner and the quality of this interaction by proposing the idea of an 'intermental development zone' (IDZ). This concept was framed as follows: for a teacher to teach and a learner to learn, both use talk and joint activity to create a shared communicative space, or 'an intermental zone' (ibid.). This zone was reconstituted constantly as the dialogue continued, and as Lorraine and the

children negotiated their way through the oral mathematical activity in which they were involved. The quality of the zone was maintained, and Lorraine enabled children to move from what Vygotsky refers to as the ZAD to that of the ZPD, where a child operates beyond their established capabilities (Vygotsky, 1978, p.141). Lorraine's skilled use of questions characterised this 'intermental zone' and allowed children like Sarah access from a mathematical ZAD to a ZPD.

The collaborative aspect was enhanced by situating the oral stories in small rooms adjoining the main classroom and by working with smaller groups of children. Two separate learning environments were organised away from each of the reception classrooms where smaller groups of children could work with their teachers, which they comment on (Interview, 21.6.2013):

> It's a really good place for the storytelling. You're kind of happier. The room kind of dictates the way you teach to a certain degree, doesn't it?

Lorraine acknowledged how the potential outcome of an oral mathematical story depended on location and the interaction with children:

> …a really intense learning experience and what made the difference really I think it's the size of the group. It's the location but it's also that, it's that interaction, isn't it?

> (Interview, Sharon and Lorraine, 21.6. 2013)

Discursive instruction, which included skilled questioning as part of the dialogue kept educators' and children's minds attuned in 'intermental zones' (Mercer, 2002) and allowed children to access a mathematical ZPD, a notable outcome of Lorraine's oral mathematical stories. Quality oral story dialogue potentially creates shared communicative spaces (intermental zones) (ibid.), which lead to mathematical zones of proximal development; Lorraine described how 'It's more they enter into it on a different level'.

Children and educators participated in this different form of pedagogy in collaborative ways. Where policy curriculum texts had deficits when aligned with Casey's (2011) mathematical model as noted in Chapter Two, Lorraine's oral mathematical story practice mapped favourably to each of his pentagonal points. Further, collaborative instruction (Eun, 2010) featured as part of her implementation of oral mathematical story. Though the intended policy curriculum texts (DfE, 2014a; DfE, 2013) were limited in the emphasis they placed on collaboration, the enactment of oral story by Lorraine in the examples cited encouraged collaborative instruction. That mathematical learning happened as part of a participatory framework was evident in the extracts discussed. In traditional, directive, transmissive teaching, discussion can become controlling with children participating in an expected way and it is the possibility of changing this that made oral story powerful as a pedagogical approach for mathematics. Oral story potentially changed the nature of mathematical teaching allowing the teacher to use the story to act as the vehicle for thinking mathematically in ways that allowed children to participate with mathematical problems and also with each other in more meaningful ways as part of what Lave and Wenger (1991) describe as a 'participatory framework', and where differences of perspectives evoke learning about mathematical ideas.

As part of a collaborative culture, teacher Lorraine seemed to appreciate that knowledge was co-constructed rather than a fact transmitted from teacher to child. To encourage shared responsibility as part of a collaborative oral mathematical story culture, children were encouraged by Lorraine to take turns as oral mathematical storytellers while she took the role as story listener. The chapter now turns to Eun's (2010) fourth category and considers how the practice of oral mathematical story aligned with responsive instruction.

Responsive instruction

The principle of responsive instruction is based on the premise that teachers create relationships with children 'founded on mutual respect' and is identified by Eun (2010, p.408) as particularly pertinent for language minority children and those from a different cultural background from that of their teacher and suggests the importance of establishing a relationship between home and school. Both Lorraine and Sharon established classroom cultures where children were valued and respected. Lorraine and Sharon were sensitive to individual needs and interests that children brought to these mathematical experiences and took account of variation among children along their diverse development paths (Eun, 2010). Indeed, it was noted how the use of actions and supporting props served to make accessible the abstract ideas of the oral stories for language minority as well as for mainstream children. Oral story was a multicultural activity which reached out to children from diverse cultural and linguistic backgrounds in the way favoured by Vygotsky as part of responsive instruction (Eun, 2010, p.408). A professional storyteller positioned oral story as an alternative to reading and describes how when telling a story she can more readily seek out children who are not concentrating:

> But I think also, there's a big implication for children who find it hard to concentrate. I will always notice there are children who will start wiggling and picking someone's clothes while you're turning a page, don't do that when you have that eye contact because basically, you're not having to read, you're not having to worry about this. You're just…and you can sort of find those children and really engage with them (laughter) and they're suddenly really involved. So I think there's a lot more involvement.
>
> (Interview, 20.11. 2012)

Establishing contact with families and the wider community was identified by Lorraine as a satisfying outcome of oral story work with children. Lorraine

recounted that as storytellers children take this experience home and how this impacted on her experience as a teacher:

> ...And it's really good fun and then when children start to join in, and how quickly they learn a story, you know, it's absolutely magical and like I said before, when families are coming in and saying that they've told the story to them, I just think, if we'd read the story, it wouldn't have had that impact, just from reading a book. They might have said, "Oh, we read a really good story," or something but to actually be able to go home and be a storyteller, you know, I just think that when children take their learning home, I just think it gives you so much, such positive feeling as a teacher.
>
> (Interview, 9.11.2012)

Lorraine commented on less confident children and the shared participatory experience oral story offers them:

> Yeah and in a way, I think when you ask children a question, and then attention's all on them, for those less confident children, that's quite scary but if you're joining in with everybody saying the same thing, then you know, it's in a way, you don't have to be quite so brave, do you?
>
> (Interview, 9.11.2012)

Lorraine then more specifically commented on how children acquiring English join in and respond to oral story emphasising the value of the mediating tools described earlier:

> Yes, and even, we've got a little boy who has virtually no English and he has joined in with quite a lot of the actions and the odd phrase and I just think for him, it's been really, really useful. And obviously having the story map for the visuals for him as well has been very good.
>
> (Interview 9.11.2012)

However, responsiveness of educators was linked to their beliefs about teaching and learning, their mathematical understanding and confidence. However, not all oral mathematical story experiences were characterised by responsive instruction and there were examples where opportunities to extend or develop mathematical thinking for whatever reason were overlooked.

Contextualised instruction

Vygotsky (1978) called for the contextualisation of instruction, and the benefit of oral story as a pedagogical choice for mathematics is that it is a way of encapsulating mathematical learning in a story which was a context children related to: story offered a favourable 'situatedness of learning' for mathematical themes. As part of oral mathematical story children participated in an activity of interest that motivated their learning process. Oral story presented as a problem-solving situation which children were motivated by and the mathematical knowledge was put to use for a story purpose which young children connected with.

That oral story makes mathematics accessible by situating mathematical ideas in a story context was proposed by one year two teacher, who used phrases such as 'story sense' (interview, 30.11.2012) to characterise this contextualisation of mathematical ideas in story. Deputy head teacher Janet saw context as like a hook for understanding: 'So, if we can then take a story and make it relevant to those children, that's going to be the hook in for them to be able to actually properly understand it*'* (interview, 26.10. 2012). Reception class teacher Sharon outlined how story context: *'…*puts it into context as well, so then it makes the maths more meaningful to them and they know why they're learning that' (Sharon, 9.11.2012). An example of mathematical ideas being contextualised in a story is when Lorraine developed the story to include 3D shapes with a cylinder and a cuboid travelling in different ways over hills to see each other, inviting a child to explain the features of a cylinder shape that allow it to roll:

> Lorraine: What do you think makes her a good shape for rolling, Rafi?
> Child: There's a big face that goes all the way round.
> Lorraine: There is, isn't there?

Child: Then it goes all over. Then, it rolls.

('The Greedy Triangle', 8.3.2013)

Lorraine used story context to differentiate shapes, summarising the discussion with the children:

> And she could roll. Lovely rolling there. So, Missus Cylinder rolled. Mister Cuboid had to jump because he couldn't roll because he wasn't curved.
>
> ('The Greedy Triangle', 8.3.2013)

The classroom practices these reception children experienced prompted problem-solving activities and created active rather than passive identities (Boaler, 2002, p.134). In the same way, students who experienced project-related activities were able to use mathematics in different situations because they had participated as mathematical problem solvers in the classroom (ibid., p.134); these children reconstructed mathematical ideas heard in story to alternative play and storytelling contexts, satisfying Casey's (2011) idea of isomorphism and Eun's (2010) principle of contextualised instruction. Oral mathematical story learning, when part of an educator's professional response (Ball and Bowe, 1992), built on children's experience; and when situated in a story experience that required problem solving (Eun, 2010), such as 'Penguin' and 'Jack-O-Saurus', offered a different way of 'knowing' or understanding mathematics (Boaler, 2002). This research asserts that through the context of story, children developed a relational understanding (Skemp, 1992) of mathematical ideas because story allowed a contextualisation of mathematical ideas which would not otherwise be achieved and this encouraged children to take this learning to other narrative contexts. Lorraine's action of becoming a story listener encouraged children to take the role as storyteller and recreate their own mathematical story, which supports Casey's (2011) idea about isomorphism.

Activity-orientated instruction

The development of children essentially occurs through activity and the principle of activity-oriented instruction acknowledges the mediating function of human activity in developing psychological processes. Oral story experiences were considered to be 'activity-orientated' rather than passive as identified by Janet when she described how children respond when professional storytellers tell stories: 'So, it's a very (pause) active experience for the children. I think sometimes reading from the book can be a bit passive for them… **…**it's more active, isn't it? It's less passive' (Interview, 26.10.2012).

As part of these oral mathematical story experiences, children combined words with physical actions of manipulating the props and as noted previously it was the physical action with the story prop which prompted their mathematical thinking. Oral mathematical story allowed playful problem posing with story and related materials in ways which supported enjoyable thinking about mathematical possibilities as part of activity-orientated instruction (Eun, 2010). Thus, oral mathematical story is positioned as a form of activity which as a mediator of mathematical thinking, grounded in social interactions, enhances mathematical instruction for young children.

Developmental instruction

Children participated in oral story activities that allowed them to use mathematical knowledge and skills in meaningful ways with a sense of purpose, which they generalised using story language. Thus, oral mathematical story represents a type of learning, which leads development, and supports several criteria of developmental instruction. That oral story experiences cultivated mathematical

and storytelling knowledge and skills that children generalised to other situations that require similar intellectual functioning (Eun, 2010, p.411; Casey, 2011), such as in play or when they took the role of storyteller, is a claim this research asserts as an outcome of the play and story narratives which were analysed in Chapter Six.

Integrated instruction

As a mediator of instruction, oral story has the potential to motivate several aspects of a child's development with both horizontal and vertical integrative qualities. Oral mathematical story experiences were integrative horizontally, combining several curriculum disciplines, such as: mathematics; literacy; and personal social and emotional. Oral story integrated: physical development, as children manipulated story-related props, abstract and logical thinking processes as part of mathematics; and Personal Social and Emotional (PSE) development, as they empathised with story characters, all of which contributes towards an integrated curriculum experience. Horizontal integration and the possibility for cross-curricular teaching were highlighted by reception class teacher Sharon:

> Yeah, I mean I love it because I really like cross-curricular teaching and the thematic way of teaching more. So I think it's really important not to be you know, have an hour of Math and then have it all breaking down and it's more meaningful if it's linked. So for me, it works really well because you're combining lots of different approaches and ways of learning. So I relate to it really well.
>
> (Interview, 9.11. 2012)

Discussion with a year two teacher indicated how story positions mathematics in a cross-curricular way: 'To me, it felt like it was much more cross-curricular whereas in other circumstances, mathematics feels like it's a bit more out on the limb on its own' (interview, 30.11.2012). One of the professional storytellers emphasised that most stories refer to PSE.

> There are all kinds of ways you can get moral messages and actual facts and history and all those kinds of things across. But I think certainly, in terms of traditional stories, there's lots of opportunity to bring mathematical things but I think there's quite a lot more than just numbers…there are quite a lot of other things in stories.
>
> (Interview 20.11.2012)

This storyteller made an explicit connection between 'dividing' as a mathematical idea and PSE as a curriculum discipline:

> The other thing I would say that I'm really fascinated with is the links between maths and PSE. And I think stories are a great way to represent not just about dividing but just kind of how, you know maths and well-being. There's quite a lot of stuff to do with that about satisfying your own needs and kind of sharing out and how it is.
>
> (Interview 20.11.2012)

Such possibilities for oral story are further exemplified by this storyteller in the following extract when she described her intention to use the Russian folktale 'Teremok! Teremok!' :

> It's not just about some numbers or some shapes. There's kind of a feeling going on and there's sort of them all adding up is kind of about how they're included. And I think children have got a strong sense of justice and that's okay. And then at the end, they can't include the bear. So, and then they all go back out in the order they've come in. And the children seem to really enjoy that…
>
> (Interview 12.10.2012)

The vertical integrative quality of oral story required use of several aspects of mathematical knowledge and skills as tools to problem solve the mathematical themes as part of the story structure, which is an important indicator of development and a primary goal of integrated mathematical education from a sociocultural perspective. Jon saw oral story as an opportunity to provide an integrative approach for mathematics and that through story mathematics is less fragmented and about : '…getting used to doing everything as a whole and not separately' (interview, 12.10.2012). Oral story is integrative as different mathematical concepts or aspects can connect as noted in Chapter Six, which

recounted Lorraine's telling of 'Jack-O-Saurus' and 'Penguin'. Table 7.2 on the page which follows tabulates the ideas discussed and develops the table proposed in Chapter Three by drawing together theoretical perspectives and practical outcomes.

Instructional principles. Based on Eun's (2010) interpretation of Vygotsky's theoretical perspective.	Oral mathematical storytelling as a pedagogic tool. Considerations when positioning against the instructional framework based on socio-cultural theory.
Mediated Instruction • Three categories of mediation can be represented as a triangulated relationship between symbolic systems (language), tools, and adult. • Translating between abstract and concrete can present mathematical difficulties. • Diagnostic tests of development should include assessment of imitative activity (ZCD). • Educator as enquirers can model learning. • Mediated activity through signs and tools supports memory, which is a central psychological function.	Oral mathematical storytelling • Oral story mediated relationships between words, tools (story-related materials such as cut-out fish, story maps, and actions) and adults like Sharon who dressed as a shape witch for 'The Greedy Triangle'. • Oral story was a translational tool where mathematical ideas were context bound. For example cut-out fish and ladybird spots allowed children to translate between abstract and concrete representational forms of mathematical ideas, and vice versa. • Imitative activity in children's story narratives revealed surprises about their mathematical capabilities for example Sarah and 'Penguin'. • There was potential for the adult to adopt an open 'enquiry' stance: Lorraine took the role as story listener sitting alongside children. • Memory was supported with the help of story maps, story-related materials, gestures and repetitive language which together mediated the meaning of mathematical ideas imaginatively.

Discursive Instruction • Higher functions originate as actual relations between human individuals. • Collective, communicative intelligence enables children to make better sense of the world. • Internalisation of mathematical thinking is complex.	Oral mathematical storytelling • Quality oral story dialogue created shared communicative spaces which potentially led to mathematical zones of proximal development. • Quality dialogue of oral mathematical story for example 'Jack-O-Saurus', kept minds attuned and allowed children to benefit from collective understanding as they participated in possibility thinking: 'What if there are more ways?'; 'What if one dinosaur had more eggs in their nest than the other one?'. • In play and story narratives children like Sean expressed their internalised mathematical thinking associated with the stories heard. (continued)
Collaborative Instruction • Higher psychological functions develop as a consequence of cooperation and collaboration. • Communities of practice give different meaning to a discipline. • Within a participatory framework collective thinking allows children to see differences of perspectives and to take what they want to their individual activity. • Guiding collective thinking activities is a responsibility for educators and can be achieved through interpretative discussion.	Oral mathematical storytelling • Oral mathematical storytelling lent itself to collaborative work when educators were willing to construct a story with children and experiences were enhanced by situating the story in smaller rooms. • The oral mathematical story communities of the reception classes thought about mathematics in a problem solving way. • Collaborative story work allowed children to hear mathematical and story ideas and fashion these for themselves: Sarah crafted her own version of Penguin. • Where educators were willing to embark on discussions where they did not know the answer, possibilities for genuine collective thinking opened up which was a characteristic of Loraine's interactions with children.

Responsive Instruction	Oral mathematical storytelling
• Educators need to be responsive to children of different cultural and linguistic backgrounds as well as to individuals. • Sensitivity to a child's fluency and how this impacts on their membership to a community of learning. • Responsive reflective questioning assists instruction.	• Educators considered the cultural community of the children by establishing contact with families and the wider community. Teachers described children taking their mathematical storytelling home. • Oral mathematical story did not challenge the membership of children who were acquiring the language through which the story was told. It was noted how these children joined in with repetitive phrases and how actions with visual tools gave clues about the story content. • The more notable story experiences were characterised by responsive reflective questioning.
Contextualised Instruction	Oral mathematical storytelling
• Cultural context is a feature of a situated learning perspective: Knowledge needs to be situated in an experience which requires problem solving. • Development and learning are differentiated by an ability to generalise problem-solving skills.	• Oral story situated mathematical ideas in a story context which required a problem to be solved which encouraged children to participate as problem solvers. • Through oral story children thought in a problem-solving way, which possibly facilitated generalisation as noted with 'Ladybird on a Leaf' when children used language such as 'keeps' to describe the pattern of the ant adding on and the rain removing the spots. (continued)
Activity-orientated Instruction	Oral mathematical storytelling
• Socio-dramatic play leads development in young children. • Imaginary situations develop abstract thought.	• Oral story and related play were active rather than passive experiences. Play opportunities were planned for by providing space and time along with story-related materials. Physical action with story materials prompted mathematical thinking. • Play and story featured in this research project as imaginary ways of contextualising abstract mathematical ideas.

Developmental Instruction	Oral mathematical storytelling
• Cultivating knowledge and skills that learners can generalise to situations requiring similar intellectual function. • Divergence in attainment is driven by qualitatively different ways of thinking mathematically.	• The application of what children learn to other situations requiring the mathematical thinking of stories heard, though difficult to track, was apparent in their disposition to think mathematically and explain mathematical ideas using story language. • Oral mathematical story opened out problem solving and flexible ways of thinking about mathematics. Children took the role as oral mathematical storytellers which gave insight about their mathematical capabilities for example Sarah went beyond number bonds for 10 to include 11.
Integrated Instruction • Development is based on a balanced integration of intellectual functions such as cognition, perception, memory and attention. • Teaching should focus on the interrelated nature of development of the child. • Curricular integration of literacy and mathematics needs to be balanced to avoid stylised mathematical stories.	Oral mathematical storytelling • Intellectual functions in oral story included memory as children recalled the plot sequence, associated phrases and actions. • Mathematical oral story interrelated several developmental areas: literacy, mathematics, and social and emotional development. • The relationship between story and mathematics was challenging and required managing to achieve genuine story experiences.

Table 7.2: Oral mathematical storytelling as a pedagogic tool.

Oral story as a form of instruction can be used by educators to develop children's mathematical understanding though any claim about the extent to which this is achieved is beyond the bounds of this work. Mathematical ideas mediated as part of oral storytelling were achieved using simple props such as the cut-out fish for 'Penguin' which, together with words and actions, worked as symbols for mathematical thinking about number complements. Children not only interacted with the story but also with their teacher, other children, with the tools and symbolic representations of mathematical themes. Teachers can shift roles

between that of storyteller to participant observer as part of these instructional processes as Lorraine did when she took the role as 'story listener'.

Children's mathematical thinking was supported by translating between different representations (Hughes, 1996; Pound, 2006, p.48) and it was the process of translating between these representations that helped children understand the associated mathematical ideas which they replayed as storytellers. Children translated between abstract and concrete representations of mathematical ideas and vice versa in their play and storytelling narratives which followed adult-led story experiences. Oral story and associated materials were translational tools which allowed mathematical ideas which were context bound to be converted or translated to concrete expression.

Oral mathematical story experiences are socially mediated and therefore have the potential to drive mathematical development. Dialogic interactions contributed to these mathematical discursive interactions. A classroom culture conducive to collaborative instruction was more readily facilitated by taking smaller groups to dedicated spaces where children could take on the role as storyteller. Small group work promoted collaboration freeing interactional patterns between children and their teacher, though this small group work did not fit so readily with the school culture beyond reception stage. Oral mathematical story allowed children to apply the mathematical ideas to a context of a story in an activity-orientated way as they manipulated the associated story materials.

The analysis of data through a Vygotskian perspective characterises oral mathematical story as an effective instruction tool alongside the eight instructional principles set out by Eun (2010). Thus, oral storytelling is positioned as a potentially powerful instructional approach for teaching and learning mathematics

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which satisfies a sociocultural model of teaching and learning. This sociocultural framework brought together theoretical implications for oral mathematical story instruction and highlighted how as a pedagogical choice it can enhance mathematical teaching and learning as educators overcame the challenges and experienced surprises and satisfaction with this alternative pedagogical approach.

Satisfaction and shifts in mathematical epistemologies

Early theoretical constructs based on interviews carried out at the start of the project suggested that oral mathematical story as a pedagogical approach was viewed by participants as free and flexible when compared with other teaching approaches and were confirmed later in the research:

> And on a positive level, when you're teaching something, a mathematical concept, and you've got your plan in you, checking your plan, you're referring to and you're making sure you've included everything in your plan, in a way this is easier, because you've got…once you're in the storytelling, you're going with the flow, aren't you? You're kind of not really having to think, "Have I made sure I've asked them that question and introduced this bit of language?"
>
> You know, in a way you could …you could argue that it's easier once you've got over your shyness or your lack of confidence…
>
> It's much more interesting…
>
> (Interview, Sharon and Lorraine, 21.6.2013)

The head teacher alluded to the possibility of oral story offering educators professional enjoyment, which was substantiated as an outcome in discussion with reception class teacher Sharon:

> Well I've enjoyed them. Like you say, you gain confidence as you go, and I've really enjoyed [oral mathematical stories] now I've done a few. The first one, I did feel quite nervous, but then I enjoyed them a lot more now, and it's nice and they just give you a chance to be really creative in storytelling…

This pedagogical approach shifted educator mathematical epistemologies as educators reflected on how the experiences influenced their practice. Lorraine recorded how the oral story project challenged her view of herself and enhanced her professionalism:

> I think it's really challenged that view of myself as being not very creative, and I think its …it's kind of just opened up new possibilities, and I think …you know, if I was going for an interview or something I'll be quite happy to do more storytelling now whereas before this I would never have chosen to do something risky or a bit unusual or anything like that. I think it's…it's just opened up lots of new possibilities and new ways of doing things and…less…it's less about control, isn't it?
>
> (Interview, Sharon and Lorraine, 21.6.2013)

Lorraine related the impact of the project on her experience as a teacher:

> I have learnt to let go of my control! When I have done any storytelling in the past it has been storyteller to story listeners. This has helped me realise that it is a living interactive relational experience which is creative, exciting and unknown. I have grown in confidence from a teacher who stuck to traditional tales to being able to create my own stories based on mathematical concepts, confidentially telling them with just a simple story map as a prompt.
>
> (Reflective account, Lorraine, August 2013)

The thesis now turns to the challenges for educators of implementing oral mathematical story as a pedagogical approach for mathematics.

Challenges of the practice of oral mathematical story

Chapter Five discussed some of the challenges educators expected at the start of the project. The data from later interviews following implementation of oral story suggest the possibility for a satisfying teaching and learning experience for both educators and children. Lorraine viewed oral story as a performance albeit different from other teaching performances:

> Every time we teach, we're performing. But because it's kind of out of your comfort zone a little bit, it feels like more of a

> performance. I don't know. I think it does because it's a …because it's a narrative and because it's got a beginning, middle and end.
>
> (Discussion, Sharon and Lorraine, 21.6.2013)

The practical business of oral mathematical storytelling posed the challenge as to how educators would achieve a balance between story and mathematics to preserve a genuine, rather than stylised, mathematical story experience which Sharon and Lorraine acknowledged. Sharon comments:

> I just find a bit of a challenge when I'm doing this, is knowing…I don't want to…because…how to get the balance right between keeping the story going and actually involving the children and getting them doing some thinking as well. That's quite difficult …I think.

(Discussion with Sharon following 'Monkey See, Monkey Do', 5.7.2013)

This sense of striking a balance was noted by Lorraine in her reflection at the end of the project, confirming a challenge identified at the start of the project and noted in Chapter Five:

> Never sure whether I have let the children take over too much and the maths is lost and at other times the freedom means that the maths changes. Therefore, some stories e.g. Two of Everything are great for teaching mathematical concepts whereas more open stories allow for children to play with mathematical ideas. I think children need both! Different ways of being involved.
>
> (Documented reflection, Lorraine, August 2013)

This research proposes something at the other end of the spectrum to a default position of worksheets and acknowledges that there are challenges to this approach in practice. However, oral mathematical story supports each of the eight integrated instructional principles which form a sociocultural framework and can lead to professional satisfaction. Educators participated in this alternative form of pedagogy in different ways, which corresponded with their approaches to planning and their views about teaching mathematics. Mathematical learning

happened as part of oral story participatory frameworks in ways which corresponded with the Vygotskian principles set out by Eun (2010). The practice of the two reception class teachers showed how educators respond to and manage interactions with children as part of the orchestration of these alternative mathematical experiences in different ways; though this practice could be differentiated by the type of questions asked, this was not fixed as the teacher who asked closed questions at times created meaningful mathematical moments. The differences between classroom practices impacted on oral story experiences with some encouraging children to explore mathematical ideas and make fresh connections.

Implications

That oral story and related materials together encourage mathematical thinking in ways that satisfy what good teaching and learning mean from a Vygotskian perspective and in ways that allow an integrated mathematical understanding as proposed by the mathematical models discussed in Chapter Six and earlier in Chapter Two is an assertion this chapter makes. Further, as cultural artefacts, story-related materials in the form of props play a critical role as mediators of mathematical thinking as part of these oral mathematical experiences. It is the way in which these oral mathematical stories are constructed through human interaction with mediating artefacts as part of goal-orientated teacher activity which is important.

The three categories of mediation, 'tools', 'symbols' and 'other human', with the learner in the centre, were part of these oral mathematical story experiences, although this idea can be developed in that when children took the role as storyteller they were mediators of learning. Lorraine, for example, was effectively

inside the triangle when her pupil Sarah, as a mediator of mathematical ideas, told 'Penguin'. Thus a development of this Vygotskian idea concerning mediated instruction is that children as storytellers can be mediators of mathematical thinking, moving from inside the imagined triangle to one of the outer points.

The question about what will be legitimised as appropriate classroom practice for children and their teachers as part of these story experiences, raised in Chapter Three, was responded to in Chapter Six, and raises further implications in this discussion. In the context of this research, the implication may be that oral story as a pedagogical approach requires a shift in educator perspective about what is important about teaching and learning and the possibility for an integrative approach to implementing the curriculum like that of Lorraine's approach to planning. Consequently, changing the way mathematics is taught opens up a new discourse which potentially allows or legitimatises a different way of teaching mathematics, what it means to work mathematically in a school context using this alternative pedagogical approach, how children might participate, and opens the opportunity for a more creative approach to teaching mathematics and the potential to interpret the curriculum more in line with Skemp's (1976) relational understanding of mathematics. Thus, oral story as a pedagogical choice can create the relational track for mathematics to run on, though this depends on how as a policy approach it is implemented in practice. Lorraine created sociocultural mathematical experiences that aligned with Casey's (2011) ten-point pentagonal model and the eight Vygotskian instructional principles proposed by Eun (2010).

The practice of oral mathematical story when implemented by educators like Lorraine opened out mathematical experiences beyond that documented in intended policy (DfE, 2014a) for young children. The analysis of the EYFS

curriculum policy text (DfE, 2014a) noted a deficit mathematical model with a heavy emphasis on counting, with no reference to problem posing or conjecturing (Pound, 2006); and yet when Lorraine implemented oral story, these young children demonstrated rich examples of problem posing using the conjectural question 'what if?' Further, children like Sarah and Sean, as noted in Chapter Six, used concrete materials to reconstruct and solve their own story-related problems supporting the isomorphism feature of Casey's (2011) model. Children explained and used language such as 'keeps', which supported the generalisation feature of Casey's (ibid.) model. Thus, there is potential to re-write the early years curriculum so that it encompasses mathematical activity observed as part of these story experiences to include: conjecture; isomorphism; and generalisation. Mathematics is proposed in the National Curriculum (DfE, 2013) policy text as a creative inter-connected discipline which aligned more favourably with Casey's (2011) sociocultural mathematical model than the Early Years curriculum (DfE, 2014a). The notable deficits of the primary curriculum text were the lack of focus on children reconstructing mathematical ideas and the lack of emphasis on play which would allow children to translate between abstract and concrete as they manipulated related materials. It was the dedicated play provision of reception classes along with a play-based learning ethos which allowed the instructional principles proposed by Eun (2010) and Casey's (2011) model to emerge. Thus, children in year one would benefit from this play-based provision in two ways: first, to open up the opportunity for small group work (Marks, 2014); second, to translate using story-related materials from abstract to concrete and vice versa and potentially overcome concern about difficulty with translation (Hughes, 1996) which can misinform adults about children's capabilities.

Conclusion

The nature of instruction within a Vygotskian paradigm proposed by Eun (2010) offered a framework through which the theoretical constructs for this research were viewed. Oral story is social in nature, and potentially will involve individuals making connections with others, as it represents a social constructionist way of thinking; this research explored how oral story allowed children to make mathematical connections as part of discursive and collaborative instruction.

Stories are opportunities to think about mathematics. However, this depends on individual educator mathematical epistemology. Within the context of a state infant school there were various mathematical epistemologies which were particularly noted in the approach educators took to implementing curricula policy when planning for mathematical instruction. In a culture of accountability, which in this case appeared to extend beyond that of the school, there is tension between how policy and practice play out and this impacted on the application of oral mathematical story.

The practice of oral mathematical storytelling as a pedagogical approach aligns favourably alongside the eight instructional principles proposed by Eun (2010), although the practice is not without challenges for educators. The possibility of mathematising horizontally and vertically (Treffers and Beishuizen, 1999) is complicated when positioned within the horizontal and vertical dimensions of policy implementation or 'enactment' (Maguire et al., 2014). In light of the empirical work carried out, what is possible was noted through observations of reception class teacher Lorraine facilitating mathematics in instrumental and relational ways which satisfied the earlier conceptualisation of mathematics from

a socially constructed perspective. In terms of intended government education rhetoric, or actual policy as curriculum texts, oral story as a creative alternative pedagogical approach can be implemented though not necessarily in a uniform or standardised way, as is the case with policy implementation more generally (Ball and Bowe, 1992), which is problematic in a culture of accountability where outcomes of activity are measured. The data indicates that educators can play with oral mathematical story and this playful approach satisfies Vygotskian principles of instruction (Eun, 2010). However, such playfulness relies on educators being confident and willing to take a sociocultural perspective of teaching and learning mathematics, in a culture of accountability with competing imperatives, a position which I argue for in the next chapter.

Chapter Eight Concluding discussion

This chapter draws together the threads of the thesis and offers the reader an evaluation of how well the research questions have been answered. The chapter reconciles my findings with others and refers back to the literature review in earlier chapters. The main findings are summarised with an acknowledgement of the limitations and weaknesses of this project. Recommendations are made along with points for further research. Two research questions were framed as follows: *In using oral story as a pedagogical approach for mathematical thinking, what characterises the nature of the interaction between teachers and children and the role of children as mathematical storytellers? How can such narratives be documented?* Three outcomes of this empirical work stand out as making original contributions to research about the possibilities for oral mathematical story and can be represented by three strands, which are discussed in turn. As part of this discussion the twelve questions raised in Chapter Three are responded to drawing on the empirical research analysed in Chapters Five, Six and Seven. First, the reader is offered a brief reminder of the themes running through the chapters of the thesis.

Chapter Two considered a social-historical-cultural perspective on mathematics alongside education policy for children up to eight years of age in England. A model based on the work of Casey (2011) was adapted to conceptualise mathematics and framed the interpretation of research outcomes as children listened to stories, played with story-related materials, and took the role of mathematical storytellers. Included in this framework was the idea that conjecture can be viewed as part of a child's mathematical disposition and as a way of thinking about mathematics creatively, with the question 'what if?' positioned as

central to connecting mathematics and story in a playful way. A three-step model proposed by Ball and Bowe (1992, p.100) supported the idea of participants in the project re-contextualising policy texts such as the early years and primary curricula. A theme of this model was 'policy-in-use' (ibid.) which correlated with the actions of implementing oral mathematical story. The implementation of policy texts was found to be more complex than the process outlined by Ball and Bowe (ibid.) who categorised responses as either 'professional' or 'technician'. Thus, where educators stood in relation to policy and related pressures influenced how they implemented oral story as a pedagogical choice for mathematics. This chapter examined how the early years and primary curricula (DfE, 2013; DfE, 2014a) aligned with Casey's (2011) conceptualisation of mathematics and identified gaps and contradictions within and between these curricula texts. The chapter concluded that mathematics is difficult to conceptualise, policy texts concerning early childhood mathematics are political and hold conflicts and tensions, all of which present as challenges for oral mathematical story.

Chapter Three considered the nature of instruction within a Vygotskian paradigm proposed by Eun (2010), and provided a framework through which the theoretical constructs and data for this research were viewed. The chapter analysed presented an argument which positions oral mathematical story as a potentially suitable pedagogical approach to encourage children's mathematical development. The idea of children reconstructing mathematical ideas heard as part of oral story experiences in play or story narratives was asserted as a possible outcome of these activities. Twelve research questions arose from theorising about what it means to teach and learn from Vygotsky's sociocultural

perspective on development and learning, which were responded to in later chapters.

Chapter Four outlined how the research project took an interpretive approach with constructionism as the epistemological stance. The theoretical perspective most closely drawn from was interpretivism (Crotty, 1998). The methodology was based on ethnography using constant comparison as an approach taken to analyse the data generated by using methods which included: participant observations; interviews; reflective accounts; and participant written reflections. This chapter set out the process and defended this work as an enquiry that can be taken seriously.

Chapter Five served as an overview describing what I did with the data generated using the methods referred to in Chapter Four. I explained how I constructed meaning from the data, through the analysis of words using the constant comparison method. This chapter identified what characterised oral mathematical story experiences and the challenges which this pedagogical approach presents. The coding of data provided insight into individual participant mathematical epistemologies and the approach they took to planning their classroom mathematics teaching.

Chapters Six and Seven found that children and educators can play with oral mathematical story and that a playful approach satisfied Vygotskian principles of instruction and learning (Eun, 2010). Chapter Six explored how oral mathematical story as a pedagogical approach legitimised children's flexibility of thinking mathematically and symbolising of mathematical ideas in ways which surprised

educators. Chapter Seven focused on how the use of oral stories and related materials, as cultural artefacts, were mediators of educator goal-orientated activity to make it 'more mathematical' in the sense of Casey's (2011) conceptualisation model, using the eight Vygotskian instructional principles (Eun, 2010) set out in Chapter Three as a lens through which the data were viewed. Chapter Seven positioned oral story as a potentially powerful instructional approach for teaching mathematics. However, it was noted that this outcome relied on educators being confident and willing to take a sociocultural perspective of teaching and learning mathematics.

Original contribution

The original contribution to knowledge made by the thesis is represented by three features. First, it lies in the detail of the exploration of the interaction between teachers and children, illuminating new ideas about the nature of such interaction in the context of using oral mathematical story as a pedagogical tool with whole classes and smaller groups of young children. Second, the study's findings relate specifically to children taking the role of mathematical storytellers and again, though complementing other studies, it reaches beyond previous theory to this particular possibility. This study details child-initiated mathematical narratives through analysis of observations of their play and storytelling following adult-led activities. Third, in addition to new knowledge in the field of early years mathematics, it develops a novel way of documenting children's mathematical narrative, combining mathematical and observation models with video of storytelling to stimulate reflection by children, teachers and parents.

Original contribution: strand one

Responding to six of the research questions raised in Chapter Three shows the original contribution this work makes regarding interaction between teachers and children, in the context of using oral mathematical story as a pedagogical tool. The first question considered is, how will differences between classroom practices impact on oral story experiences? There were notable differences in the approaches to planning mathematical activity among educators analysed in Chapter Seven. Lorraine's approach to planning was about finding links in any story; for her colleagues, it was about finding a story to fit curriculum objectives. These patterns of response to curricula, categorised as 'professional' and 'technician', (Ball and Bowe, 1992) resulted in different story experiences for children, with a 'professional' response aligning with 'relational' rather than 'instrumental' mathematical experiences. There were several features which characterised Lorraine's teaching: she was skilled at posing questions; she searched out explicit understanding; she recognised the limitation of children's answers and the possibility to extend their thinking; she sought alternatives to the correct answer prompting deeper understanding. Further, she actively partook as a story listener sitting alongside children. Approaches to planning and spoken language differentiated instruction practice observed, with higher order questioning encouraging discursive mathematical instruction.

In earlier chapters, the gaps in curricula policy texts were attributed to the drive for performance which is more readily assessed by taking an instrumental rather than a relational (Skemp, 1976) perspective on mathematics. Chapters Six and Seven set out examples of oral mathematical story experiences with conjecturing, generalising and isomorphism as features. Thus, these gaps in the curricula were

filled when oral story was used by reception class teacher Lorraine, in ways characterised by the eight instructional principles proposed by Eun (2010). Lorraine implemented curriculum policy through the medium of oral story in ways which opened out a broader view of mathematics; her classroom practice impacted favourably on these mathematical experiences.

The next question considered is, how will mathematical ideas be symbolised as part of oral storytelling? This question raised in Chapter Three was answered in Chapters Six and Seven, which showed how educators and children used props such as cut-out fish and blue eggs to symbolise number complement ideas as part of the 'Penguin' and 'Jack-O-Saurus' stories, respectively; teachers provided simple props to support this symbolisation which children modelled. Chapter Seven analysed the interplay between symbolic systems (spoken language), tools (props), and educators as storytellers. Props were symbols that acted as mediators of mathematical thinking; the act of manipulation by children posed new problems to solve. Children like Sean corrected errors made by referring to the props and thus props played a crucial role in symbolising mathematical thinking.

This leads to the question: How will children and educators participate in this different form of pedagogy? Chapter Seven noted how oral story potentially changed the nature of mathematical discourse and allowed children to participate in mathematical stories in ways that differed from that of other learning situations. Lorraine described a shared participatory experience and highlighted the advantage for less confident children. In terms of associated behaviour, she

noted that children drew on clipboards listening to 'Jack-O-Saurus' and cut out fish listening to 'Penguin' as they participated as part of these story experiences.

This idea of a shared participatory experience relates to the question raised in Chapter Three: How will mathematical learning happen as part of an oral story participatory framework? This happened as part of the oral story experiences through discourse, actions, and the handling of story-related props. Oral story was characterised in Chapter Five by a flexibility which facilitates playful mathematical thinking. The question 'what if?' prompted posing and solving of mathematical problems. As a consequence of the way story contextualises mathematics it was argued that this helps children think about and remember ideas; for example, children imagined what 10 looked like using 'Ten is a Crab' (Sayre and Sayre, 2003) or, in Chapter Six, the 2D square was imagined as growing into a 3D cube.

These examples support a response to the question of what will be legitimised as appropriate classroom practice for children and their teachers as part of these story experiences. Thinking playfully about mathematical ideas was legitimised as appropriate classroom practice. Oral story offers a flexibility of thinking mathematically; flexible mathematical thinking is legitimatised as part of interactions and encourages interconnections between mathematical ideas. This flexibility meant that mathematical ideas conceptualised as part of the story 'Penguin' included: number complements; commutative property of addition; conservation of number; size and division by sharing; time; and tessellation, which supports an interconnected model of mathematical learning.

The central question important to this is, how will educators respond to and manage interactions with children as part of the orchestration of these alternative mathematical experiences? Educators responded to and managed interactions with children in different ways and it was notable how smaller groups allowed more dialogue, as there were fewer behaviour problems. However, the work of Marks (2014) is relevant here as reduced group size alone as an intervention is insufficient; smaller story group size needs features such as skilful questioning and thoughtful provision of materials that support the visualisation of abstract mathematical ideas. Though the work found that smaller groups for oral mathematical story activity yielded rich data, it is necessary to look beyond the size of the group to the practice as part of these small group activities. Further, some of the interactions between teacher and children were coded as 'missing opportunity' indicating the need for educators to be competent mathematically so that they can respond to more challenging possibilities, regardless of group size.

Original contribution: Second strand

The second strand relates specifically to children taking the role as mathematical storytellers and it was noted how this work reaches beyond previous theory to this particular possibility. A key question relevant to this strand is, how will the spoken language of these stories allow children to express their mathematical thinking? This question was satisfied through analysis of play and story narratives in Chapter Six. Children used story language to explain mathematical patterns and there are several examples noted in Chapter Six where children use the words of 'Ladybird on a Leaf' to explain the mathematical patterns $N+n-n=N$ and $N-n+n=N$ with the word 'keeps' suggestive of generalisations.

Chapter Three posed a further question relevant here, how can oral story be facilitative of the transformation of ideas shared socially to individuals? Analyses found that children partook in adult-led shared story experiences before retelling or playing out the stories as individuals. This transformation of stories shared in groups to individuals can be delineated in two ways as noted in Chapter Six: children created mathematical play narrative; children orchestrated mathematical story. We saw in Chapter Six how Sarah, Sean and Taren transformed the story heard into their own play and story narratives using story-related materials.

Of concern at an early stage of the project was whether there would be any 'isomorphism' of mathematical ideas heard in story to other contexts such as play? For this research, the term 'isomorphism' was interpreted as children reconstructing mathematical ideas heard in stories in their play and story narratives. Chapter Six described examples of 'isomorphism' of mathematical ideas heard in story to other contexts: Olive and Carey took the ideas about capacity which they heard in 'Teremok! Teremok!' to a play context; Sean re-enacted mathematical ideas of 'Ladybird on a Leaf' in his play; and Sarah re-constructed the 'Penguin story', extending the number complement idea to include the number 11.

Related to this activity was the question, how playful will children be with mathematical ideas and how will this be expressed? Flexible or playful thinking about mathematical ideas was central to the project, which found that oral mathematical story allows children to build conceptual structures or schemas for mathematical ideas, as they think playfully about mathematics through a story context. Conjecturing facilitates this playfulness with ideas using the question

'what if?' or the action of manipulating the story-related materials. As noted in Chapter Six, Taren played with the story so that the animals arrived in twos filling the hut faster. Thus, children were playful with mathematical ideas through their words and actions as part of story and play narratives.

Oral story as a translational device allowed children to translate mathematical ideas between abstract and concrete and vice versa. The analysis of data in Chapter Six showed how children listened to abstract ideas, represented these in concrete ways using props and as abstract ideas through story words. Children observed in Chapter Six engaged in translation, which Hughes (1986) describes as the process of moving between different representations of mathematical ideas. The mathematical thinking of children like Sean was quite sophisticated and, in its own way, reflective, which are characteristic of orality proposed by Ong (2002, p.56). These observations satisfied the question of how children would translate between abstract and concrete representations of ideas and vice versa.

Chapter Seven acknowledged that a deep understanding of internalisation of mathematical ideas was beyond the scope of this work and thus the theme of what will characterise a quality 'intermental zone' and allow children access from a ZAD to a ZPD was not fully realised. However, that stories shared socially were internalised by children, is a claim asserted; for example, Sean expressed his internalisation of the shared 'Ladybird on a Leaf' story in his play narrative. As oral mathematical storytellers, children like Sarah and Taren imitated stories, stepping from what they already knew to something new (Vygotsky, 1986, p.187) and this activity provided insight into their mathematical capabilities.

Original contribution: Strand three

The third strand develops a novel way of documenting children's mathematical narrative, combining mathematical and observation models with video recordings of children's play narratives to stimulate reflection on mathematical storytelling by children, teachers and parents. We saw in Chapter Six how Sean's play narrative was mapped across to Casey's (2011) mathematical model using Carr's (2001) learning story format in a way which included both the child and his parent's voice. Using the proposed observational framework documented oral story qualitatively, incorporating views of children, parents and educators, and in this way captured children's mathematical thinking (Appendix 3).

These three strands serve to respond to the overarching research question which this work set out to answer: strand one responds to what characterises the nature of the interaction between teachers and children; strand two, the role of children as mathematical storytellers; and strand three considers how such narratives can be documented.

Reconciliation of my findings with other research

The empirical data referred to here goes beyond the work of Schiro (1997) or Carlsen (2013) in that it explores the unique flexibility to play with mathematical ideas through the medium of oral story rather than rearticulate identified mathematical themes contextualised in story. Carlsen (2013) characterised the orchestration of oral story as 'wondering' about the implicit mathematical opportunities in a fairy tale and thinking of ways to make these explicit through questioning. This empirical work developed this theme further and found that children were remarkable in the way they imitated oral mathematical storytelling

and playfully extended mathematical ideas; this imitative activity providing valuable insight into their mathematical capabilities.

Oral story situates mathematical thinking in a context that requires problem-solving thinking and provides a different way of knowing about mathematics. Though Boaler's (2002, p.178) theories did not fully fit with the sociocultural perspective of knowledge being constructed between people, the idea that oral story created communities in which children thought flexibly about mathematics is relevant; mathematical knowledge was shaped or constituted by the story situation in which it was developed and used (ibid., p.2, citing Lave 1988). How oral story learning was contextualised or situated by adults influenced children's reconstruction of mathematical themes as part of play or story narrative.

Summary of the main findings

In summary, the research is both supported by previous literature and makes a further contribution in that it theorises that oral story as a pedagogical choice encourages children's mathematical thinking and educator enjoyment of teaching. Meaning constructed by children as they listened to an oral mathematical story was a function of the images created, associations made, and questions asked, which gave children a model to work with and allowed their construction of mathematical ideas as they imitated stories heard; imitative activity as part of play or story narratives provided insight into these children's mathematical capabilities. As part of these experiences, educators changed the way they taught mathematics and this opened out a pedagogical approach which legitimatised a different way of thinking about the business of teaching mathematics. Analysis of data suggests that the practice of oral story legitimises

a more creative mathematical classroom discussion and expectation about behaviour. There are accounts where conversation was less dominated by the teacher and took on a multiplicity of directions, as was the case with at least three of Lorraine's story experiences.

Lorraine's teaching was viewed through a sociocultural lens and such an approach is more likely to promote dialogue and support diverse learning activities, encouraging children to 'participate as active constructors of knowledge rather than as passive receptors of pre-made knowledge' (Eun, 2010,p.403). It is acknowledged that not all oral story experiences did this and that it depended on the way the teacher promoted thinking through skilful questioning, a feature which differentiated the work of the two educators analysed in Chapter Seven. There were examples of story experiences where children were passive receptors of preformed knowledge rather than active constructors of mathematical ideas. These less active oral story experiences were characterised by lower order questioning and less in the way of playfulness.

Acknowledgement of limitations and weaknesses

There were two notable limitations to this work: first, participant mortality (Thomas, 2013) as referred to in Chapter Four meant that the project was located for only a short time in year one as for different reasons both teachers became unavailable; second, educators in Key Stage two resisted participating beyond initial interviews, closing their doors to the practice of oral mathematical story as part of the project, at least. Thus a limitation of the project was that there was insufficient opportunity to explore the possibilities in depth beyond reception classes. However, relocation of the project to an early years context resulted in

re-positioning the educator 'alongside' (Coles, 2013) children, more creative mathematical experiences, with opportunities for children to play and retell stories in the dedicated play areas. This shift from year one to reception resulting in notably favourable outcomes, is discussed in Chapters Six and Seven.

Recommendations

Three interrelated recommendations emerge from this empirical research. First, that educators are made fully aware of the complex socio-cultural nature of learning as part of their initial and ongoing professional training. Second, that educators are aware of the multi-dimensional nature of teaching and learning mathematics and that this can be at odds with their individual mathematical epistemology. Third, that the macro- and micro-political arenas of politics and classroom are more carefully aligned with a curriculum which is flexible and which encompasses a sociocultural perspective on mathematics.

In conclusion, oral mathematical story as a pedagogical approach allows children to mathematise horizontally and vertically (Treffers and Beishuizen, 1999), to think 'proceptually' (Gray and Tall, 1994), and to build conceptual structures or schemas (Skemp, 1976) for mathematical ideas as they think playfully about mathematics through a story context using story-related materials. Gifford (2005, p.44; 2004a) advises that children need both open-ended contexts and structured activities for learning which oral story can offer; the more open-ended story experiences observed, led to children carefully structuring original mathematical narratives. Therefore, children need to be given the opportunity to observe and imitate this approach to mathematics as part of their early years education and

become participants in what can be described as a genuine sociocultural activity that encourages mathematical thinking.

The thesis proposes that oral story potentially changes the nature of mathematical teaching allowing the educator to use the story to act as the vehicle for thinking mathematically in ways that allow children to participate with mathematical problems and also with each other in more meaningful ways than other approaches such as worksheets. However, this requires a shift in the culture of the wider political arena of intended policy and responding to this opportunity requires conceptual understanding of both the nature of the subject of mathematics and teachers' views on what it means to teach and learn.

Further, this research identified 'gaps' in both the early years and primary curricula. Downward pressure driven by government policy has resulted in educators taking a numeracy-based or 'instrumental' (Skemp, 1976) interpretation of curricula, which is more readily assessed than a 'relational' (ibid.) approach to understanding mathematics. A re-structured curriculum policy framed by sociocultural perspectives as to what it means to teach and learn mathematics is required. Thus, a focus on mathematical processes and dispositions in addition to knowledge is required along with an alignment of policy curriculum texts with assessment tests.

Professional training needs to tackle the mathematical identity and epistemology of educators, which is influenced by their experiences as mathematical learners; professional development of the early years workforce is a key point highlighted by the Sutton report (Mathers et al., 2014). Gifford (2005, p.59) recommends that storytelling features as one of a repertoire of teaching strategies for mathematics,

cautioning that this needs to be underpinned by a strong knowledge of the subject. Carlsen (2013) advises that educators have an enquiry and problem-solving mathematical epistemology when embarking on oral mathematical story work. Consequently, changing the way mathematics is taught will call for a pedagogical approach which legitimatises a different way of teaching and thinking about mathematics and about what it means to work mathematically in a school context. With knowledge comes power and if practitioners are sufficiently knowledgeable, they will potentially have greater power and confidence in playing what Basford and Bath (2014) refer to as the assessment game, 'a game that allows them to perform the technical duties to satisfy the gatekeepers of regulation while also satisfying their own moral and ethical duties to encourage children and their families to participate in learning that is representative of their social, cultural and historical heritage'.

Further research

Further research is required to explore how a re-conceptualisation of policy would play out in practice. The theoretical construct concerning discursive instruction, with quality dialogue keeping educators' and children's minds attuned in 'intermental zones' (Mercer, 2002) allowing children to operate in Zones of Proximal Mathematical Development was raised in Chapter Three, and warrants further research. A response as to what will characterise a quality 'intermental zone' and allow children access from a ZAD to a ZPD could not be fully realised here.

This research used a Vygotskian instructional framework and Casey's model to view the practice of thinking mathematically through story. Combining these two

frameworks could provide a way of understanding the interrelationship between mathematical development, the practice of teaching, and the place of imitative activity. Finding ways to map the practice of teaching or 'policy-in-use' to the eight instructional principles set out by Eun (2010) and a relational mathematical model would support professional practice. Oral story as a pedagogical approach potentially satisfies Gifford's (2005, p.164; 2004a) call for a way of teaching young children mathematics that involves subtlety, skill and playfulness. Developing a framework to help conceptualise this practice could be valuable.

What this suggests for future

Oral mathematical story represents a hybrid of pedagogical approaches in that it is a traditional idea combined with modern practice, providing opportunities for children to demonstrate imaginative mathematics and storytelling that can be reflected upon by sharing the documenting of digital and video recordings among children, parents and colleagues in a way which conceptualises mathematics relationally. Opportunities for this approach will continue to be challenged until curricula texts move away from a deficit model of mathematics, a less pressurised culture of accountability prevails, and teachers of mathematics are trained as competent and confident mathematical educators who are willing to co-construct mathematical ideas with children.

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Appendix 1

Photographs

Teacher sharing 'Penguin' with reception group of children

[Photograph removed in this version of the thesis]

Child telling 'Penguin'

[Photograph removed in this version of the thesis]

Appendix 2

Ethics Protocol
Doctorate research project

How can educators use oral story to teach mathematics in a playful way? An exploration with children and teachers in Primary education.

Caroline McGrath, Lecturer Early Childhood Studies,
PhD student, Plymouth University.

Background

As a lecturer in early childhood studies at the City of Bristol I hold a special interest in supporting early mathematical development. The aim of this research is to understand how oral story is used and can be developed to teach mathematics in a way, which will engage children. The research will record applications of this approach in practice and seek to develop a model for educators where they take a creative approach to teaching mathematics.

The research aims to investigate the following questions:

- What are the issues around the use of oral story to teach mathematics?

- What effect does this approach have on children's mathematical behaviour?

- What effect does this approach have on teachers' experience of teaching?

These questions will be responded to through analysis of: practitioner reflective narrative accounts; audio and video recordings of practitioners using story to teach mathematics; observations of children engaged in mathematical thinking.

Research design

The researcher holds Qualified Teacher Status (QTS) and has incorporated professional story telling as part of a higher education degree programme for trainee early years practitioners over the past four years. The researcher is reasonably equipped to deliver oral story-telling and to share necessary skills with educators who participate in this project. This research is not about the training of the teachers but about what happens when oral story is employed to teach mathematics.

The following methods will be employed: interviews; observation; generation and use of documents; generation and use of visual data (photographs and video recordings); generation and use of audio recordings. These data sources and methods will potentially help address the research questions outlined above.

Role of researcher

It is anticipated that the researcher will need to be open to take on the role of educator in order to avoid over reliance on teachers who may not have had previous exposure to the necessary skills of oral story-telling and who may need support to facilitate this in addition to their daily pressures. The researcher will potentially move forwards and backwards as researcher and educator, working with class teachers to teach children mathematics through oral story.

Observations

The project will include mathematical story-telling in the normal class routine. The research will start initially with one observation of the normal school day based in each of two classrooms: reception and year one. This would be followed by a series of nine observations (thirty minutes each) of mathematical storytelling with the whole class of each year group. After each oral story with the whole class there will be an open ended play opportunity for a small group of children. These children would be observed playing with story related props for up to twenty minutes, with up to nine observations of these small groups, or of individuals. There would be a final extended observation in each class. This equates with up to twenty observations in each year group.

The framework will be flexible and reviewed during the process i.e. it might be that the researcher needs to remove the pressure from the class teacher and carry out additional sessions rather than rely on the teacher. The researcher will need to respond to the reality of teaching situations and work with class teachers according to their individual needs.

In summary, there will be up to forty classroom based observations: two pre and two post extended observations; eighteen whole class oral story-telling and eighteen oral story play related small group observations. These will be divided between reception and year one classes.

Interviews

There will be up to eight focused discussions with each class teacher. Initial semi-structured interviews will be carried out with two class teachers to gain an insight into their views and knowledge or experience of using oral story. This will be necessary to ascertain whether this approach has been employed by these educators and whether they have had previous training or whether associated skills need to be considered first. These initial semi structured interviews will determine the role the researcher will need to take: whether to intervene more as an educator demonstrating oral storytelling or whether to observe the practice of a teacher.

The six focused discussions with educators will be about what happens when oral story is used to teach children mathematics. These discussions will potentially refer to video or audio recordings of children in whole class and smaller play situations engaging in mathematical thinking. Towards the end of the project discussions will be about whether oral story has an effect on teachers' experience of teaching mathematics. There will be one-focused discussion with each of two class teachers at the final phase of the project.

In summary, there will be up to sixteen focused discussions divided between two teachers: one initial discussion; six intermittent discussions and one final discussion. The overall research design indicates up to forty observations and up to sixteen semi structured or focused discussions across two different classrooms. This will need to be reviewed as the project evolves.

The research will be sensitive to the challenge educators face when teaching in mainstream state settings; the needs of young children; the expectation of parents. The researcher realises the complexity of mathematics in terms of learning and teaching and this will be an important factor in the work. It is hoped that the intervention resulting from the research will enrich both educator and learner experience.

Informed consent

The purpose of the project will be explained and shared with participants. Educators and parents or carers will be written to. Parents or carers will have the opportunity to discuss the proposed work as well as or in preference to written information. The different stages involving educators' level of involvement will be outlined and shared on a

weekly basis. Children will be verbally informed about the project. Children will be asked for their assent to participate and given an opportunity to represent this visually.

Written consent will be obtained from educators who agree to be part of the work and use of any comments will be shared to check that it represents their thoughts. Written consent will be obtained from parents/carers on behalf of children.

Openness and honesty

At all stages participants will be consulted and where observations are carried out which relate to the research work these will be available to share and discuss with the class teacher and parents or carers.

Children will be observed in their play and learning in whole class situations. These observations will be discussed with the class teacher and made available to parents or carers. Children will not be pressurised to provide activities valuable for this work but, should such activities happen, the relevance will be shared in discussion with class teachers. It will be considered that this will be an honest record of their experience through the research intervention. The research will not be deceptive in any way.

Right to withdraw

Educators, and children will have the right to withdraw from the research and parents or carers will have the right to withdraw their child, and to have any associated data withdrawn, up to two months from when the data is finally analysed, or from when the data was shared, whichever is the later. Should children be withdrawn or withdraw, they would still attend the normal classes including mathematical storytelling, but they would not contribute to the research. Children withdrawn from the research would not feature in the whole class video recordings and would not be selected for the small group work opportunities.

The head teacher, class teachers and parents or carers of children participating will be provided with a copy of this protocol with the researcher's contact details to facilitate their intention to withdraw.

Protection from harm

Participants include educators and children they teach. The nature of the research will not involve risk to children or teachers. The work will not include sensitive topics. Permission from parents or carers will be obtained in the form of signed permission (see attached letter). Children may be academically assessed as part of this research mainly through observations. Where questioning opportunities present, these will be posed in an enquiring rather than leading way. The research will not involve intrusive intervention of any sort or psychological stress or anxiety. Educators and researcher will have Criminal Record Bureau (CRB) clearance.

Benefits and risks

It is hoped the intervention part of the research will result in a benefit to these children and will enrich their knowledge and learning experience. The material will add to mathematical knowledge and to confidence in teaching mathematics.
There are no perceived risks and it will be integrated into the routine of the day to avoid additional demands on time. The confidence of some learners may be low and this will be acknowledged sensitively.

External Clearance

Written permission will be obtained from the head teacher of the School in which this research will be conducted. The ethics protocol has been approved by Plymouth University.

Debriefing

The researcher will share the findings with the School head teacher and educators during the methodology phase and at the end of the study. A summary copy of the research findings will be made available by the researcher for all participants and parents or carers of children participating at the end of the study.

Dissemination

Outcomes of the project will be based on data generation and analysis and this will be documented as part of the PhD. An executive summary of the findings will be available to educators and parents or carers of children participating in the work through the school head teacher. The researcher will arrange a specific meeting to discuss outcomes with the head teacher. It is anticipated that at least two papers will result from this work but because it is exploratory it's not possible to say exactly at this stage what the outputs

will be. Any potential outcomes of the work will be communicated with the head teacher.

Anonymity and Confidentiality

Names of children and educators will not be included. Pseudonyms will be used rather than real names. The School will only be referred to in generic terms. Transcripts of interviews and other collected information will be kept confidential and only used for the purpose of this work. Data will be stored safely and secured by password-protected files on a shared drive.

Internal confidentiality will be achieved by ensuring that when working with more than one member of staff, associated details of others are kept to a minimum. This will be particularly relevant when findings are disseminated to the school.

Visual ethics

Visual methods such as photographs, video, drawings and graphical representations will contribute data to this work. The researcher and children participating in the project will create this visual data. All data collection will be restricted to the school environment. The researcher will comply with the regulations and guidance set out by Plymouth University.

The data will be collected by the researcher and stored safely on a password protected shared drive. Written permission will be obtained from parents and the head teacher of children at the school, to collect use and store photographs, videos and drawings. Visual images will be supported with written explanations to ensure the context, and content are preserved. The researcher will endeavour to combine visual data with text to make explicit the intended meaning. The researcher will take a moral stance to ensure that the data collected is fairly interpreted and that reflective accounts make reasonable claims.

Thank you for taking part in this work.
If you wish to discuss this work or withdraw from the project please contact:

Caroline McGrath

Appendix 3

Documenting Mathematical Observation: play narrative	
Mathematical **Feature**	**Narrative Description** **'Ladybird on a Leaf '**
Conjecturing What if? Problem posing	*The sneaky rain took four away.*
	soon the sun came along, the sun came along and put four back.
Algorithm (e.g. adding, subtracting, multiplying, dividing)	[Sean replaces two spots on each wing.]
	The ladybird thanks the sun for making the spots come back.
	This time the sneaky rain took more than four away. She, the sneaky rain takes two away.
	[Sean's hands are over the spots one hand each over two spots on either wing.]
	She decided to take more than two, more than four.
Mathematical utterances (mathematical words)	*She decided to take three more than four. Three more makes…Hey, how many does it makes? one, two, three, four, five, six, seven.*
	She took seven away. The rain took seven away. She only had five spots left.
Mathematical facts (Children's prior knowledge)	*Soon she called for her friend the little ant* [Sean starts replacing spots] *she puts on one, two, three* [placing three spots on one wing], *four ,five, six, seven*
	[placing four spots on the other wing. The spot arrangement is restored to six on each wing.]
Seen patterns (making mathematical connections)	*Where did my other ones go?* [Sean asks looking around.]
	'one, two, three, four, five, six, seven, eight, nine, ten, eleven, twelve .. there is twelve actually'. [Sean counts and touches each spot saying a number name]
Mathematical mistakes or misunderstandings	*The ant went away to have some tea and cake* [Sean shows motion of an ant walking off with his fingers. Then using both hands he brushes off six spots from each wing. She says [difficult to hear but something about the ladybird having no spots. He holds the sugar paper ladybird shape up vertically.]
Taking mathematical ideas to other contexts (Isomorphism)	*Soon she cries ''help'' and the ant says ''what now?''*
	She says all my spots are washed away.
Curiosity (within mathematical context)	*And soon the ladybird, the ant, put one, two, three, four, five, six*
	[Sean starts arranging spots over two wings but changes this to placing six on one wing before starting on the other].

Fluency (Ease of use of mathematical ideas)	*Seven, eight, nine, ten, eleven, twelve. She putted twelve more on.*
	[Sean pushes the spots further up the ladybird body.]
	And soon she thanked the ant. And soon…the rain washed this many away …
	[There are two spots left. Sean starts to count the spots on the carpet]
	One, two, three, four, five, six, seven, eight, nine…nine away. And soon the ant came along and the ant was quite cross and soon the ant said 'I was just about to have my tea and cake.' And soon the sun sawed the naughty rain trying to get the spots away and soon the sun was so cross and said 'Go away naughty rain, go away'. [Sean replaces six spots on each wing, restoring the original twelve to how he started.]

Title	Age of child in years & months	Gender	Context	Initials of observer	Date	Audio recorded reference
'Ladybird on a Leaf'	4 years 5 months	Male	Playing with related props following adult telling story	CMcG	26.4.2013	DM650000

Prompts	Observer Comments
Taking mathematical ideas to context such as play or retelling stories	Prior to the narrative account Sean makes a careful choice of twelve spots for his ladybird following a discussion with another child where he concludes that ladybirds can have however many spots they wish. Sean plays with the sugar paper ladybird and spots in a way which reconstructs the story and mathematical ideas of a story told by an adult to a play situation. What is interesting and not obvious from this record is how other children are listening to Sean, while playing with their mini ladybirds.

Use of props	Sean uses the props thoughtfully in a way which supports his actions. He uses the spots to work out how many he has taken away and how many are left. He works through number relationships using the props. 12-4=8; 12-7=5; 12-12=0; 12-10=2. Sequences relating to original story of N- n +n = N: 12-4+4=12; 12-7+7=12; 12-12+12=12. He intends to create the pattern 12-10+10=12 but makes an error and thinks there are 9 rather than 10. Sean starts with twelve spots and repeats the pattern of removing a number and adding back on the same number, four times. Sean retells the story in a way which preserves the original mathematical idea of the story told.
Connection to original story heard	There are close parallels between Sean's story and that of the story heard. It is worth noting how Sean extends the mathematical idea of number complements to a number of his choice and how this number challenges his thinking.
Extending ideas beyond the story heard	There is an opportunity to draw out more of the possibilities for the mathematical story pattern for 12 (12 –n+n=12) using different numbers for n. This could help Sean build fluency as he becomes more familiar with patterns.
Follow up if appropriate	It would be good to show the video or listen to the audio recording with Sean and his parent (s). Sean is acquiring English as a Second Language and this observation tells us something of his ability to use story language to express mathematical ideas. I would recommend this record is shared along with a copy of the audio and video recording of Sean's play with 'Ladybird on a Leaf' with colleagues.

Outcome of discussion with child	Outcome of discussion with parent
Sean's comment on watching the DVD of himself retelling 'Ladybird on a Leaf' at home: 'Hey Mum, not only 6+6 makes 12 spots! 5+7 and 4+8 also make 12!' Sean's mother writes 'He noticed that there could be several combinations of numbers to make the same total.'	Sean's mother writes the following comment on watching the DVD recording of Sean retelling 'Ladybird on a Leaf': 'We are very pleased to see Sean enjoying himself in this project. It seems that this creative approach of using ladybird spots really has got Sean interested and has made him think mathematically in relation to the story.'

Appendix 4

Codes derived from theory	
Code	**Definition of Code**
Story context	Research findings which support the use of children's literature for improving the disposition to pursue mathematical learning and mathematical thinking (Keat and Wilburne, 2009; Van den Heuvel-Panhuizen and Van den Boogaard 2008; Hong 1996) suggest this is because story provides a context for mathematical ideas. This pedagogical approach integrates: mathematics, literacy and social skills through story characters (Keat and Wilburne, 2009; Hong 1996). Griffiths (2007) promotes story as a context for learning, with inherent opportunities for practical application and visual reinforcement along with a stimulus for learning. Keat and Wilburne (2009) advocate that reading literature which contains mathematical concepts is a strategy which educators can employ to engage children's enthusiasm and interest in mathematics. Literature provides a context for concept development (Welchman-Tischler 1992). Schiro (2004,46) describes the intention behind oral story telling as an attempt to personalise and contextualise mathematics. Story and oral story place mathematical ideas in meaningful contexts for young children. Handa's Surprise (Browne 1998) either read or retold provides a meaningful context for mathematical ideas. Browne (2013), author and illustrator of this picture book makes the point that picture books are often inadvertently mathematical. Handa sets off with seven exotic fruit in a basket on her head for her friend Akeyo. Each of seven animals takes a fruit. A tethered goat escapes and knocks into a tree, which drops tangerines into Handa's basket. Both Handa and Akeyo are surprised when Handa takes the basket from her head! (Browne 1998). Seven animals each take a fruit from Handa's basket which offers context for the mathematical idea 'one less than'. A story can be retold in ways that capitalise on the context to encourage children to think mathematically. What if the first animal, a monkey, takes two fruit from the basket of seven fruit or what if there are fourteen fruit and each animal takes two fruit? The story context makes abstract mathematical ideas, accessible.

Building a story **(co-construction)**	Where the educator co-constructs or builds the story with children, this represents an exchange of ideas with the children. For this to be effective the educator needs to be inside the context, fully participating, facilitating this contribution (Pound and Lee, 2011). Building or co constructing story with children differs from reading or retelling a story as children's ideas form the fabric of the story and this requires a certain approach on behalf of the storyteller. Ideas can be story related like children suggesting the name of a a dinosaur character 'Jack-o-Saurus' or mathematical ideas such as the number of eggs to place in each nest. Building story with children is different to retelling a story. It requires prompting and managing of ideas in ways which allow a story to take shape and involves deciding what to accept or reject. Mathematical ideas in 'Dinosaur' are from children and Lorraine manages their contributions in ways which leads to the partitioning 8 in several ways before settling on 4 eggs in one nest and 4 in the other.
Acknowledgement **Accepting/rejecting**	Adults can acknowledge suggestions children make but accept or reject these as part of the fabric of the mathematical story. I include this as a code as through the project I note that some suggestions are ignored which arguably could be taken up to develop mathematical ideas (e.g. in a video recording about a shape story, a child suggests that a triangle turns into a circle and though this is acknowledged by the storyteller it is not taken as a point for further discussion.). In 'Dinosaur' most ideas are accepted but one story related idea is rejected which relates to smashing the dinosaur eggs. In 'Penguin' children suggest working with 20 fish but this is rejected. Whereas the previous code is about the skill of building a story this code is more specific in identifying what is accepted or rejected. There may be a conflict between adult agenda or intention which leads to rejection of ideas. Suggestions being accepted or rejected may tell something about what adults find acceptable. Smashing eggs is suggested by a boy but not taken as a suitable story idea. Another suggestion is on the other hand accepted, raising questions about why and what children then interpret as acceptable. Why not smash the eggs as this could be a survival tactic for the smaller dinosaur story character? It raises questions about gender: will boys and girls want to pursue oral story with different ideas some of which don't fall in line with those of the adult?

Use of props to support mathematical ideas	For very young children, puppets and props capture the imagination and offer a connection to the story. Story related props help children construct mathematical ideas. Haylock and Cockburn (2013, p.85) advise that young children need to visualise concrete objects before they can articulate number relationships: the objects attach necessary meaning. Construction of story and mathematical meaning can be assisted by props: children visualise mathematical ideas at the core of the story through the supporting materials. I propose that story props support children in translating between abstract and concrete representations of mathematical ideas (Hughes 1986). The props in the project allow children to translate between abstract mathematical ideas of story and concrete representations of ideas: when a wooden ladder with twelve rungs is provided for the oral mathematical story 'Little Lumpty', children count in multiples one ones, twos, and fives using the ladder prop to support the count. It is noticeable how after providing the ladder children's stories relate to the mathematical idea of 'counting in multiples of a number'. The blue eggs as props in 'Dinosaur' support expression of ideas about different ways of making eight. Props prompt retelling of stories and the props can support expression of mathematical ideas.
Recall of ideas through story speech	Talk or speech unifies and organises many aspects of children's mathematical behaviour. In the afterword of (Vygotsky 1978, p.126) Vera John-Steiner and Ellen Souberman comment that 'speech acts to organise, unify, and integrate many disparate aspects of children's behaviour such as perception, memory, and problem solving'. Pound and Lee (2011, p.73) comment on 'how the brain is able to connect with story, and how narrative images expand in the brain, not only clarifying the gaps, but confining the information to memory'. Story speech is important in that it allows children to perceive, remember and solve problems in a unified way. I notice how children use 'story speech' to explain and recall mathematical ideas. After hearing the 'Ladybird on a Leaf' story Marion describes the mathematical pattern N-n+n=N as: '*It was when the rain cloud washes off and the ant puts them back; and the rain cloud keeps washing them off and the ant keeps putting them back on.*' Story speech serves to unify mathematical behaviour and allows children to recall and explain mathematical ideas. This code relates to explaining mathematical ideas using story speech or related words.

Prompting of recording to support recall	In the Dinosaur story Lorraine encourages children to record the examples they discover. This serves to support recall but also by recording examples worked through it prompts children to search out new or 'more possibilities'. This could be used in a more systematic way in order to exhaust all possibilities but doesn't happen in this story. The use of clip boards at first troubled me but they find a place in the project as children represent ideas though their own drawings and listen as they record.
Repetition of story phrases	Repetitive phrases consistent in structure serve as connections for children and story tellers (Hartman 2002; Lipman 1999; Allison 1987; Bryant 1947). Repetition draws on a child's confidence and concentration (Bryant 1947).
Actions to support story telling/ mathematical ideas	Actions that accompany the story provide a kinaesthetic reminder that makes the language and tale more memorable as well as helping the children understand what is happening (Corbett 2006). Actions can be used to show events and are often made up by children and adults. In this project supporting story actions are not used in a fixed or prescriptive way as favoured by Corbett (2006, p.2) who proposes certain actions to represent certain words, but rather in the style of one of the professional story tellers who takes a more fluid approach to the inclusion of actions as a feature of storytelling. Actions in the Dinosaur story relate mainly to supporting the story. As well as actions to support the story, in 'Dinosaur', the physical action of arranging the blue eggs supports children in finding 'more ways' of arranging the eight eggs.
Facilitating mathematical explanations	As well as working the story, the educator needs to work the mathematics. The development of understanding involves building up *connections* in the mind of the listener. Oral mathematical story is promoted as a potential way of building mathematical connections: 'the more connections, the more secure and the more useful the understanding' (Haylock and Cockburn 2013, p.11). In the Dinosaur story the story teller invites children to explain mathematical ideas.
Mathematical language 'utterances'	Language is designed for doing something much more interesting than transmitting information accurately from one brain to another: 'it allows the mental resources of individuals to combine in a collective, communicative intelligence which enables people to make better sense of the world and to devise practical ways of dealing with it' Mercer (2000, p.6).Language is the channel through which

'explanations'	we achieve shared knowledge: 'it is that language provides us with a means for *thinking together,* for jointly creating knowledge and understanding' (Mercer 2000, p.15, italics in original). Language offers a system for thinking collectively and opens intellectual networks for making sense of experience and solving problems. Language is a tool for creating knowledge and is a joint activity between educator and children, between children and within children (Vygotsky, 1878; Mercer, 2000). Vygotsky (1978) considers: use of language as a cultural tool (in social interaction) and use of language as a psychological tool (for organising our own, individual thinking). Mathematical 'utterances' of counting i.e. number names and words such as 'addition' and 'equals' will be coded.
Problem solving	Polya (1945) advises us that being a problem solver is not enough: problem posing and creating involves thinking on a higher plane beyond applying what one already knows, which problem is solving. Problem solving can be in relation to story or mathematical ideas. Children solve story and mathematical problems in 'Dinosaur'. One of the professional storytellers comments on how story often involve a social or moral dimension. Towards the end of 'Dinosaur' the story concerns problem solving in relation to a moral theme of honesty.
Problem posing: What if?	A child's disposition towards learning mathematics is important: 'above all, of great importance in mathematics is the attribute of developing a 'what if?' learning disposition' (Pound and Lee, 2011, p.9). The disposition to think 'what if?' is at the heart of problem-posing and is referred to as conjectural thinking by Pound and Lee (2011, p.9). Sheffield (1999, cited by Casey, 2011) recommends asking: What if I change one or more parts of the problem? Watson and Mason (1998, cited by Casey, 2011) state that questions such as 'What if?' provoke children into becoming aware of mathematical possibilities. Possibility thinking is framed by the 'what if?' question and is central to creative work with mathematical story. I refer to Pound and Lee's (2011) interpretation of 'what if?' as a conjectural question which is posed through story. This question lies at the heart of creative thinking (Craft 2001; Haylock and Cockburn 2013; Pound and Lee 2011; Sheffield 1999, cited by Casey, 2011; Watson and Mason 1998, cited by Casey, 2011) and is a key we can turn when thinking of mathematical ideas through story. Craft (2013, p.91) suggests that a creative or imaginative

	approach includes questioning with 'what if?' as an expression of possibility thinking. This question can feature across two domains: mathematics and story. What happens to the mathematical idea if we change the story? Or what happens to the story if we change the mathematical idea?
Prompting other possibilities 'more ways'	Teasing out other possibilities: searching these out i.e. what are all the possible ways of making eight? The adult prompts children to think of other possibilities. The adult knows there are other ways of making eight in the Dinosaur story and encourages children to find these. I see problem posing as more general and prompting other possibilities as more specific. The problem posed in the Dinosaur story is that the two nests need to be restored to how they were before being disturbed or something close to this. The possibilities for the eight eggs and the two baskets are: 8+0=8; 7+1=8; 6+2=8; 5+3=8; 4+4=8; 3+5=8; 2+6=8; 1+7=8; 0+8=8. Lorraine teases out possibilities without saying what these are. To help she suggests recording which helps children have a point of reference in order to find 'more possibilities'. This idea of recording could be developed into a more systematic approach but for this story telling it is to allow new possibilities to be recorded.
Mathematical algorithm: Addition	Algorithms or procedures or mathematical calculations are essential for mathematics some of which include: addition, subtraction; multiplication and division. For the Dinosaur story the number eight is a focus and the addition algorithm features for different ways of making eight. The final arrangement of eggs could be represented as: 4+4=8. On the clipboards there are some representations of the addition.
Commutative principle (addition)	When two numbers are added together, it does not matter which one comes first (a + b = b + a). When two numbers are multiplied together it does not matter which one comes first (a x b = b x a). Haylock and Cockburn (2013) advise that commutativity of addition and commutativity of multiplication are two of the fundamental principles of arithmetic.
Mathematical error and correction	Carr (2001, p.xiii) considers errors as a way to work out what went wrong and that these are a source of new learning. I include 'mathematical errors' because I find it fascinating to observe how children correct errors; how adults make and avoid correcting

	errors (sometimes these go unnoticed); how errors present opportunities which can be returned to or reflected upon. In the Dinosaur story counting errors are made which Lorraine encourages children to check and correct. This requires several attempts. As a storyteller Lorraine challenges and ensures children correct errors made.
Strategies for checking	Children in the project correct errors when counting by employing strategies such as lining objects up, checking, or getting another child to count. Eggs are removed from the baskets to overcome the problem of making errors when counting clusters. By lining eggs up counting correctly with one to one correspondence can be achieved. Lorraine asks children to reflect on mistakes and prompts children to check. Strategies for checking feature as part of the story building.
Generalising	Generalising is about making general or broad statements (Fairclough 2011). In mathematics, it is important to see patterns, to make general statements which articulate pattern, and to explain why this is so. In articulating a generalisation children are making one statement that is true about a number of specific cases (Haylock and Cockburn 2013, p.98). Haylock and Cockburn (2013, p.297; italics in original) describe how 'generalisations are statements in which there is reference to something that is *always* the case. As soon as children begin to put words such as *each, every, any, all, always, whenever* and *if …then* into their observations they are generalising'. These words are markers of children reasoning in a way that is characteristic of thinking mathematically (Haylock and Cockburn 2013).Young children need support in making statements about generalisations (Haylock and Cockburn 2013). Repetition of a mathematical idea through specific examples can be considered as possible early stages of generalising or realising that $a + b = b + a$. This idea is not necessarily articulated by children in general terms but a child in the Dinosaur story possibly realises something about $a + b = b + a$. I suggest that in one of the Dinosaur story video clips this child suggests 'swap them around' he may be realising that $3+5 = 5+3$.

Appendix 5

Oral Mathematical Story Research Project Design

April 2010- August 2012

September 2012 - July 2013

August 2013- March 2016.

April 2010- August 2012

Investigation

Focused discussion with educator/ head teacher

Analysis of video recording of a professional story teller using story with mathematical themes to offer skill base for researcher

Attend story telling events in locality

Modelling of oral story through stages of imitation, innovation and invention

Devising an oral story mathematical model/framework

Observation of current context in Bristol locality

Examine children's literature to make a selection of suitable stories Analysis of mathematics curriculum: problem posing; problem solving; pattern; number operations addition/subtraction/multiplication/division

Pilot project using three stories: re-telling the story without the book; playing with the plot to prompt mathematical thinking; creating new stories with mathematics implicit or explicit to the content

September 2012 - July 2013

Application of oral story skills through three stages by researcher/educators

Educators to select story and associated materials to support mathematical ideas

Educators to observe researcher engage in oral story telling

Researcher to observe educators engage in oral storytelling and note response of children to this alternative pedagogical approach

Researcher and educators to observe children at play

Reflective accounts on creating; narrating; playing; co-constructing of oral narrative story in play

Classroom observation using narrative flexibly to promote mathematics Small group observations of children

Analysis of video recordings of whole class/small groups

Focused discussion with educators

August 2013-March 2016

Analysis and summary of project relating theory and practice

The construction of a theoretical framework, which combines Eun's (2010) instructional principles and Casey's (2001) mathematical conceptualisation model

A detailed line by line coding of data using both transcripts and video recordings of oral mathematical stories, related interviews and documented reflections

Though an exploratory piece of research is intended, the expectation to intervene in current classroom practice needs to be realistic. In order to ensure this, a staged process would be planned with the researcher working alongside the educator. This would potentially involve the following stages: selecting a suitable story with mathematical possibility; imitation of an existing story told in an oral way; innovation of this story (playing with the plot); invention or creation of an original oral story.

The researcher will engage with the teaching so as to fully experience the use of oral story as a pedagogical approach with children. The class teacher will observe this which enhances the data as they know the children more so than the researcher. The benefit of teachers observing the researcher are that they would assist in the generating of data about children interacting with mathematics and provide valuable insight about the children. Together we are exploring new ways of prompting children's mathematical thinking. When we use story in an oral manner it opens up an opportunity for thinking which other ways may not provide. This approach allows for surprises to be noted.

The research questions which emerged at the early stage of the project are as follows:

- What are the issues around the use of oral story to teach mathematics?

- What effect does this approach have on children's mathematical behaviour?

- What effect does this approach have on teachers' experience of teaching?

These questions will be responded to through an analysis of: practitioner reflective narrative accounts; audio and video recordings of practitioners (and researcher) using story to teach mathematics; and observations of children engaged in mathematical thinking. The researcher will work in partnership with class teachers and ask that they participate in using oral story to teach mathematics and observe the researcher teaching in this way.

The researcher holds Qualified Teacher Status (QTS) and has incorporated professional story telling as part of a higher education degree programme for trainee early years practitioners over the past four years. The researcher will be reasonably equipped to deliver oral storytelling and to share necessary skills with educators who participate in this project. This research is not about the training of the teachers but about what happens when oral story is employed to teach mathematics.

Role of researcher

It is anticipated that the researcher will need to be open to take on the role of educator in order to avoid over reliance on teachers who may not have had previous exposure to the necessary skills of oral storytelling and who may need support to facilitate this in addition to their daily pressures. The researcher will move forwards and backwards as researcher and educator, working with class teachers to teach children mathematics through oral story. The researcher will be both participant observer and observer: applying the skills of oral storytelling to teach mathematics whilst being observed by class teachers and observing class teachers teaching mathematics using oral story.

Observations

The project will include mathematical story-telling in the normal class routine. The research will start initially with one observation of the normal school day based in each of two classrooms: reception and year one. This would be followed by a series of nine observations (thirty minutes each) of mathematical storytelling with the whole class of each year group. After each oral story with the whole class there will be an open ended play opportunity for a small group of children. These children will be observed playing with story related props for up to twenty minutes, with up to nine observations of these small groups. There will be a final extended observation in each class. This equates with up to twenty observations in each year group. The framework will be flexible and reviewed during the process. The researcher will need to respond to the reality of teaching situations and work with class teachers according to their individual needs.

Interviews

There will be up to six focused discussions with each class teacher. Initial semi-structured interviews will be carried out with two class teachers to gain an insight into their views and knowledge or experience of using oral story. This will be necessary to ascertain whether this approach has been employed by these educators and whether they have had previous training or whether associated skills need to be considered first.

The focused discussions with educators will be about what happens when oral story is used to teach children mathematics. These discussions will potentially refer to video or audio recordings of children in whole class and smaller play situations engaging in mathematical thinking. Towards the end of the project discussions will be about teachers' experience of using oral story to teach mathematics. The emphasis will be on retelling stories in a fluid way following the familiar story line but playing with the story so that a problem is posed through the plot and prompts mathematical thinking to solve this problem. Whole class story observations; small group play observations and focused discussions with educators are planned around these experiences.

Appendix 6

Memo: Tension between orality and literacy (Ong, 2002)

Though there is a tension between orality and literacy (Ong 2002) there is a paradoxical richness in the opportunity orality brings, particularly to young children. This is how very young children set about becoming literate and developing an intellectual consciousness. Early cognitive development requires orality: it might be that there will be an ideal age associated with the application of this pedagogical choice to teach mathematics. An analysis of Ong (2002) points to the need to provide opportunity for literal expression. Children and adults move between orality and literacy depending on their individual stage of development: the research will provide opportunities for oral and literal expression. We are interested in finding out what happens if a mathematical idea is carefully thought about through a narrative (or story): how will children respond in oral or literal ways to this experience? The work of Ong (2002) heightens awareness of the relationship between orality and literacy, which will be relevant to the context of exploring the use of oral story to teach mathematics to young children who have 'an oral mindset' as part of early cognitive development. In summary the disadvantages of orality based on Ong (2002) are: orality is not consciousness raising in the way literacy is; the repetition of an explanatory line of thought is under challenge orally; orality requires memorable content; orality will need careful patterning to be memorable; orality results in situational rather than abstract thinking; as we become literate our thought patterns and verbal patterns change. With this in mind we could seriously question why one would pursue such a line of research. The potential pitfalls of using oral story as a pedagogic choice can be summarised as follows:

	Orality and literacy Ong (2002)	*Problem in the context of using oral story to teach mathematics*	Considerations in context of research
1.	Orality is not consciousness raising in a way that literacy is	Will we limit learning at a higher conscious level?	Provide opportunity for oral and literate expression of mathematical thinking.
2.	Repetition of detailed explanation is difficult orally	If adult or child needs to repeat an explanation in detail how will this be achieved?	Audio and video record oral activity. Ensure the story structure is such that it can be repeated.
3.	Orality requires memorable content	How will we ensure the content of a mathematical story is memorable?	Sequence and structure and choice of mathematical idea will need careful consideration.
4.	Orality needs careful patterning to be memorable	How will we decide on a suitable pattern of words?	Repetition of phrases important.
5.	Orality results in situational rather than abstract thinking	How will we overcome this restriction?	Play will provide insight into how children abstract or situate mathematical concepts.
6.	Thought patterns and verbal patterns change by becoming literate	How might adults be offering a different orality?	We need to consider the difference between adult and child orality.

Appendix 7

Oral Story and mathematics: Semi-structured interview schedule

Factual Biographical information

Date:

Name:

Qualification:

Role:

Time span in current role:

Motivation to be part of project:

Curriculum followed when planning teaching:

Experience of using oral story to date:

Prompt questions concerning project

What does the phrase 'oral story' conjure up in your mind?

How would you define this term?

What is your experience of oral story to date? Have you listened to a story told orally? Have you used it as part of your teaching?

Research related questions

What do you think will be the issues around the use of oral story when facilitating teaching mathematics?

What do you predict will be the effect this approach may have on children's mathematical behaviour?

What do you anticipate will be the effect this approach will have on your experience of teaching?

Would you have a story in mind which will lend itself to oral storytelling?

How will you set about including oral story as part of your teaching?

Appendix 8

Interview subject Lorraine

9 November 2012

<u>Speaker key</u>

S1   Researcher

S2   Reception Class teacher

Timecode	Speaker	Transcript
00:00:00	S1	...and I would say, and this one is my back up one in case one doesn't work. So it's 9th of November, 2012 and I'm with [name of teacher].
00:00:12	S2	That's right.
00:00:13	S1	And we are at Reception Class and I'm hoping to have a brief discussion because I realised time is very precious. But I'm very interested in your, I suppose, firstly, I would like to ask a little bit about your background in terms of your experience and then I've got the three key questions to ask. But I suppose starting point would be to establish your experience.
00:00:40	S2	I qualified 24 years ago. In the early years, I did a PGCE in early years. My role here, obviously I'm a class teacher but I'm also the Foundation Stage Leader and I've been here...I think this is my fourth year here but I've been a Foundation Stage Leader in two other schools.
00:00:58	S1	Okay.
00:01:00	S2	So it's a role that I'm quite familiar with.
00:01:02	S1	Yes, yes. Okay.
00:01:05	S2	Yeah.
00:01:06	S1	That's really useful. And If I was to say oral story, how would you...what comes to mind and how much it differ from story, other forms of story?
00:01:19	S2	It's funny because this year, I feel like I've only just started doing more oral story-telling. I always felt really confident about...in reading stories to children and even making up my own words to them or even not even looking at the words while I had the book in my hand because I knew them so well.

		But I'm actually sitting there in front of the children with no book. This academic year is the first time that I've actually really started doing that and the children in this class so far, they know two stories off by heart and we did, I call this Mister, well we called it Mr. Wiggle and Mr. Waggle, I think he calls it Mr. Ziggle and Mr. Zaggle. We did that to start with and then we've done The Little Red Hen as well. And it's just being really exciting and we filmed the children telling the story and I think just feel so much more confident now I've had a go because I could tell that actually, it was quite straightforward and simple but I think it's just believing that you can do it and actually, if you make a mistake, it doesn't really matter either because we model making mistakes and everything else we do with children and yet suddenly, we kind of think we've got to be these amazing storytellers like Martin and Paula when they come in. And actually, it's fine because we're learning to...and it's just being really liberating actually and the children have gone home and told the stories to their parents and that's just being absolutely fantastic and we've also had to go, changing little bits of the story as well to make our own stories and we film those on the iPads, so the children can then share those with the class which has been really great.
00:02:56	S1	It's amazing. And I've got the same nervousness about it. Well, maybe not the same as yours but...and the students I'm working with, I want to try and get them into oral storytelling and they are better than me. What would you say is the key, I mean not to worry about mistakes sounds like a key but is there any tip or a piece of advice that you could give?
00:03:23	S2	Yeah, I practice it at home.
00:03:24	S1	Practice?
00:03:24	S2	Yeah.
00:03:25	S1	Okay.

00:03:25	S2	On my own at home doing the storytelling. In as much expression as I could and I think with other aspects of teaching, you don't really do that, let's sit and say things aloud. You sit and do a lot of thinking but actually, doing a storytelling just to yourself at home, and sit here on your own, voice aloud and getting into the rhythm of it because in a way, you know, [inaudible 00:03:48] has done some brilliant shorter versions of traditional tales but you don't hear the rhythm from reading it. And once you've got the rhythm, it helps you remember it.
00:03:57	S1	Okay.
00:03:57	S2	Yeah. So definitely, practice aloud.
00:03:59	S1	Practice aloud. And how many times or just...?
00:04:02	S2	Just until it feels...
00:04:03	S1	Just until?
00:04:04	S2	Yeah. And I would say, obviously, having the story map as well as a prompt.
00:04:07	S1	Great. Right. That's fantastic and that's what I've been encouraging the students, to do practice and have a story map and don't worry about if you lose your way, just refer to your reference you know, story map. Okay. That's really useful. And then the challenging that I'm interested in is connecting the story, the oral story to Mathematics. What would be your initial thoughts on that?
00:04:32	S2	Well, I think the choice of story is going to you know obviously impact on that. With the first one we did, Mr. Wiggle and Mr. Waggle, obviously, it's up the hill and down the hill, so it's already that kind of positional language coming out in the story itself. So I mean we didn't tale a particular mathematical stance with any learning linked to it but there'll be a lot of possibilities there about up and down, and high and low, and measuring, and making different height, hills, and acting as how to. With Little Red Hen, there are lots of

		opportunities for sorting different seeds and grains, and obviously, with the baking, there are loads of mathematical opportunities in there. And I think in the same ways we'd used...we'd find the mathematical links in any story. It's the same with oral storytelling really. I just think it's so liberating for children to know the story so well, that those links become, it becomes a little bit easier for them and for adults, or an audience.
00:05:46	S1	Yes, it's very interesting that you should say that. As soon as I've started to look, I've seen mathematical opportunity which is obvious but it wasn't obvious to me. But now that I'm looking for it, it is. Does that make sense?
00:05:57	S2	Yeah, definitely. And then there are other books which clearly have a mathematical focus like The How Much is a Million that I've mentioned. But there's also one called One...Ten is a Crab, One is a Snail and Ten is a Crab¸ I used that last year with a group of children and particularly, they're really able mathematicians and it was absolutely brilliant for creating very large numbers using animals and they're like, number of legs and everything. But some fantastic mathematical learning from that point as well. But I think there are certain books you know, that really want to just learn off by heart, so the book can go to one side because as soon as the pictures are there, the children don't create their own pictures in their head, do they?
00:06:29	S1	Yes, yes, that's very interesting point and the oral experiences relying on them, creating pictures. And another thing that I'm interested in is, the authors, for example, Eileen Browne, she was surprised when I explained to her how I was looking at this book and using it for the language of "One less than,": there's seven fruits in a basket, "one less than 7 is 6",. And she was amazed and then also, I wrote to Janet Burroway and she was amazed that there was so much

		mathematics in The Giant Jam Sandwich. So the author is surprised, so it's unintentional but it's there.
00:07:11	S2	But don't you think that's often how people see Maths generally? They think Maths is something separate but actually it's in our everyday lives?
00:07:17	S1	Yes.
00:07:18	S2	And that's why we can pull it out of all these different things. And we've used Handa's Surprise in the same way, One Less because it's you know, you can act it out with the children, can't you? And they kind of take that because I think that co-concept of One Less is a really tricky one.
00:07:32	S1	Yes, it is. And research indicates that that's a tricky concept. One More, children respond to but One Less, not so.
00:07:38	S2	I think they learn more very early, don't they? Because they want more, you know more, so.
00:07:44	S1	Okay. Well, that's very useful for me and I suppose, to a certain extent, you've answered my questions but maybe I'll ask you a little bit about what influence or impact do you think it has or will have on children's mathematical thinking or behaviour, or have you seen anything in particular that is in your mind, as a result of using oral story?
00:08:09	S2	I think, in terms of children's mental images of number, I think stories really help with that. Because with all the storytelling, they are conjuring up their own you know, pictures in their mind, and I think if we're exploring Maths through oral storytelling, then that gives them those sort of mental pictures. So I think for instance, with Ten is a Crab, I forgot what it was called, I think it's Ten is a Crab, and that was fantastic for certain children who really hadn't got that...they hadn't got a picture, you know, Numicon maybe haven't worked for them or you know, they haven't got that picture in their head of what Ten looked like but to think Ten as a crab, they then suddenly have a picture of the crab's legs and

		pincers, five on each side and lots and lots of mathematical thinking and pictures in their heads. So I think in that way, it really helps children.
00:09:02	S1	Okay. Yes.
00:09:03	S2	And in terms of.... And I think anything that engages children is going...in terms of mathematical behaviours you know, and books that are about problem-solving and investigation and finding out, the more we kind of encourage those skills, the better their mathematical behaviours really, I suppose.
00:09:24	S1	Yes, yes, I totally agree. And then I suppose it's funny but it sounds like it's coming out, the impact on experience as a teacher because you mentioned at the beginning of our discussion that this is the first year that you've really gone home, rehearsed and said aloud a story and taking it to the children, what experience does it give you?
00:09:46	S2	Oh, it's just...it's being magical actually. I've really enjoyed it because you know, when you've been a teacher a long time, it's that you kind of try lots of different things. But first of all, I've felt really proud of myself...(Laughter)
00:09:58	S1	Yes, yes, I would.
00:09:59	S2	...of my achievement. And it's really good fun and then when children start to join in, and how quickly they learn a story, you know, it's absolutely magical and like I said before, when families are coming in and saying that they've told the story to them, I just think, if we'd read the story, it wouldn't have had that impact, just from reading a book. They might have said, "Oh, we read a really good story," or something but to actually be able to go home and be a storyteller, you know, I just think that when children take their learning home, I just think it gives you so much, such positive feeling as a teacher.
00:10:34	S1	Yes, definitely.
00:10:35	S2	So I've just found it really good fun and really rewarding, and the other thing is filming them doing their storytelling has

		been really useful because I could see who's not joining in. So I could sort of...there were a couple of children not joining in and I said to them, "Oh when we do The Little Red Hen's then, I'm going to be really watching to see if you could join in." And they did.
00:10:55	S1	They did?
00:10:55	S2	Yes, so I could really praise them for that.
00:10:57	S1	Okay. Yes.
00:10:59	S2	Yes, and even, we've got a little boy who has virtually no English and he has joined in with quite a lot of the actions and the odd phrase and I just think for him, it's been really, really useful. And obviously having the story map for the visuals for him as well has been very good.
00:11:16	S1	That's very interesting because I was worried about children who might not join in or...because children can rely on visual and how will they respond to oral, so that's very interesting point that you should raise.
00:11:26	S2	Yeah and in a way, I think when you ask children a question, and then attention's all on them, for those less confident children, that's quite scary but if you're joining in with everybody saying the same thing, then you know, it's in a way, you don't have to be quite so brave, do you?
00:11:42	S1	No, no.
00:11:43	S2	But it's you know, I imagine it's quite liberating for children once they know that actually they are, they do need to do it.
00:11:48	S1	Yes, yes.
00:11:48	S2	And they can't just sit back and listen.
00:11:51	S1	Now, thank you. Thank you very much and I love the way you described it as magical, so, and that's the word to hold on to. So thank you very much.
00:11:57	S2	Okay. Brilliant.
00:11:58	S1	That's brilliant. I'll press the stop...

Reflections

This teacher has twenty four years, experience as a teacher and is acting as a foundation stage leader. I think this is a rich interview because of the responses provided by this participant. This interview frames what the ethos of the project is about. Lorraine expresses pleasure which is reflected in her choice of words to describe oral story telling as an approach with children.

When asked to define oral story Lorraine describes a more established confidence reading story books and relates to Corbett training and how this recent work has given her new confidence as an oral storyteller. This academic year is the first time she has adopted oral story. Later in the interview she describes the difference between reading and telling; 'As soon as the pictures are there, children don't create their own pictures in their head, do they?' She places emphasis on how story can help children visualise for example the number 10. She describes work with 'One is a Snail and Ten is a Crab' to create large numbers. Mental images of numbers are supported through stories. With oral story children are conjuring up pictures in their minds. Further she identifies one less as a challenge for children and the value of the story Handa's Surprise as a way of addressing this. She notes how story context and dramatisation of story supports children's mathematical thinking. She comments on risk taking: 'we model making mistakes', suggesting her view about how children learn. Lorraine practised storytelling at home commenting: 'hearing your own voice aloud' and 'getting into the rhythm of it' and having a 'story map' and notes how with other aspects of teaching you do not do this.

She comments on the connection of a story to maths and notes how the choice of story will impact on that. She refers to Mr Wiggle and Mr Waggle and positional language and comments on '…lot of possibilities there' and for 'The Little Red Hen' having '…opportunities for sorting': Loads of mathematical opportunities [in the story]. Lorraine seems to see it from the point of view of starting with the story and though positional language is identified as a feature of the story the emphasis is different: it is not about starting with the mathematics and seeking links to story. This is a refreshingly different perspective to other participants (see interview with deputy head for example).

She makes a point that it is so liberating for children to know the story well and how this makes the mathematical links easier.

Her reflection on oral story experiences: 'It's been magical'; 'Proud of myself'; 'How quickly they learn a story is absolutely magical'; 'Fun'; 'Rewarding' ; 'Use of filming to see who is joining in'. There is a very early reference here to something that happens later in the project when children are oral mathematical storytellers.

She comments on the inclusive quality of oral mathematical story by describing how a child with English as an Additional Language, 'joins in with actions …joining in with words'. She comments on the link between home and school: 'taking learning home' and states '…but to actually be able to go home and be a storyteller, you know, I just think that when children take their learning home, I just think it gives you so much, such positive feeling as a teacher'.

Appendix 9

Coding of oral mathematical story observation: Two of Everything

Qualitative Analysis of data: Conceptual labels from open coding – Video recording of oral Mathematical Story telling Two of Everything 22 February 2013 Lorraine file WS650105; video files M2U00533 and VID00002. It is interesting to note the value of looking at both video perspectives as this added to the coding. I am using the codes which were first developed to understand the 'Jack-o-Saurus' Dinosaur story. There is a small group of eight reception class children. Note beyond the 9 minutes transcribed there is dialogue of up to 13.30 minutes about snack time and putting 10 bananas in the pot. Mathematical algorithm 10+10=20 features as part of this conversation.

Time code	Label to capture essence of description	Speaker	Transcript
00:00:00	Story context Actions to support story telling	Storyteller	Once upon a time, there was a man called Mr. Haktak. Mr. Haktak lived with his wife, Mrs. Haktak. And they were very old and very poor in a poor [inaudible 00:00:13]. They did have a home but it was a tiny little hut. Not a very big home at all. But they didn't have very much money so they were very poor. Now then. They didn't have very much money and all they could eat was what they could grow in their tiny garden. It's a tiny garden. And that's what they ate – the vegetables and the fruit that they could grow in their tiny garden. Now and again, they grew enough. They grew more than they needed. So what do you think they might have done with the extra vegetables they didn't need? What might they have done? Just all [inaudible 00:00:48] them. What might they do with all the vegetables that they didn't need? Agnes?

00:00:55	Problem solving	Agnes	Throw them away.
00:00:58	Acknowledgement Rejecting	Storyteller	Oh no, they didn't throw them away. They took them to the market to sell them. But they're still really poor. Now, one day Mr. Haktak was digging in his garden, and he dug and he dug and he dug. Could you help me join in with the digging?
00:01:17	Building a story Repetition of story phrases Actions to support storytelling Use of props to support mathematical ideas	Storyteller and Children	And he dug, and he dug, and he dug. And he dug, and he dug, and he dug.
00:01:28	Story context	Storyteller	(Gong Sounds) When all of a sudden, his spade hit something hard.
00:01:34	Story context	Child	Haaaay.
00:01:36	Story context Actions to support story telling Use of props to support mathematical ideas	Storyteller	"What could it be?" said Mr. Haktak. (Gong Sounds) So he dug, and he dug, and he dug, and he discovered, buried in the ground, a big pot. It was pretty old and it was made out of brass. "What a strange pot," he said to himself.
00:02:01		Child	I never [inaudible 00:02:02] it's a type of special of metal.
00:02:05	Use of props to support mathematical ideas Mathematical language 'how many' 'count them'	Storyteller	It's a special type of metal. Thank you for helping people to understand that. [inaudible 00:02:09] It's really heavy for Mr. Haktak because he was quite an old man. It's very heavy for him to carry home. And as he was carrying it home, struggling around the road, he dropped his purse and his last coins in it. Shall we see how many coins he's got in there? (Banging Sounds) Let's see. Could we count them?
00:02:33	Mathematical language	Children	One, two, three, four, five.

00:02:41	Story context	Storyteller	Poor Mr. Haktak. He's only got five coins left that he keeps in his purse. Because he didn't want to
	Use of props to support mathematical ideas		drop it again, he thought, "I'll just put it in the pot." (Clanging Noise) And off he went. And he carried
	Mathematical language		it home. Ugh! All the way home.
00:02:54	Story context	Child	It might have gave him a bad back.
00:02:57	Story context	Storyteller	It might have given him a bad back. Now, when he got home, Mrs. Haktak took one look at the pot
	Use of props to support mathematical ideas		and she said, "What a strange pot. That's no good to us! It's too small to cook in, I mean too big to cook in and too small to have a bath in. That's no good to us." She decided to have a little look at it,
	Mathematical language		in the pot. As she looked in, her hairband fell into the pot. Now she only had one hairband so she thought, "I better get it out." And she put her hand in and she felt around for the hairband. But she brought out…
00:03:34	Mathematical language	Children	Two.
00:03:35	Use of props to support mathematical ideas	Storyteller	Two hairbands. And she thought to herself, "That's really strange." So she had another look in the pot.
00:03:40	Story context	Child	It's a magic pot.
00:03:43	Story context	Storyteller	And she pulled out a purse with how many coins in?
00:03:47	Mathematical language	Children	Five.
00:03:48	Use of props to support mathematical ideas	Storyteller	And then, she put her hand in and she pulled out another purse. Exactly the same. Shall we see if it's also got five in?
00:04:01	Mathematical language	Children	One, two, three, four, five.
00:04:10	Mathematical language	Storyteller	So two purses, each with five coins in.
00:04:17		Child 1	Did my dad make (Overlapping Conversation)?

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00:04:18		Child 2	(Overlapping Conversation) pocket.
00:04:19	Story context	Storyteller	It might be a magic pot. Oh my goodness.
00:04:22	Mathematical algorithm: addition	Child	Five and five makes ten.
00:04:25	Mathematical algorithm: addition	Storyteller	Five and five does make ten. You were doubling it.
00:04:27	Mathematical algorithm: addition	Child	And now they've got ten coins.
00:04:29	Story context Problem posing	Storyteller	They have got ten coins. Now then, they were both really excited when they discovered what had happened. And Mrs. Haktak said, "I wonder if I put my coat in the pot, then when I look in the pot I might be able to take out one coat, two coats and then we'll both have a nice warm coat to wear in the winter." And that's what she did. So they put on their nice warm coats and they had an idea that if they put a cake in the pot, that when they put their hand in, they wouldn't just bring out one cake. They'd bring out…
00:05:07	Mathematical language	Child	Two cakes.
00:05:08	Problem posing: what if?	Storyteller	And if they put two bread rolls in the pot, when they put their hand in…
00:05:16	Mathematical error	Child	Ahhh! Three!
00:05:19	Mathematical error and correction	Storyteller	They might bring out three. But if they put two in, they take those two out, and how many more do they get out there?
00:05:23	Mathematical error and correction	Child	Four.
00:05:24	Mathematical language: 'double'	Storyteller	All together there would be four because there would be the two they put in and another two that the magic pot had made for them. So you can imagine they were really excited. But then they had the idea, that if they put their ten coins back in the pot, that the pot would make them twice as much money. It would make them double the money.
00:05:45	Mathematical language: 'double'	Child	(Gasp) Double.

00:05:46	Story context	Storyteller	So do you know what they did? All that evening, they kept putting the money in the pot, taking it out and then putting it back and taking it out, until the whole of their floor of their hut was covered with money. They had so much money, they were really rich.
00:05:59	Story context	Child	Uh oh.
00:06:01	Story context	Storyteller	Now then, early the next morning, Mr. Haktak set off not with a basket of vegetables to sell but basket full of gold coins. And he went off to the market to buy lots of new things for them.
00:06:14		Child	Yes, lots.
00:06:15	Story context	Storyteller	He bought so many parcels, they were stacked really, really high. And he couldn't see where he was going. So when he got to his front door, he used his foot and he kicked the door open. But, Mrs. Haktak had stood just behind the door by the pot. When he kicked the door open, the door hit her and she fell in the pot.
00:06:37		Child	Uh oh.
00:06:38	Story context Mathematical language: 'two more'	Storyteller	And her legs were just sticking out the top. Mr. Haktak thought, "Oh dear. I've knocked Mrs. Haktak in the pot." So he pulled her feet and pulled her out. But then they looked around and there were two more feet sticking out of the pot.
00:06:53		Child	No.
00:06:53	Story context Repetition of story phrases Use of props to support mathematical ideas	Storyteller	So they pulled, and they pulled, and they pulled, and they pulled, and they pulled, and they pulled, and out came another Mrs. Haktak. Well the first Mrs. Haktak was very cross. She said, "What would you need with two Mrs. Haktak's? I'm your wife. You don't need another Mrs. Haktak." She was very, very angry. She didn't really know what to do. Now Mr. Haktak was a little bit worried because she was so angry. So he moved away from her and he accidentally tripped and he fell in the pot.
00:07:23		Child	(Laughter)
00:07:26	Story context	Storyteller	So the two Mrs. Haktak's pulled him out of the pot. But then there were two more legs sticking out of the pot.

00:07:33		Child	(Laughter)
00:07:33	Story context	Storyteller	Now, who's that going to be?
00:07:35	Story context	Child	Another. Another Mr. Haktak.
00:07:39	Story context Mathematical language: 'how many'	Storyteller	Yeah. It was going to be another Mr. Haktak. So now, how many Mr. Haktak's have we got?
00:07:45	Mathematical language: 'two'	Children	Two.
00:07:46	Mathematical language: 'two'	Storyteller	Two. And how many Mrs. Haktak's have we got?
00:07:48	Mathematical language: 'two'	Children	Two.
00:07:49	Story context	Storyteller	But, this is the first Mrs. Haktak said, "Oh my goodness. Now our troubles are double." But then she had a very clever idea. She said…she looked at the Mrs. Haktak and she said, "We look exactly the same." And Mr. Haktak looked at Mr. Haktak and he said, "And we look exactly the same. So maybe because we look the same, we could be really good friends. We could even be like brothers and sisters." So (Overlapping Conversation)
00:08:18		Child	Maybe twins.
00:08:19	Story context	Storyteller	…they did. Or maybe twins, yes. Because twins are two of a set. So, they decided to use their money to build another hut, exactly the same.
00:08:31		Children	Uh oh.

00:08:33	Story context Actions to support story telling Use of props to support mathematical ideas	Storyteller	So they had one hut with the first Mr. Haktak and the first Mrs. Haktak living in it. And they had another hut exactly the same with the second Mr. Haktak and the second Mrs. Haktak. And they kept putting things in the pot until they had two of everything so that they both had exactly the same in their huts, except there was one thing different. In one of the huts was a big brass pot. And do you know? They were really careful never to fall in it again.
00:09:08	Problem Posing	Child	But may…they can't put a brass pot in another brass pot because it wouldn't fit.
00:09:15	Acknowledgement Accepting	Storyteller	No. That's true. It wouldn't. And that's (Overlapping Conversation).
00:09:20		Child	Just because they're that way.
00:09:23		Storyteller	If you try to put another one inside, you mean?
00:09:25		Child	You just have to put that way?
00:09:27		Storyteller	Yeah.
00:09:28	Problem Posing	Child	Or if she tried to put that in the same pot, it would be very, very tricky.
00:09:35		Storyteller	Uhm, yes.
00:09:36		Child 1	And it would…(Overlapping Conversation).
00:09:37		Child 2	What if we get two pots in a pot, it will be magic pots.
00:09:44	Problem Posing	Storyteller	If we did put two little pots in there and then took them out of the magic pot, how many pots would we have then?
00:09:49	Mathematical language: 'four'	Child	Four.
00:09:50	Mathematical language: 'four'	Storyteller	Four. We did, wouldn't we, because we'd have two (Overlapping Conversation) and two more.
00:09:51	Mathematical language: 'twenty'	Child	Or 20!

00:09:53	Problem Posing: what if?	Storyteller	What about if we put ten coins in?
00:09:57	Mathematical language: 'twenty'	Child	We'd have 20.
00:09:58		Storyteller	We would then, wouldn't we?

Appendix 10

Coding of oral mathematical story observation: The Greedy Triangle

Qualitative Analysis of data: Conceptual labels from open coding – Video recording of oral Mathematical Story telling The Greedy Triangle Lorraine 28 February 2013 audio file. Related video files: M2U00543 and VID00001.MP4. There is a group of approximately thirty reception class children and a visualiser with small straws is used to support abstract mathematical ideas. Lorraine refers to this use of visualiser in a small group interview where she reflects on experience telling oral mathematical stories with large and small groups. This telling is followed by play with playdough and straws.

Time code	Label to capture essence of description	Speaker	Transcript
00:00:00	Story context Building a story (co construction) Actions to support story telling/mathematical ideas Mathematical language: 'triangle' Mathematical language: metaphors	Storyteller	Once upon a time, there was a triangle. This triangle was so busy. He was always busy doing different things. He was busy being the roof on a house, a sail on a boat, a slice of pie, or half a sandwich. But the best thing that he liked to do was to get into the little space when people put their hands on their hips because that way he got to hear all their stories. And then he'd go back to all his shape friends and tell them all the fantastic stories that he had heard. And his friends loved it. But one day, he started to feel a little bit grumpy. Can you do grumpy faces?
00:00:49		Child	I don't know how.
00:00:54	Story context Building a story (co construction) Actions to support story telling/mathematical ideas	Storyteller	Now, he started to get a little bit bored of doing the same things every day. So he decided to go and see the Shape Wizard who lived on the other side of the hills. And he went up the hills and down the hills and up the hills and down the hills, all the way to the Shape Wizard's house where he knocked on the door. (Knocking Sounds) The Shape Wizard opened his door and he said, "Can I help you?" And the triangle said, "I'm so fed up with doing the same things all the time. I know that if I just had one

	Mathematical language: 'triangle'; 'rectangle; 'pentagon'; 'one more'' Mathematical language: metaphors Use of props to support mathematical ideas: visualiser Repetition of story phrases		more corner and one more side, I would be happy." Woosh! The Shape Wizard gave the triangle another side. And he became a rectangle. "I am so happy!" He went up the hills and down the hills and up the hills and down the hills, all the way home. He was so excited by all the new things he could do. He could be a tile on the floor, a tile on the wall. He could be a TV screen, a computer screen. He could be a picture frame or a window frame. After a while, he got a bit bored of doing the same things all the time. So guess what he did. He went to see the Shape Wizard who lived on the other side. And he went up the hills and down the hills and up the hills and down the hills and up the hills and down the hills and up the hills and down the hills, until he got to the Shape Wizard's house where he knocked on the door. (Knocking Sounds) The Shape Wizard opened up the door and said, "Can I help you?" And the rectangle said, "I'm fed up with doing the same things all the time. If I just had one more corner and one more side, I would be happy." Woosh! The Shape Wizard gave the rectangle another corner and another side and he became a five-sided shape called a pentagon.
00:03:02	Mathematical language: 'pentagon'	Children	Pentagon.
00:03:03	Story context Actions to support story telling/mathematical ideas Mathematical language: 'pentagon'; Mathematical language: metaphors Use of props to support mathematical ideas: visualiser Repetition of story phrases	Storyteller	He was so happy he went up the hills and down the hills and up the hills and down the hills and up the hills and down the hills, all the way back to his house. Now, now that he's a pentagon, there weren't so many things he can get to do. Sometimes he got to be a wall tile or a floor tile. But a lot of the time, he got to be a section on a football. Remember footballs, when you see them and they have the black and white pieces? Well if you look closely, what are those? It's a pentagon. And you know what? When he was a shape on a football, what used to happen to him all the time? Yes?
00:03:39	Error (not necessarily mathematical)	Child	He was black.
00:03:40	Mathematical language: 'one more'; 'hexagon'	Storyteller	He got kicked a lot and he didn't like that. So he went to see the Shape Wizard and he went up the hill and down the hill and up the hill and down the hill and up the hill and down the hill and up the hill

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	Use of props to support mathematical ideas: visualiser Repetition of story phrases		and down the hill, until he got to the Shape Wizard's house where he knocked on the door. (Knocking Sounds) The Shape Wizard said, "Can I help you?" And the pentagon said, "I don't like being a pentagon. If I had one more corner and one more side, I know that I would be happy." So, woosh! He became a six-sided shape, see if we can get it on the wall, called a hexagon.
00:04:32	Mathematical language: 'hexagon'	Children	Hexagon.
00:04:34	Mathematical language: 'hexagon'	Storyteller	Hexagon.
00:04:36	Mathematical language: 'hexagon'	Child	A wide hexagon.
00:04:38	Mathematical language: 'hexagon' Mathematical language: metaphors Use of props to support mathematical ideas: visualiser	Storyteller	It's a very wide hexagon because it can have some long sides and some short sides. Or they can have sides all the same length. Well he thought, "Oh, I like being a hexagon." So he went up the hills and down the hills and up the hills and down the hills and up the hills and down the hills, all the way back to his house where he got to be a floor tile, a wall tile. And you know what he liked to be best? Inside a beehive, you will find lots of hexagons. And they make up all the little spaces in the beehive. And the hexagon loved being part of a beehive because he could watch the bees buzzing about. Can we hear any bees buzzing?
00:05:19	Story context	Children	(Buzzing Sounds)
00:05:22	Story context Building a story (co construction) Actions to support story telling/mathematical ideas Mathematical language: 'triangle'; 'pentagon'; 'side'; 'corner'	Storyteller	And they buzzed in and they buzzed out. And it was so relaxing and so lovely that he forgot to go and visit his friends anymore. Friends started to go really sad. Any sad faces? And after a while, the hexagon started to miss his friends and he thought, "Actually I can't really remember why I didn't want to be a triangle." So he decided to go and visit the Shape Wizard. And he went up the hills and down the hills and up the hills and down the hills and up the hills and down the hills and up the hills and down the hills, all the way to the Shape Wizard's house where he knocked on the door. (Knocking Sounds) The Shape Wizard said, "Can I help you?" And the hexagon said, "I just want to be a triangle

	Use of props to support mathematical ideas: visualiser Repetition of story phrases		again." And so, woosh! Off flew one side and one corner and he became a pentagon. Woosh! Off flew another side and another corner and he became a….
00:06:31	Mathematical error	Child	Square….
00:06:33	Mathematical error and correction (in this sequence it was a rectangle though in another story it could be a square)	Storyteller and Children	A rectangle.
00:06:35	Mathematical language: 'side'; 'corner'	Storyteller	Woosh! Off flew another side and another corner and he became….
00:06:45	Mathematical language: 'triangle'	Children	Triangle.
00:06:45	Mathematical language: 'triangle'	Storyteller	And the triangle said, "I'm just so happy to be me."
00:06:53		Children	It's The End.
00:06:55	Story context	Storyteller	That's right. The End. I'm so glad you were watching so closely. You noticed that I did something wrong, that's so brilliant because I can learn from that because making mistakes is a great way of learning, isn't it? The End.
00:07:09	Story context	Children	The End.
00:07:10	Story context	Storyteller	I did the opposite, didn't I? I did, "Once upon a time…."
00:07:15	Story context	Child	I thought that you went, "Once upon a time," and then you told the story. And then you forgot to say the end.
00:07:21	Story context	Storyteller	I put the beginning at the end, didn't I? That wasn't right.
00:07:24	Story context	Child	I thought you were doing another story.

| 00:07:26 | Story context | Storyteller | I could have done, couldn't I? Straight into another story. But I haven't got another story yet. I'll know one for next week. |

Appendix 11

Coding of oral mathematical story observation: Dinosaur

Qualitative Analysis of data: Conceptual labels from open coding – Video recording of oral Mathematical Story telling Dinosaur Story 21 March 2013 Lorraine video file M2UOO554. Note: edited audio recording used for transcript. There is a group of eight reception class children.

Time code	Label to capture essence of description	Speaker	Transcript
00:00:00	Story context	S1	So I've got a little story for today. Once upon a time…
00:00:07	Story context	S2	Once upon a time…
00:00:08	Building story (co construction)	S1	…there was a little dinosaur, what would he be called?
00:00:11	Story context	S2	There was a little dinosaur.
00:00:12		S1	Oh should… would you like to listen to it and then we can maybe do it together afterwards.
00:00:17		S2	Okay.
00:00:17	Building story (co construction)	S1	So once upon a time there was a little dinosaur what can we call him?

00:00:19		S2	Um…
00:00:20	Building story (co construction)	S3	Jack!
00:00:21	Building story (co construction)	S1	Jack! Jack? Jack-o-saurus?
00:00:24	Building story (co construction)	S3	Jack-o-saurus.
00:00:25	Story context	S1	Also… once upon a time, there as a little tiny dinosaur named Jackosaurus and the thing that Jack-o-saurus loved to do is to jump. Every day, he would go down by the river and he would jump…
00:00:42	Repetition of story phrase	S2	And jump…
00:00:43	Repetition of story phrase	S1	… and jump and jump!
00:00:44	Repetition of story phrase	S2	… and jump, and…
00:00:45		S1	And he especially liked to try…
00:00:48		S2	I got the toy.
00:00:49	Actions to support story telling	S1	… and catch dragonflies. When he saw a dragonfly he would jump and jump…
00:00:59	Repetition of story phrase	S2	… and jump…
00:00:59	Repetition of story phrase	S4	… and jump…
00:01:00	Engagement	S1	… and jump to try and catch it. They'd fly higher in the air and he just couldn't catch them. One day, he is down by the river and saw a dragonfly fluttering. So he jumped…
00:01:17	Repetition of story phrase	S2	Jumped…
00:01:18	Repetition of story phrase	S3	…and he jumped…
00:01:18	Repetition of story phrase	S4	…and he jumped…
00:01:18	Repetition of story phrase	S5	…and he jumped…

00:01:18	Repetition of story phrase Actions to support story telling	S6	…and he jumped…
00:01:21	Repetition of story phrase Actions to support story telling	S1	…and he jumped! But the dragonfly flew very quickly into the forest. So he decided to chase it and he ran, he ran…
00:01:30	Repetition of story phrase	S2	He ran…
00:01:30	Repetition of story phrase	S3	He ran…
00:01:30	Repetition of story phrase	S4	He ran…
00:01:30	Repetition of story phrase	S5	He ran…
00:01:34	Repetition of story phrase	S1	And he ran…he still didn't catch it so he ran and he ran…
00:01:36	Repetition of story phrase	S2	…and he ran…
00:01:36	Repetition of story phrase	S3	…and he ran…
00:01:36	Repetition of story phrase	S4	…and he ran…
00:01:36	Repetition of story phrase	S5	…and he ran…
00:01:40	Repetition of story phrase	S1	…and he ran. Still didn't catch it. Just run a bit faster now. And he ran
00:01:43	Repetition of story phrase	S2	And he ran…
00:01:43	Repetition of story phrase	S3	And he ran..
00:01:43	Repetition of story phrase	S4	And he ran…
00:01:43	Repetition of story phrase	S5	And he ran…
00:01:45	Repetition of story phrase	S1	And he ran…
00:01:45	Repetition of story phrase	S5	And he ran…

00:01:45	Repetition of story phrase	S4	And he ran…
00:01:45	Repetition of story phrase	S2	And he ran…
00:01:45		S3	(Laughter)
00:01:48	Use of props to support story and mathematical ideas Problem posing: what if?	S1	(Gasped) All of sudden he tripped over. Oh my goodness, he didn't see the two dinosaur nests and he tripped over and knocked all of the eggs out of the nest! "Oh no!" he said. What if a really scary big dinosaur comes back and I've knocked over the nest and he might eat me. So he just thought… What do you think he needs to do?
00:02:18	Problem solving (story context)	S4	Run out off the forest.
00:02:19	Acknowledgement (rejected)	S1	Run out off the forest? He could run out off the forest.
00:02:22	Problem solving (story context)	S2	Put them back in.
00:02:24	Acknowledgement (accepted)	S1	Put them in? Okay, should we put them in? How are we going to know where to put them?
00:02:29		S5	Ah…
00:02:30			(Overlapping talking)
00:02:33		S4	[inaudible 00:02:33]
00:02:35		S3	I didn't have any.
00:02:36		S1	You didn't have any, well in a minute.
00:02:37		S5	Me either.
00:02:38	Prompting other possibilities: complements for number eight	S1	We might… we might see if we can put them in, in a different way and then… would you like to have a go at it? So.

00:02:42			(Overlapping talking)
00:02:45	Prompting of recording to support recall	S1	We do the [Inaudible 00:02:45] they do look like dinner bowls really but we are pretending they are nests. Now so you put the eggs back in the nest for him but then he thinks "Oh I can't remember how many were in each nest." How many have we put in each nest?
00:03:01		S4	Um…
00:03:02	Mathematical language	S1	Would you count it for me?
00:03:03	Mathematical language	S4	Three.
00:03:03	Mathematical language	S3	Three.
00:03:04		S2	Um…
00:03:06	Mathematical language	S3	Six.
00:03:06	Mathematical language	S4	Six.
00:03:09	Mathematical language	S2	Actually five because I counted five
00:03:11	Strategy for checking	S1	Well done for doing that careful counting, it's always worth checking isn't it, when we're counting.
00:03:15	Mathematical language Mathematical algorithm: addition	S2	But all together… there were eight…
00:03:17	Mathematical language	S3	Eight…
00:03:18	Mathematical language	S4	…eggs. Eight.
00:03:21	Mathematical language: addition	S1	So we have got eight altogether…
00:03:23		S2	Um…
00:03:24	Mathematical language	S1	…three in this nest and…

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00:03:26		S4	(Cough)
00:03:27	Mathematical language	S1	… five in that nest.
00:03:28	Mathematical language	S3	Eight!
00:03:28	Mathematical language: addition	S1	Eight altogether.
00:03:28	Mathematical language	S2	Eight.
00:03:30	Prompting other possibilities: complements for number eight	S1	Now Jackosaurus is feeling a little bit worried because he said "Well yeah, it could be three in one nest and five in another. But it might be a different way."
00:03:40		S3	[inaudible 00:03:40]
00:03:41	Prompting other possibilities: complements for number eight	S1	Think Lexie [Inaudible 00:03:41] what could it be differently.
00:03:44		S4	Um…
00:03:45		S6	[Inaudible 00:03:45]
00:03:46	Problem solving: child suggests mathematical idea	S2	I think that one of them in another nest.
00:03:49	Use of props to support mathematical idea	S1	In another nest, what do you mean? Could you show me? Oh what have you done now?
00:03:59	Mathematical language Actions to support mathematical idea	S4	Put one, two, three, four in one nest…
00:04:03	Mathematical language	S3	Four!
00:04:03	Mathematical language	S4	… and one, two, three, four in the other nest.

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00:04:06	Mathematical language: addition	S3	That makes eight!
00:04:07	Mathematical language: addition	S1	Ah, and that makes eight.
00:04:08		S4	Oh yeah!
00:04:09	Facilitating mathematical explanation	S1	So do you think that would be a really good way of putting them in? Why do you think that's such a good way of putting them in?
00:04:17	Mathematical language : child offers explanation	S3	Because they both have four.
00:04:19	Problem solving: sharing of clipboards (social skills) Prompting of recording to support recall	S1	Because they got four, they are equal aren't they, they are both the same. So we've got two different ways then. I'm going to find it hard to remember all of these ways that we're finding of putting eggs in the nest. Could anybody just note them down for me, if anybody wants... I haven't got... because I didn't think... I've only got four clipboards so I wonder if we could share them a little bit for me.
00:04:41		S5	Okay [inaudible 00:04:42]
00:04:43		S4	[Inaudible 00:04:43]
00:04:46	Problem solving in different context: sharing (Social skills)	S2	I'm going to share with Netta.
00:04:48		S1	Okay, Netta, do you want to go and sit with [inaudible 00:04:51].
00:04:50	Mathematical language: multiplication	S5	Four times four.
00:04:53		S4	And then I'll go back again…
00:04:54			(overlapping talking) I did a mistake (one child)
00:05:01		S1	That's alright.
00:05:02		S4	Yeah.

00:05:02	Strategy (prompting thinking about errors)	S1	What did I say about mistakes? Do you remember what we said about mistakes earlier?
00:05:04		2S	Um…
00:05:07			(overlapping talking)
00:05:07	Strategy for checking (prompting thinking about errors)	S1	When we make mistakes that's often when we learn something new…
00:05:09	Mathematical language: addition		(overlapping talking) four and four
00:05:11	Recall of ideas through story speech	S1	Does anybody remember, before we did four and four, we had another way of putting the eggs in the nest.
00:05:15		S2	[Inaudible 00:05:16] add
00:05:16		S3	[inaudible 00:05:16]
00:05:16		S4	Ah….
00:05:16		S1	That's an amazing word!
00:05:17	Mathematical language: addition	S5	Add.
00:05:18	Mathematical language: addition	S1	Add. That's another amazing word.
00:05:22		S2	[Inaudible 00:05:22]
00:05:23	Mathematical language	S4	Equals.
00:05:26	Mathematical language	S1	Equals, you're remembering all that learning we've been doing about…
00:05:29		S3	[inaudible 00:05:29]
00:05:30	Mathematical language	S1	Writing calculations [inaudible 00:05:31]

00:05:33			(overlapping talking)
00:05:34	Mathematical language Recall of ideas through story speech	S1	Before we had four in one nest and four in the other, can you remember what we had before that?
00:05:39	Mathematical language	S3	Fives. No.
00:05:39	Mathematical language: addition	S4	Five and three.
00:05:41	Mathematical language	S5	Three of the other.
00:05:44	Prompting of recording to support recall	S1	Ah maybe we should note that way down as well.
00:05:45			(Overlapping talking)
00:05:49		S2	What was that?
00:05:50	Mathematical language	S1	I think they have three in one and five in the other.
00:05:53	Mathematical language	S4	Equals, equals.
00:05:55	Mathematical language: addition	S5	Because four plus four equals eight!
00:05:59		S1	It does, so…
00:06:01			(Overlapping talking)
00:06:01	Problem posing: What if?	S1	… Jackosaurus looked at the four eggs in one basket… in one nest. And the four eggs in the other nest and he thought to himself "Oh but what if this isn't right? What if this isn't… what if one dinosaur had more eggs in their nest than the other one ?"
00:06:13		S6	(Cough)
00:06:19	Mathematical language	S3	It's Really hard to write a three.
00:06:22	Mathematical language	S1	Really hard to write a three?

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00:06:22		S4	No it isn't.
00:06:23		S2	I… I found it easy. It's just like this.
00:06:29		S4	[Inaudible 00:06:29]
00:06:30		S1	That's it? Just play around with it and see what happens.
00:06:33		S2	I can't remember the other one.
00:06:37	Problem posing: what if? Prompting other possibilities	S1	But he's really worried because he found two ways but he's just wondering if… they are the only two ways of putting these eggs back into the nest.
00:06:43		S4	No.
00:06:44			(Overlapping talking)
00:06:45	Prompting other possibilities	S1	Do you think there might be different way, Jessica…
00:06:46	Problem posing: what if? Child posing problem with story context		(Overlapping talking) what if it's not the same problem?
00:06:46	Problem posing: what if? Story context	S4	[Inaudible 00:06:46] What if it's not the same dinosaur.
00:06:48		S3	I forgotten the way that you did before.
00:06:51	Mathematical language	S1	With three in one and five in the other.
00:06:54	Problem posing: what if? Child posing problem with story context	S3	But what if it's the same dinosaur?
00:06:58	Mathematical language: addition	S2	Three and five.

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00:07:02		S3	[inaudible 00:07:03]
00:07:03	Mathematical language: addition	S5	Three and five.
00:07:05	Facilitating mathematical explanation	S1	What have you got now, Jessica.
00:07:05	Mathematical language	S5	Five. Three, five.
00:07:07		S2	[inaudible 00:07:07]
00:07:09	Mathematical language	S1	We've got three in this one and five in that one.
00:07:12	Commutative principle (addition)	S5	Because last time there was five with that one and…three in that one
00:07:14		S4	Oh I need to do the [inaudible 00:07:15]
00:07:17	Commutative principle (addition)	S1	Oh so you swapped it over.
00:07:19		S4	Look what I did.
00:07:20		S3	[Inaudible 00:07:20]
00:07:20		S1	What have you done there, do you know what that's called? It's a question mark.
00:07:25	Mathematical language	S3	[Inaudible 00:07:24] eight.
00:07:26		S4	It's a question to the story.
00:07:28		S1	A question for the story.
00:07:30			(Overlapping talking)
00:07:46	Use of props to support mathematical idea Mathematical language	S5	I can't say, one, two, three…

00:07:48		S1	[Inaudible 00:07:48]
00:07:51	Mathematical language	S5	… five!
00:07:51	Mathematical language	S1	Five in this one now.
00:07:52		S5	Um…
00:07:53	Facilitating mathematical explanation: addition	S1	How many all together?
00:07:55	Mathematical language	S5	It's eight
00:07:55	Mathematical language: addition	S1	Eight altogether.
00:07:57		S2	Um…
00:07:58	Story context (emotion) Prompting other possibilities: more ways	S1	So, Jack-o-saurus is still very worried and Netta [inaudible 00:08:03] what if there are more ways…
00:08:02		S	(overlapping talking)
00:08:05	Prompting other possibilities: more ways	S1	…more ways of doing it.
00:08:06		S2	(Overlapping talking)
00:08:07	Mathematical language	S3	I like to do the three first because then [inaudible 00:08:10]
00:08:10	Prompting other possibilities: more ways : child using language of possibility	S2	More ways.
00:08:11			(Overlapping talking)

00:08:12		S1	Okay. If we are finding it hard to share, what could we say to each other?
00:08:17		S4	[Inaudible 00:08:19].
00:08:12		S1	So Austin if you write that…
00:08:23		S4	Um…
00:08:23		S1	Okay, and then hand it… would you hand this to Jessica then and the clipboard.
00:08:28			(Overlapping talking)
00:08:30		S1	You do it the way [inaudible 00:08:31]. Next time I'll bring more… more clipboards. It's hard to share something when you're, when you're writing on it, isn't it?
00:08:40			(Overlapping talking)
00:08:43	Mathematical language: addition	S1	I can really see. I think… Jessica, what… what made you want to do the three on that side and five on the other side.
00:08:50	Mathematical language: addition	S2	Because there's three on that and five on that.
00:08:54	Mathematical language: addition	S1	You wanted to do the same way, the three first and then the five.
00:08:59	Mathematical language	S2	And then it's more [inaudible 00:09:01]
00:09:00			(Overlapping talking)
00:09:03	Mathematical language	S1	There's more here.
00:09:05			(Overlapping talking)
00:09:07		S1	There are.
00:09:07			(Overlapping talking)
00:09:11		S1	There actually [inaudible 00:09:12]

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00:09:13		S2	[Inaudible 00:09:13]
00:09:15	Problem solving: adult suggestion	S1	We could put one line through it, cross it out.
00:09:17			(Overlapping talking)
00:09:20	Problem posing: what if? story context	S3	What if they are not the same dinosaur… if they're not same dinosaur?
00:09:26	Problem posing: what if? story context	S1	What about if they're not the same dinosaur? What would we need to do?
00:09:30		S3	They need [inaudible 00:09:31] same dinosaur [inaudible 00:09:34]
00:09:34			(Overlapping talking)
00:09:38	Problem solving: story context	S4	We have to crack them open.
00:09:40		S1	Crack them open, oh.
00:09:42		S6	[inaudible 00:09:43].
00:09:45	Problem solving: story context	S2	Crack!
00:09:47	Acknowledgement: rejecting child's suggestion	S1	You better not break the eggs because the dinosaur would be really cross then when he comes back or when she comes back. Yeah.
00:09:51			(Overlapping talking)
00:09:54	Commutative principle of addition a+b=b+a	S1	… Jackosaurus. The Jackosaurus knows that it can be three and five or three in that one and five in that one and knows that it can be four in each. But he's really worried.
00:10:04			(Overlapping talking)
00:10:05	Mathematical language	S4	…four in each.

00:10:06	Prompting other possibilities: 'more ways'	S1	It could be just four in each. But he's really worried and he thinks he would really like some help to see if there are any other ways of sharing the eggs out.
00:10:14		S3	No. There are.
00:10:14	Prompting other possibilities: 'more ways'	S1	What do you think [inaudible 00:10:15]?
00:10:19	Use of props to support mathematical idea	S6	We might need to put…
00:10:26	Facilitating mathematical explanation	S1	What have we got now?
00:10:29	Mathematical language: addition Mathematical error	S6	Um… Two plus five in that one
00:10:34	Mathematical language: addition Mathematical error	S3	Two and five. Two and five.
00:10:36	Mathematical error: adult aware	S1	It's two five? So we have three and five.
00:10:40	Problem posing: what if?	S2	If we… what if we [inaudible 00:10:45]
00:10:44			(Overlapping talking)
00:10:45	Mathematical language	S1	It's more in that one.
00:10:46	Commutative principle addition child suggesting a +b=b +a	S2	What if it we… if it's the wrong way around, so I have to swap it and it might [inaudible 00:10:54] over there and they might get [inaudible 00:10:56]
00:10:57	Acknowledging: accepting suggestion a +b=b +a	S1	You mean, so when we've tried these in this one and these in this one then we need to swap them because it might be the wrong way around, it might be.
00:11:04		S2	Yeah.

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00:11:05	Mathematical error: adult returns to address mathematical error	S1	But [inaudible 00:11:07] you didn't think it was five in this did you?
00:11:10		S3	It might be…
00:11:10	Strategy for checking	S1	Do you want to see how many there are in there?
00:11:11		S4	[inaudible 00:11:11]
00:11:13		S5	Um…
00:11:14		S1	Let's see, let's just finish this one first, my lovely. That's it.
00:11:17			(Overlapping talking)
00:11:18	Mathematical language	S1	Pete is just doing some counting. [Inaudible 00:11:20] they will get?
00:11:20	Mathematical language Mathematical error	S4	Seven!
00:11:22	Mathematical error: challenges error	S1	Is it seven?
00:11:22		S4	No.
00:11:23	Strategy for checking	S1	Do you remember when we're doing careful counting, it's always worth checking…
00:11:26	Mathematical language	S5	One, two, three, four, five, six.
00:11:32	Mathematical language	S1	[Inaudible 00:11:32] six, okay. Okay.
00:11:37	Mathematical language Mathematical error	S3	Seven.
00:11:38	Strategy to check (probing)	S1	Do you know what I think might be easier, because you know when things are all in a bit of a bundle. It's quite hard to count. What sometimes makes it easy to count is…
00:11:47	Mathematical language	S2	Six.

00:11:48	Strategy for checking	S5	Put them in a straight line.
00:11:48	Strategy for checking	S1	Put them in a straight line.
00:11:49	Mathematical language	S2	It's six.
00:11:49	Strategy for checking	S1	Is it six? Yeah. Shall we check by putting them in a straight line?
00:11:56	Generalising (possibly) Commutative principle: child suggesting a +b=b +a	S4	Um… we need to swap them around.
00:11:59	Commutative principle (addition) a +b=b +a	S1	And then we need to swap them around.
00:12:00	Story context	S2	We need to be quick. The big dinosaur is coming.
00:12:02	Story context	S1	Big dinosaur might be coming, yeah. In fact, can you hear that thudding?
00:12:07	Story context	S2	It's the dinosaur.
00:12:19		S1	(whispering)
00:12:10	Mathematical language	S3	Six.
00:12:12	Mathematical error : correction	S1	Six, it is six.
00:12:13			(Overlapping talking)
00:12:14	Mathematical language	S1	So we have got six and how many in that one?
00:12:16	Mathematical language	S2	Two.
00:12:17	Mathematical language	S3	Two.

00:12:17	Mathematical language: addition	S1	Two. So how many altogether?
00:12:20	Mathematical language	S4	Eight.
00:12:20	Mathematical language	S6	Eight.
00:12:20	Mathematical language Facilitating mathematical explanation	S1	Eight? Six and two? Eight altogether. What else did you say we needed to do, Austin?
00:12:26	Generalising (possibly) Commutative principle: child suggesting a +b=b +a	S5	Swap them around.
00:12:27	Mathematical language: commutative principle addition	S1	Swap them around, go on then because, as well as six or two you can have…
00:12:33		S3	(Whispering)
00:12:34	Mathematical language Mathematical connection: commutative principle addition Generalising (a +b=b +a)	S4	Two and six.
00:12:36	Mathematical language	S1	Two and six, it still makes eight!
00:12:38	Mathematical language	S3	Eight!
00:12:40	Mathematical language	S1	It does, doesn't it, it still makes eight.
00:12:42		S5	[inaudible 00:12:42]
00:12:42	Story context	S1	Oh that thudding is getting louder (gasp)

00:12:47	Story context	S2	Thud, thud, thud.
00:12:48	Story context	S1	Oh it is getting louder, I can hear it.
00:12:49	Story context	S2	Thud, thud, thud.
00:12:51	Problem posing	S1	What are we going to do? What we are going to do, Jackosaurus is really worried now.
00:12:54		S6	I know.
00:12:55		S1	What do you think?
00:12:56	Mathematical language Problem solving: story context	S6	Four and four and then we can run away.
00:12:59	Mathematical language Problem posing: story context	S1	Four and four and then we can run away. Do you think that's the fairest way of doing it, go on the Sarah.
00:13:04		S4	I think we need to check if they are the right dinosaur.
00:13:08	Problem posing: story context	S1	Okay but how we are going to check if they are the right dinosaurs?
00:13:11	Problem solving: story context	S4	Smash it open…
00:13:13	Acknowledgement: rejecting (Story suggestion not accepted)	S1	Oh, you can't smash an egg.
00:13:15	Problem solving: story context	S4	But we can put them back.
00:03:18	Acknowledgement: rejecting (Story suggestion not accepted)	S1	Not if they're smashed.
00:13:20		S4	Yeah.
00:13:21	Problem solving: story context	S3	Although, we could just say...

00:13:22	Story context	S1	Is that dinosaur coming?
00:13:25	Problem solving: story context	S3	Yeah [inaudible 00:13:25] just run away!
00:13:29	Problem solving: story context	S2	Run away (laughter)
00:13:29	Problem solving: story context	S3	I know (Overlapping talking)
00:13:33	Problem solving: story context	S2	Stay there until the dinosaur comes and say sorry.
00:13:37	Acknowledgement: accepting (Story suggestion accepted)	S1	Aw, that's sounds like a really lovely thing to do. Jackosaurus would stay and say sorry. Do you think dinosaurs will understand?
00:13:44		S4	No.
00:13:44		S5	No.
00:13:45		S3	No.
00:13:45	Acknowledgement: accepting (Story suggestion accepted)	S1	But I think that's a really lovely idea.
00:13:48		S5	[inaudible 00:13:48]
00:13:48	Problem solving: story context	S3	Every single dinosaur could actually understand because they're all the same language.
00:13:52		S1	Oh, so a dinosaur can understand another dinosaur?
00:13:55		S2	No.
00:13:56		S1	I think.
00:13:56		S4	Yeah.
00:13:57	Problem solving: (moral discussion)	S1	If we… if we broken something or done something, we would wait to say sorry wouldn't we, that's definitely something that human beings would do.

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00:14:03	Problem solving: story context	S5	We'll say sorry.
00:14:05		S1	Yeah, you're quite right.
00:14:06		S3	They don't understand.
00:14:07		S1	You don't think dinosaur would understand?
00:14:09		S3	Um…
00:14:10		S4	Yes they will.
00:14:10	Problem solving: story context	S2	They won't understand our language.
00:14:12		S1	No they wouldn't understand our language. Do you think they understand…
00:14:15	Story context	S4	It's getting louder.
00:14:15	Story context	S1	It's getting louder?
00:14:19	Story context	S4	Yeah, louder.
00:14:20	Story context	S3	Quick, quick, hide!
00:14:21		S4	(Laughter)
00:14:22	Repetition of story phrase Actions to support storytelling	S1	Right, so what does Jack-o-saurus do? He runs, and he runs, he runs, and he runs…
00:14:23	Repetition of story phrase Actions to support storytelling	S2	And he runs.
00:14:23	Repetition of story phrase Actions to support storytelling	S3	And he runs.
00:14:23	Repetition of story phrase Actions to support storytelling	S4	And he runs.

00:14:27	Repetition of story phrase Actions to support storytelling	S3	[Inaudible 00:14:26] faster! It's getting louder.
00:14:29	Repetition of story phrase Actions to support storytelling	S1	Faster! And he runs, and he runs…
00:14:29	Repetition of story phrase Actions to support storytelling	S1	and he runs.
00:14:29	Repetition of story phrase Actions to support storytelling	S1	Oh, it's getting louder, it's getting louder. It's getting louder.
00:14:34	Problem posing: story context	S3	What about the dragonfly?
00:14:36	Problem posing: story context	S1	Oh, where's the dragonfly now?
00:14:38	Problem solving: story context	S3	Up there!
00:14:38	Acknowledgement: accepting	S1	Up there? Shall we go, let's just jump. Jump!
00:14:41			(Jumping) Eat it up.
00:14:43		S1	Has he eaten it?
00:14:44		S3	Yes.
00:14:45	Mathematical language	S1	Oh just one… has he just eaten one?
00:14:47	Mathematical language	S4	Yes. Two.
00:14:48	Mathematical language	S1	Oh there's another one, quick jump!
00:14:49			(Jumping) (grunt)
00:14:50		S5	I catch them.
00:14:51		S2	I catch it.

00:14:51	Mathematical language	S1	How many now?
00:14:52	Mathematical language	S4	Nine!
00:14:53	Mathematical language	S3	Ten!
00:14:54	Mathematical language	S1	Ten? You've eaten ten?
00:14:54		S3	Yeah.
00:14:54		S4	Yeah.
00:14:55	Story context	S3	Quickly! It's getting even louder.
00:14:56	Story context	S1	Oh it's getting nearer, it's getting nearer, it's getting nearer. (gasp) quick!
00:15:01		S3	There's a fly
00:15:01		S1	Jackosaurus….it's a fly, another dragonfly, quick jump up and eat it.
00:15:06			(Jumping) (grunt)
00:15:08			(Overlapping screaming)
00:15:10	Problem solving: story context	S3	I know. Go there and then run home and he might not see us.
00:15:17		S1	Right so, what are we going to do?
00:15:18	Problem solving: story context	S2	[inaudible 00:15:21] climbed up in a tree?
00:15:21	Acknowledgement: accepting	S1	Hide up in a tree?
00:15:21		S4	Yeah.
00:15:22		S5	(Laughter)
00:15:23		S1	Quick hide! Hide! Hide!

00:15:26		S3	[Inaudible 00:15:25] I'm perodactyl.
00:15:29		S1	Okay, you're climbing up in a tree because you're a perodactyl.
00:15:30			(Grunt)
00:15:31		S1	Are you going to climb [inaudible 00:15:31]
00:15:34			(Overlapping talking)
00:15:34		S1	Sonny is hiding, I can't see Sonny.
00:15:36			(Overlapping talking)
00:15:38		S1	You're climbing.
00:15:40		S2	I'm, I'm…
00:15:41			(Overlapping screaming and talking)
00:15:49		S4	They can't see us.
00:15:50	Mathematical language	S1	The big dinosaur arrived and he looked at the nest and he counted the eggs, one, two, three, four and he counted the other nest, one, two, three, four. He sat on the nest and went to sleep.

Appendix 12

Story as the mathematical servant

Little Lumpty: reflective account 15 December 2012

These story tellings connected counting in multiples of two to an adapted version of Little Lumpty.

I think at the heart of this project is a need to teach mathematical ideas in a playful way. However the work involves working with teachers who are governed by a curriculum which can be interpreted by some educators in an instrumental rather than relational way. I note how subsequent story experiences with Little Lumpty are less playful and more instrumental particularly the last one of the series of three; a hundred square was included in response to a suggestion by the year one class teacher. The first telling involved adult scaffolding but what I need to do is to remove some of the structure and open it out to a more playful problem posing approach; so that the story is not the servant to mathematics.

It is about teaching mathematics in a creative way which combines oral story and mathematical ideas. What I have achieved is the connection of an oral story to mathematics and encouraged children to think of mathematical ideas connected to the story narrative. This is evident in the mathematical conversations which followed the main oral story (audio recordings 23.11.2012 and 30.11.2012). What I failed to achieve in the third telling is playing with mathematical ideas while telling the story.

The playful telling requires a relationship being established between the oral storyteller and the children so that together the story is co-constructed. It requires a confidence in terms of connecting with mathematical ideas which may evolve. This may be easier with small groups. In line with the Pie Corbett model for literacy there needs to be a focus on the innovation and invention of stories by playing with the plot.

Appendix 13

Oral Mathematical Story Project

Repeated phrases + simple structure enables children to take over more easily.

What are the issues around the use of oral story to facilitate children's mathematical thinking?

- Size of group. Large groups mean that the storytelling process loses some of its intimacy and I think children are less likely to take over the storytelling.
- How much to let children take over — losing the mathematics or changing it?
- Taking risks — more powerful if we are not trying to control the mathematical outcome.
- Space and time — e.g letting children take their shoes off, sit on cushions — making it special. Repeating the same story is valuable.

What have you noticed about how children respond to oral mathematical storytelling?

I have been amazed at children's responses — it has been important to have repeated phrases so that chn. can join in from the outset.

Two of Everything — I was amazed by how quickly the children understood the concept of doubling.

Children respond in more detail when in a small group. 'hildren often add their own actions.

Two of Everything . mystery of what will come out of pot had children particularly engaged.

What impact does oral mathematical story telling have on your experience as a teacher?

I have learnt to let go of my control! When I have done any storytelling in the past it has been storyteller / story listeners. This has helped me realise that it is a living interactive relational experience which is creative, exciting and unknown. I have grown in confidence from a teacher who stuck to traditional tales to being able to create my own stories based on mathematical concepts, confidently telling them with just a simple story map as a prompt. I have also realised that I have underestimated some children — being surprised by the storytelling confidence displayed by children such as Lee / Freya who are v. quiet in whole class storytelling - P.T.O

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When I first began working on this project I would get really anxious about the storytelling

Now I feel confident about adapting and creating my own stories and feel I will use this a lot more to introduce mathematical concepts.