PRESCHOOL COUNTING: WHAT DEVELOPMENT IN UNDERSTANDING OF COUNTING LOOKS LIKE FOR A CHILD DURING THE NURSERY YEAR

by

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ABSTRACT

This study aims to expand the current literature by exploring how counting develops for the children in this study over the preschool nursery year. An embedded case study approach (Yin, 2009) was used to address the aim. Three data-collection methods were used; task-based interviews with children, interviews with parents and documentary evidence.

The individual trajectories of the seven children in the study were tracked over a year-long period using Gelman and Gallistel's (1978) principles of counting. This research contributes to current knowledge as analysis of the individual trajectories led to the identification of four phases of development in counting. In each phase, children develop specific counting skills and children appear to demonstrate these skills at a similar point in their developmental trajectory. The findings of this study are generated from a very specific group and there is no suggestion that the findings of this study are generalisable to a larger population of learners. However, they contribute to the body of research by providing a conceptual framework which builds on our understanding of how children's counting develops during the preschool nursery year.

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LIST OF ABBREVIATIONS

BERA - British Education Research Association

CAWL – The Commission on Assessment without Levels

EPPE - The Effective Provision of Preschool Education Project

EYFS - Early Years Foundation Stage

DfE – Department for Education

PSRN – Problem solving, reasoning and numeracy

HNE – Home numeracy environment

SES - Socioeconomic status

CHAPTER ONE - INTRODUCTION

1.1 Introduction and rationale

I first became interested in early counting when working as a classroom teacher. I was teaching four and five-year olds in a very deprived area of Central London where many of the children started school with little or no English. I was fascinated with the range of counting ability the children demonstrated, even at such a young age. As I moved on to teach older year groups in the same school, I found that those children who had struggled with counting in the Early Years were the same children who struggled to grasp mathematical concepts later on. As a classroom teacher I also found that I received lots of training and had access to a wide range of materials to support my teaching of early literacy skills. However, I found that there was less support for my teaching of early mathematics.

Counting is widely thought to be a prerequisite for other mathematical skills, such as addition and subtraction (Briars and Siegler, 1984). Research supports this and indicates that counting ability provides the best predictor of more general mathematical performance (Aunola *et al.*, 2004). It is argued that this is because competence in basic number skills, such as counting, allows children to improve their competence in solving more challenging problems because they are able to focus their attention on the more complex problem solving (Resnick, 1989).

There is a range of research identifying the relationship between children's preschool experiences and their future outcomes. A large-scale study in the UK, 'The Effective Provision of Preschool Education Project' (EPPE), drew a number of conclusions about children's experiences prior to starting school (Sylva *et al.*, 2004). The project concluded that

preschool experience enhances children's intellectual development during the early years of primary school, particularly for disadvantaged children. Also, it was found that an earlier start to preschool (before three years old) related positively on intellectual development at the ages of six and seven. Another significant finding was that a good quality home learning environment related positively on children's intellectual development and was more important that social class (Sylva *et al.*, 2004). Researchers have also demonstrated that children's early mathematical skills on entry to school can predict their later school achievement (Duncan *et al.*, 2007). Research in Germany found that the effects on numeracy development of preschool experience are still evident when children reach the age of seven, even when the children's family background and home learning environment were controlled for (Anders *et al.*, 2013). There are many reasons why children arrive at school with a wide range of mathematical skills. Firstly, more children are attending early education settings prior to starting school (Hinkle, 2000; Doig, McCrae and Rowe, 2003; Barnett *et al.*, 2006). Secondly, children's socioeconomic status has been shown to relate to their mathematical knowledge (Starkey, Klein and Wakeley, 2004; Thomson *et al.*, 2005; Klibanoff *et al.*, 2006). Thirdly, differences have been found between different social groups, such as boys and girls (Cockcroft, 1982).

One thing that makes learning to count difficult is that counting has distinct purposes. Threlfall (2008) describes three types of counting: oral counting, enumeration and counting for cardinality. 'Oral counting' has the intention of reciting the numbers in a string but with no reference to objects. This is also referred to as the 'sequence' context (Fuson and Hall, 1983) and includes reciting number strings in nursery rhymes. 'Enumeration' involves matching the number string to objects but with no intention of counting how many objects

there are. This may include counting steps as children climb a set of stairs. ‘Counting for cardinality’ involves a number being used as a cardinal number by naming the size of a group and telling us how many things there are.

The numbers used in the counting sequence can be used for different purposes. They are used in counting, they correspond to numerical symbols, they are used to describe the numerosity of a set, they are used in measuring, they are used to indicate position and are used to categorise items (Fuson and Hall, 1983). These different purposes see numbers being used as both adjectives and as nouns. For example, the number four can have different meanings depending on the context. In the sentence ‘the cat had four kittens’ the number is an adjective. However, in the phrases ‘seven is a prime number’ and ‘three is less than four’ the numbers are nouns. A key step in children’s development of the concept of number is moving from using and understanding number as an adjective to number as a noun (Haylock and Cockburn, 2008). This movement involves children’s understanding developing from concrete objects to abstract and more general concepts such as ‘three is less than four’.

As counting is part of mathematics and a foundation for early calculation, this led me becoming interested in finding out more about how young children’s understanding of counting develops within this school context, in order to help our understanding of early counting. Developmental changes in counting are observable over a school year with marked differences in the counting of children from the beginning of the school year to the end. The school I was working in was in a deprived part of London and nearly all pupils spoke English as an additional language. The children would arrive at school with a range of preschool experiences and would often speak very little or no English. With regards to mathematics, the

children's levels on arrival at the school were considerably below the expected levels for their age. As discussed in sections 1.5 and 2.13.5, children's levels were assessed using the non-statutory curriculum guidance 'Development Matters in the Early Years Foundation Stage (EYFS)' (Early Education, 2012). This school context, which is discussed in more detail in section 1.5, led to me becoming interested in further understanding how children's understanding of counting develops. If there is more detailed understanding of this development it may be possible to know how best to support the children in this school context and in other similar situations, with children arriving at school with levels considerably below the age-related expectations.

1.2 Theoretical framework

Our current understanding of children's counting is framed by the five counting principles identified by Gelman and Gallistel (1978). The first three principles define the counting procedure. These three principles are the stable order principle, the one-to-one principle, and the cardinal principle. The stable order principle states that the tags are applied in a consistent order over each count. The one-to-one principle states that each item is tagged with only one distinct counting word and that each counting word is only applied to one item. The cardinal principle states that the number word allocated to the final object counted represents the number of items. The fourth principle is the abstraction principle and determines the types of sets that can be counted. This principle states that the first three principles can be applied to both tangible and intangible objects. The fifth principle is the order-irrelevance principle that states that it does not matter what order the items are counted.

Gelman and Gallistel (1978) proposed a 'principles first' view of counting which argued that before children master counting they implicitly understand the innate number-specific principles. However, others propose a 'principles after' or 'alongside' approach, arguing that children's proficiency in counting precedes, or runs adjacently, to understanding of the five counting principles (Briars and Siegler, 1984; Fuson, 1988; Carey, 2004; Le Corre et al., 2006; Sarnecka and Carey, 2008). Briars and Siegler (1984) found that three, four and five-year olds could correctly count on their own before they could distinguish between unconventional but correct counts and incorrect counts. Despite being able to count on their own, three and four-year olds, and some five-year olds, were not able to distinguish between conventional and unconventional correct counts which were modelled to them by a puppet. Therefore, their research indicated that counting skills come before knowledge of the counting principles (Briars and Siegler, 1984).

This study used Gelman and Gallistel's principles of counting (1978) as a theoretical framework to structure the design of the research and the analysis of the data. I adopted the research approach used by Briars and Siegler (1984), who explored children's understanding of counting by observing children's responses to a puppet's errors in counting. This is because it has been shown that children are better able to recognise counting errors when others count than in their own counting (Mierkiewicz and Siegler, 1981; Gelman and Meck, 1983; Fuson, 1988). Also, when identifying others' mistakes children need only monitor adherence to the counting principles rather than applying each of the counting principles (Gelman and Meck, 1983). However, my research differed to that of Briars and Siegler (1984) because I ensured a meaningful approach to working with young children (Donaldson, 1978) by setting the questions in a meaningful context in order to support the children in

demonstrating their understanding of counting. This ‘meaningful context’ is explored in more detail in section 2.12.1.

1.3 The research questions

In completing this study an extensive review of the relevant literature was carried out; this is discussed in detail in chapter two. This literature review reveals a gap in the current research around how individual children’s understanding of counting develops over time. This led to my overarching research question being:

How does a child’s counting develop during the preschool nursery year?

Three aspects of this research question were addressed in more detail under the sub-questions:

1. *What does the development in understanding of counting look like for a child during the preschool nursery year?*
2. *How does a child’s baseline attainment and their reported previous experience in counting relate to their development in understanding of counting during the preschool nursery year?*
3. *How does reported teaching relate to the development in understanding of counting during the preschool nursery year?*

1.4 Aim and methods

This study aims to expand the current literature by exploring how counting develops for the children in this study over the preschool nursery year. Through this aim I would like to generate materials which support teachers of early mathematics, such assessment tools and

pedagogic aids. This study explores how teaching input, preschool experiences and reported parental involvement relate to children's development in understanding of counting.

As detailed in chapter three, an embedded case study approach (Yin, 2009) was used to address the aim. To collect the required data, three data-collection methods were used; task-based interviews with children, interviews with parents and documentary evidence. Task-based interviews were used to find out how children's understanding of counting developed over the nursery year. Interviews with parents were used to find out about children's preschool counting experiences. Documentary evidence was collected and analysed to find out about the teacher's assessments of the children and the teaching input in the nursery. The individual trajectories of the seven children in the study were tracked over a year-long period. These trajectories were then analysed to identify a learning trajectory for counting. The findings of this study are generated from a very specific group and there is no suggestion that the findings are generalisable to a larger population of learners. However, they contribute to the body of research by providing a conceptual framework which builds on our understanding of how children's understanding of counting develops during the preschool nursery year.

1.5 The research context

The school involved in this study is situated in the London Borough of Tower Hamlets and is a community primary school that serves a predominantly Bangladeshi community. During the period of time when this research took place, alongside my role as researcher, I was the Deputy Headteacher of the school. It is important to consider my position in the school and the personal, social and cultural context in which the research took place so that the impact of

these can be considered in the context of the design, the generation of the data, and the outcomes of the research (Etherington, 2004). This is discussed further in chapter 3.

Tower Hamlets is a physically small borough with an area of just less than eight square miles. According to the 2011 census the borough is the second most densely populated in London, with a population of 254,100 (Office for National Statistics, 2011). The borough has the largest Bangladeshi population in England with 32% of the population of Tower Hamlets being Bangladeshi, compared to 3% in London and less than 1% nationally. 34% of the residents in Tower Hamlets use a main language other than English. This compares to 22% in London and 8% nationally and is the third highest percentage in England. 8% of Tower Hamlets residents have poor, or no fluency in English, which is the second highest nationally and compares to a national figure of 4%. According to 'End Child Poverty', Tower Hamlets has the highest rate of child poverty in London and is the second most deprived London borough and the third most deprived borough nationally. 79% of children in Tower Hamlets live in low-income families (*End Child Poverty*, 2015).

In the school year that the research took place the number of pupils on roll at the school was 471. This compares to a primary national average of 269 putting the school in the top 80th percentile of primary schools nationally, meaning that 80% of schools had a smaller number on roll. The main indicator of low socioeconomic status at the time of the research was indicated by the percentage of children in the school who were eligible for free school meals. In the school where the research took place this was 52% of pupils. The national average was 26% so this means the school was in the top 80th percentile of primary schools nationally. The school had 100% of pupils from minority ethnic groups. This is considerably higher than the

national average of 30.7%. Finally, the school was in the top 80th percentile according to the school deprivation index. This was 0.59 compared to 0.24 nationally (*RAISEonline*, 2015).

The school also had a considerably higher percentage of pupils who had a first language other than English, 97.5%, compared to 19.5% nationally (*RAISEonline*, 2015). The majority of these pupils came from a Bangladeshi background. The official language of Bangladesh is Bengali. However, most of the Bangladeshi families who attend the school speak the language Sylheti, which is spoken in the North-Eastern region of Bangladesh, Sylhet. At the start of the study, through discussions with members of the local Bangladeshi community and Bangladeshi school staff, it became clear that when speaking in Sylheti, adults used English count words rather than Sylheti count words because the English count words were simpler to use. This means that the children in the study were exposed to the English counting words prior to starting school but that the language used alongside these counting words varied depending on the language used in their home.

The nursery had 66 pupils who attended on either a full-time or part-time basis. Of these pupils, 95% were Bangladeshi, 3% were Somali, and 3% were from other Asian backgrounds (*School X Data*, 2015). The pupils in the class started in nursery in the September following their third birthday, so ranged from 37 to 48 months old. The nursery was split into two classes, with each class having their own teacher and two members of support staff. The class teacher who taught the children involved in this study was in her third year of teaching and had taught for the previous two years in the school's Reception class. Four of the six staff in the nursery spoke Sylheti but three of these staff were not qualified teachers or early years educators. This aligns with researchers who argue that where children do receive support in

their home language, the bilingual support is often from unqualified staff (McEachron and Bhatti, 2005). The teaching in the nursery classrooms was conducted primarily in English. This is described as *monopolist*, with all teaching and learning taking place in English, which is the dominant language of wider society (Barwell, 2003).

At the time of the study this nursery was following the non-statutory curriculum guidance 'Development Matters in the Early Years Foundation Stage (EYFS)' (Early Education, 2012). The nursery's approach was guided by four key principles detailed in this document; that every child is unique, that children thrive best through the building of positive relationships, that children become independent, critical thinkers in enabling environments, and that every child is entitled to the highest quality of learning and development opportunities (School X, 2014). The curriculum guidance provided the nursery staff and classroom teacher with material to support the implementation of the statutory requirements of the Early Years Foundation Stage (Department for Education (DfE), 2014). This curriculum guidance detailed three 'prime' areas of learning and four 'specific' areas of learning. Mathematics, the focus of this study, was a 'specific' area of learning and was broken down into 'number' and 'shape, space and measure'. Details of age bands of children were given alongside guidance for the teaching of each area of learning including; observing what the child was learning, what the adults could do to support the child, and what the adults could provide to support the child (Early Education, 2012). The teachers also made use of another government document 'Numbers and Patterns: Laying foundations in mathematics' (The National Strategies Primary, 2009) to support their planning and teaching of counting. This document provided further detail and examples of activities for each area of counting detailed in Development Matters (Early Education, 2012).

1.6 The structure of the thesis

Following on from this chapter, in chapter two I discuss and review the literature relevant to this research. I consider what is involved in counting, the development of understanding of counting, theories about how children learn to count, teaching and learning counting in the early years, parental involvement in counting prior to starting nursery and the language and culture of counting. In chapter three, I detail the research design and methodology. I also explain how the data was analysed. In chapter four, I discuss my research findings and explain the phases of development that I have identified. Finally, in chapter five, I conclude with a summary of the study, explain the contribution to theoretical and professional knowledge and make recommendations for future research.

CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

This review of the literature aims to determine what is already known about the development of understanding of counting and to identify the competing discourses. The first part of the literature review describes what is actually involved in counting and the theories about learning to count. The chapter then moves on to review the literature regarding the teaching and learning of counting in the nursery, parental involvement in counting and the language and culture of counting.

2.2 Numerosity

To understand counting an understanding of numerosity is required. Numerosity specifies the numerical size of a collection of objects and is not variable (van Loosbroek and Smitsman, 1990). The evolution of numerosity at a biological level has been examined through research with infants by exploring their sensitivity to different sets of items. Researchers have found that babies are able to recognise the difference between sets of one, two or three objects before the age of one through a methodology of habituating babies to a number of objects and recording their fixation on the screen when the number of objects was changed (Starkey and Cooper, 1980; Strauss and Curtis, 1981; Wynn, 1992; Feigenson, Dehaene and Spelke, 2004). It has also been shown that infants can match a number of drumbeats to a slide with the matching number of items on (Starkey, Spelke and Gelman, 1990). This suggests that the method of input, whether it is sounds or images, does not affect the infant's ability to distinguish between sets of different numerosities (Sophian, 1998).

The research with infants has been used to support claims that humans have an innate counting mechanism (Wynn, 1992; Dehaene, 1997; Le Corre and Carey, 2007). There is much debate about how this innate counting mechanism works with some suggesting it works through subitising, which is described in section 4.6.1, (Fuson, 1988; Fischer, 1992; Dehaene, 1997) and others suggesting it works through spatial awareness (Lecuyer *et al.*, 2004; Harvey *et al.*, 2013). At the present time, there is no conclusive evidence to support either of these theories. Some even argue that the literature can be disregarded because it reveals no clear evidence that infants are sensitive to discrete numbers because the infants' performance on the tasks given can be explained by other nonnumeric cues such as length or area or the fact that infants were not looking at the screen enough (Mix, Huttenlocher and Levine, 2002).

By the age of three, many children can recite the count list in the standard order up to at least ten but this count list is numerically meaningless (Fuson, 1988; Wynn, 1990, 1992; Le Corre *et al.*, 2006). However, even before they understand the numerosities of larger numbers, children treat these larger number words as referring to a specific, unique cardinal values, even for number words beyond their counting range (Sarnecka and Gelman, 2004; Lipton and Spelke, 2006). Children are beginning to work out the properties and relationships between numbers.

2.3 Verbal counting

A fundamental part of learning to count is learning to say the number words in the conventional order (Fuson and Hall, 1983). Children are exposed to number words in a range of different contexts; sequence meanings, context meanings, cardinal meanings, ordinal

meanings, measure meanings, and non-numerical meanings such as addresses or phone numbers (Fuson and Hall, 1983).

At the initial stage of counting, children often begin by learning the pattern of noises and memorising them, there is not necessarily any connection to objects (Threlfall and Bruce, 2005). In this research, I describe this as 'verbal counting' and define it as being able to correctly speak an ordered string of numbers. Verbal counting can lead to the problem of children creating a string of words and not separating each of the number names. Verbal counting is an important step towards understanding the stable-order principle, which is discussed in section 2.4, because the child has memorised the sequence of numbers in the correct fixed order.

The structure of the English sequence of number words to one hundred begins with a rote list of the first twelve words. This is followed by a pattern, except for the irregular 'thir-' and 'fif-', for the words thirteen to nineteen that repeat the early number words followed by '-teen'. Once they have learnt the sequence to twenty children then have to learn the set of rules to generate the higher numbers (Ginsburg, 1977). There is then a decade pattern of *x*-ty, *x*-ty one, *x*-ty two, …, *x*-ty nine in which the *x* words are regular repetitions of the first nine words for 'four' and 'six' to 'nine' but are not regular for two, three or five (i.e. for 'twenty', 'thirty', and 'fifty') (Fuson, 1991).

2.3.1 Children's development of verbal counting

Learning the conventional sequence of number words begins with verbal counting. Previously, Piaget (1952) dismissed the need for this by arguing that children should develop their 'pre-number' skills before they were able to engage with verbal counting. Piaget claimed

that children needed to understand the principle of conservation of quantity before they could understand the concept of number. However, Gelman and Gallistel (1978) challenged Piaget's work when they developed a theoretical model of the acquisition of number that had an emphasis on counting. Other researchers also challenged Piaget's work, arguing for more of an emphasis on verbal counting (Donaldson, 1978; Hughes, 1986) and arguing that they found young children spontaneously counting as part of their everyday social activities (Saxe *et al.*, 1987).

Some researchers suggest that the irregularities in the sequence of number words mean that learning the number words from zero to twenty becomes a recall task (Ginsburg, 1977; Fuson, Richards and Briars, 1982; Fuson, 1991). It has even been suggested that children memorise the number words up to 29, despite the patterns (Munn, 2008). Once children have learned the sequence to twenty, they learn the pattern above the twenties, e.g. 'x-ty, x-ty one, x-ty two…', and memorise the multiples of ten. This does not necessarily happen concurrently, with research showing that some four and five-year olds who understood the pattern above twenty did not yet know the order of the multiples of ten (Fuson, Richards and Briars, 1982). Researchers have found that when children are asked to count there is a tendency for them to finish counting with a number ending in nine or zero (Ginsburg, 1977; Siegler and Robinson, 1982; Fuson, 1988; Aubrey, 1993). This is a significant point for teachers of young children who may adapt their teaching practice in reaction to these findings.

Researchers have broken down the development of verbal counting down into five levels (Fuson, Richards and Briars, 1982). Firstly, at the 'string' level, the number words are a forward-directed, continuous sound string and are not thought of as separate words. Next, at

the ‘unbreakable chain’ level, the separate words are still forward-directed but can be distinguished and become objects of thought. The number sequence is still recited and has to be started at the beginning. Thirdly, at the ‘breakable chain’ level, children can begin to recite the number word sequence from numbers other than one. Next, at the ‘numerable chain’ level, children understand that the number words have numerical meaning so they can count to a given number from any starting point. They understand that numbers can be counted, added and subtracted. Children at this level may still not understand conservation of number. Finally, at the ‘bidirectional chain’ level, children can produce the number words easily and can work in both directions (Fuson, Richards and Briars, 1982).

Research has shown that children learn to distinguish between counting words and non-counting words early, with the majority of two and three-year olds, when asked to count, starting the counting sequence with ‘one, two, three’, and continuing to use exclusively counting words (Gelman and Gallistel, 1978; Fuson, Richards and Briars, 1982). Those children who did not use counting words used alphabetical letters, which are learned in a similar rote fashion to number words (Gelman and Gallistel, 1978; Fuson, Richards and Briars, 1982).

There is a high variability in the length of an accurate verbal counting sequence produced by children between the ages of 3½ and 6 years old (Fuson and Mierkiewicz, 1980; Fuson, Richards and Briars, 1982). It is argued that the process of memorising the count sequence is strongly affected by children’s opportunities to practise this sequence (Fuson, 1991) and is acquired at varied ages (Fuson, Richards and Briars, 1982). Studies have shown a link between socioeconomic status and the length of the accurate number word sequence, with

children from middle-class backgrounds counting to a higher number accurately than those children from a lower socioeconomic status of the same age (Ginsburg and Russell, 1981). This is significant because the number-word sequence needs to be embedded and overlearned by children before they can begin applying the sequence to accurate counting (Fuson, 1991). The teaching of counting is discussed in section 2.13.

2.3.2 Common mistakes when learning to verbally count

Researchers assessed the counting of children to identify common mistakes made in the counting sequence (Threlfall and Bruce, 2005). They assessed the verbal counting of three and four-year olds by asking them to show a teddy how well they could count by counting as far as they could. From their sample of 93 children 54% just stopped counting when they had recited a correct string. For those children who continued counting Threlfall and Bruce identified five categories of mistakes. This first of these mistakes, made by 17 children, was adding one number to the number string which was incorrect, for example, the correct number string up to 'six' followed by the number 'eight'. The second mistake, made by eight children, was continuing the number string in the correct order but omitting some numbers. The next mistake, made by seven children, was producing a repeating loop of numbers, for example, the correct string up to 'five' followed by repeating the numbers 'six, seven' over and over again. The fourth mistake, made by six children, was returning to, and then repeating, part of the number string that had already been recited. The final mistake, made by five children, was continuing the number string in an idiosyncratic way. This is a useful reflection point in my research and I explore the development of children's verbal counting to explore this point in more detail in section 4.2.

2.3.3 Use of gesture when verbally counting

In English culture, along with many other cultures, fingers are used to represent numbers (Hughes, 1986). When children match their verbal counting with finger counting the movement of the fingers provides a multisensory input. This holding up of the fingers as they count conveys both cardinal and ordinal aspects of numbers (Moeller *et al.*, 2011). However, there is some debate about whether a reliance on finger-based representations is beneficial or detrimental as children's mathematical knowledge develops (Moeller *et al.*, 2011). Children use their fingers to count, even without being explicitly instructed to do so (Butterworth, 1999). It is argued that it is important to move towards mental representations of number because children need to learn more than the finger counting strategy alone (Floer, 1995; Kaufmann and Wesselowski, 2006 both cited in Moeller *et al*., 2011). This is achieved by moving from finger representations to concrete representations followed by mental representations of number. This use of gesture appears to be significant and is explored in more detail in my own research in chapter four.

2.4 Stable order principle

The first of the counting principles identified by Gelman and Gallistel (1978) is the stable order principle whereby children consistently apply tags to the items counted. Children violate the stable-order principle by producing different numeral lists at different times (Fuson, Richards and Briars, 1982; Baroody and Price, 1983; Fuson and Hall, 1983; Frye *et al.*, 1989). Fuson, Richards and Briars (1982) observed a common pattern to the acquisition of the counting word sequence. Firstly, children produce a correct 'conventional' portion of some part of the beginning of the conventional sequence (e.g. 'one, two, three, four'). Secondly, they produce a stable nonconventional portion of the sequence that is different to

the conventional sequence but is produced with some consistency by the individual child. Finally, they produce a non-stable portion that is not repeated consistently over a series of counts (Fuson, Richards and Briars, 1982). However, other researchers have not observed this phase in young children during their own research (Threlfall, 2008).

2.5 One-to-one principle

The one-to-one principle involves matching one number word to each object. One-to-one correspondence occurs regularly in children's daily lives, such as giving one sweet to each person, not just in a counting context, so children have many opportunities to develop their skills in one-to-one correspondence. Early research into the understanding of one-to-one correspondence showed that when two sets are presented spatially differently young children are unable to recognise the one-to-one correspondence between objects and relate the total amount to length (Piaget and Szeminska, 1952). They argued that children only show an operational understanding of the one-to-one correspondence once they become aware that the change in the perceptual appearance of the rows has no bearing on their actual numerosity. However, Donaldson (1978) argued that Piaget's conservation task did not make 'human sense'. In a landmark study McGarrigle and Donaldson (1974) aimed to explore children's understanding of conservation by setting a task that made more sense to the child. Two rows of sweets were laid out for the child and they were satisfied that each row had the same number. Then a 'naughty teddy' appeared and messed up one row of sweets. Once the naughty teddy was safely back in his box the child was asked if there were the same number of sweets. Over half of four to six-year olds were able to give the correct answer (McGarrigle and Donaldson, 1974). This appears to support their argument that children can conserve

number from a younger age than that demonstrated in Piaget's research (Piaget and Szeminska, 1952).

Research has shown that children as young as four do understand the one-to-one principle through the social construct of sharing, for example, giving out one cake to each of their friends (Frydman and Bryant, 1988). In early years settings pre-counting matching activities of object to object have been traditionally available to develop this principle. However, there is little or no evidence of children being able to transfer this skill from object to object matching, such as matching a tea cup to a saucer, to matching number words to objects when counting (Thompson, 2008). For children to apply one-to-one correspondence to counting they must say one number for each object. They must learn that each number name they say matches one object. This requires the skill of keeping track of which objects have been counted. The initial stages of learning to count emphasise the co-ordination of speech and movement as children tag each object in the count as they utter each number (Porter, 1999).

2.5.1 Common mistakes when learning the one-to-one principle

Fuson (1991) notes a number of common errors made by children with regards to the one-to-one principle. The first two of these errors violate the correspondence of the word to the point; a child can point to an object without saying a word, or a child can say multiple counting words whilst only pointing once at an object. The next two of these errors violate the correspondence of the point and the object; a child could skip an object without counting it, or they could count an object multiple times. The next error violates both the correspondence of the word to the point and the correspondence of the point and the object. This error involves a child pointing at two or more objects whilst only one word is said. Other frequent errors regarding the one-to-one principle are 'skim errors' whereby a child moves their finger along

a row of objects saying words without really pointing at objects and 'flurry errors' whereby a child produces a flurry of words and of points directed generally but not specifically at the objects (Fuson, 1991).

2.5.2 Use of gesture in the one-to-one principle

A child's ability to coordinate tagging objects with saying the number word, and therefore adhering to the one-to-one principle may be supported through pointing or touching objects (Graham, 1999). Gesture involves using a body movement to support communication (Sfard, 2009). It has been shown that a feature of maternal communication between English mothers and their 20-month-old infants is gesture and that this supports speech and scaffolds communication (O'Neill *et al.*, 2005). It has been demonstrated that children count more accurately when they are able to gesture (Alibali and DiRusso, 1999; Graham, 1999) and that gesture is most beneficial when children are learning to count (Saxe and Kaplan, 1981).

Gesture in counting can range from physically moving the objects to pointing at a distance. It has been shown that touching gestures support greater accuracy in counting than pointing gestures (Gelman and Meck, 1983). However, the gestures used by children may indicate a development in their counting. In a study of 96 three to five-year olds is has been shown that the youngest children touched as they counted, whereas the four and five-year olds often just pointed, with some five-year olds counting accurately without pointing (Fuson and Mierkiewicz, 1980). Research in the US found that preschool age children almost always point when counting 10 to 20 objects. However, they found that kindergarteners almost always use eye fixation when counting the same amount which appears to suggest that children progress from pointing to eye fixation (Ginsburg and Russell, 1981). Children move from touching objects, to pointing near the objects, to pointing at the objects from a distance,

to tracking them using eye fixation. This development has been described as “progressive internalisation” (Fuson, 1988).

There are several possibilities as to why gesturing facilitates improved accuracy in counting; gesture helps children to apply their knowledge of the one-to-one principle, gesture allows children to represent their counting externally and gesture is a cognitive facilitator (Graham, 1999). It is proposed that the use of gesture may help children avoid two errors common in the application of the one-to-one principle (Alibali and DiRusso, 1999). The first of these errors is a partitioning error whereby those items that have been counted and those that have still to be counted get confused. Gesture may allow children to keep track of the partitions they have created between the counted and the uncounted (Beckwith and Restle, 1966). The second error is a coordination error whereby children do not coordinate the number tags with the items to be counted. The action of physically touching each item to be counted may support children in assigning a tag to each object counted (Gelman and Gallistel, 1978). Other researchers support the concept of gesture as a cognitive facilitator (Alibali and DiRusso, 1999; Goldin-Meadow *et al.*, 2001). They suggest this is because gesture stores the child’s place in the counted set of objects physically. As the child does then not have to hold this information in their working memory, they are better able to perform other aspects of counting. The presentation of the items to be counted can impact on children’s accuracy in counting (Alibali and DiRusso, 1999). Objects may be presented linearly, randomly or in a circle. Children may find it easier to count items set in a row because it is easier for them to track which items have been counted and which are left to count (Alibali and DiRusso, 1999).

2.6 Cardinal principle

The cardinal principle states that the last number said in a count refers to the numerosity of the whole set (Gelman and Gallistel, 1978). Although children may be able to count a set of objects they may not yet understand that the purpose of counting is to enumerate a set of objects so may not yet have acquired the cardinal principle. The cardinality of a set can be found by counting or by subitising. Research has shown that children up to five years old rarely refer to quantification when asked what the purpose of counting is (Munn, 2008). The cardinal principle is only relevant to counting and is jeopardised if either the one-to-one or the stable order principle are inaccurate. To understanding cardinality a child must recognise that a number word refers to numerosity in general and that the last number word said in a count refers to the precise numerosity of that set (Wynn, 1992). The current EYFS curriculum does include an understanding of cardinality (Early Education, 2012) but does not emphasise the importance of this aspect of teaching number (Gifford, 2014).

2.6.1 The relationship between cardinality and counting

There is debate about the relationship between cardinality and counting. It is proposed that cardinality and counting are two different things because counting is a process, a means of getting an answer, whereas cardinality is a goal (Saxe *et al.*, 1987; Bermejo and Oliva Lago, 1990; Bermejo, Morales and Garcia deOsuna, 2004). Some argue that children first learn to count and then use their counting knowledge to develop their understanding of the cardinal principle, perhaps triggered by subitising (Schaeffer, Eggleston and Scott, 1974; Frye *et al.*, 1989), which is discussed further in section 2.9. To support this argument Wynn (1990) proposes that counting begins as a meaningless activity, with the reciting of number strings, nursery rhymes, etc. However, from this, and from the mathematical language they hear, children begin to abstract important mathematical concepts from their exposure to counting

words. Children learn the meaning of each individual number word in ascending order starting at *one*, then *two*, and then *three.* After this, children learn the cardinal word principle and the meanings of the other counting words within their range (Wynn, 1990). This theory states that children learn the cardinal meaning of 'one' first, before going on to learn the cardinal meaning of 'two', 'three' and 'four' in order. They then make a shift in their learning to understand the meaning of the rest of the number words (Wynn, 1990). Others argue that children first understand something of cardinality through subitising, and develop the counting skills to determine cardinality afterwards (Fuson, 1988).

2.6.2 Demonstrating an understanding of the cardinal principle

There is disagreement about what demonstrates an understanding of the cardinal principle. Gelman and Gallistel (1978) proposed that a child is considered to understand the cardinal principle if: they repeat the last word used in a count; they emphasize the last word used in a count; they say the correct number word after the set has been counted earlier or they state the correct numerosity of a set without counting. To come to their conclusions, Gelman and Gallistel (1978) observed children counting sets of objects in standard counting situations. This meant that the children only had to apply their counting knowledge to a limited situation and did not have to show they understood all of the counting principles. Others disagree with Gelman and Gallistel's criteria for understanding of the cardinal principle arguing that the child may just be recalling the last word because this is what they have seen others do, without understanding that counting is a means to determining cardinality (Fuson and Hall, 1983; Fuson, 1988; Wynn, 1992; Sophian, 1995). It is argued that observing children count is not sufficient to determine their conceptual understanding of counting and therefore their understanding of the cardinal principle (LeFevre *et al.*, 2006).

Sarnecka and Carey (2008) question whether the cardinal principle is more conceptual than Gelman and Gallistel's definition. They argue that the cardinal principle involves both the ordinal and cardinal aspect. Each number spoken is used in an ordinal sense, to label the objects and to keep track of them. The ordinal number of the last item in the set is the cardinal number of the set. Therefore, if a child is not yet a 'counter' then when asked to count a row of five objects they may be able to count correctly and declare that there are 'five'. However, if they are then asked to 'show me five' they will point to the fifth object and say 'that one'. In this example, a child is interpreting the words as labels for the individual elements in the count, rather than understanding the cardinal principle. A child needs to develop an understanding that number words can be used temporarily as 'ordinals' to keep track of the order, then be used as 'cardinals' to name the size of the group (Ewers-Rogers and Cowan, 1996).

A range of different questions have been posed by researchers in order to establish if children understand the cardinal principle resulting in varied findings. Some researchers have used the question 'how many' to try to establish if children understand the cardinal principle (Schaeffer, Eggleston and Scott, 1974). This question was used with three-year olds and the findings suggested that these children lacked the cardinal word principle (Schaeffer, Eggleston and Scott, 1974). When asked 'how many' items are in a set directly after the items have been counted and covered up (so that the children could not count them again) the children did not respond with the last word used in the count (Schaeffer, Eggleston and Scott, 1974). However, it is possible that the children were confused by the question, as having just counted the items they had already indicated how many there were or they may have simply forgotten so would need to recount. In order to remove this potential for confusion Sarnecka

and Carey (2008) counted aloud a set of objects that the child could not see and then asked the child how many there were. They argued that ‘how many’ questions should not be used as a measure of cardinal principle understanding because children could have learned the procedure for answering this question by always responding with the last number said.

Responses to the ‘how many’ question have been used to categorise children into six different stages of development of their understanding of cardinality: ‘pre-counter’, ‘reciter’, ‘corresponder’, ‘immature counter’, ‘rigid rule follower’ and ‘counter’ (Bermejo, 1996; Sarama and Clements, 2009). Children will provide a random answer when at the first stage, ‘pre-counter’. Children at this first stage may be able to answer correctly for small quantities (between one and three) but may be recognising the quantities on sight rather than being able to count them. As children move onto the next stage, ‘reciter’, they will respond with the number-word sequence, but will not tag each item. At the next stage in development, ‘corresponder’, children will respond to the question by recounting the whole set; they will not yet have an understanding of cardinality. At the fourth stage, ‘immature counter’, children will respond with the last number tag they used, even if this is incorrect. Children at this stage are not yet able to check if their counting is accurate. At the next stage of development, ‘rigid rule follower’, the child will respond with the largest number-tag they have used in the count, even if this was not the last number tag. The child is beginning to understand the rules of counting but continues to make errors. At the final stage of development, ‘counter’, the child will be able to respond to the question correctly and will also be able to monitor their counting and the counting of others for accuracy. It is only at this final stage that children have an understanding of cardinality. These stages may be useful in tracking progress made by individual children.

Some researchers have used an alternative question to examine children's understanding of the cardinal principle. Instead of being asked 'how many,' children have been asked to generate a particular size from a larger set through the question 'give me *x*' (Schaeffer, Eggleston and Scott, 1974; Fuson, 1988; Frye *et al.*, 1989; Wynn, 1990, 1992). Gelman and Gallistel (1978) did not ask a 'give me' question in their research so this may have been a limitation of their research. Children appear to find this task more difficult than being asked 'how many' and the task gets more challenging when children are asked to produce a larger number (Schaeffer, Eggleston and Scott, 1974; Wynn, 1990, 1992; Sarnecka and Gelman, 2004; Le Corre *et al.*, 2006; Le Corre and Carey, 2007; Sarnecka *et al.*, 2007; Condry and Spelke, 2008). Therefore, children are able to respond more accurately to 'how many' questions rather than to 'give me *x*' questions (Frye *et al.*, 1989; Wynn, 1990; Sarnecka and Carey, 2008). Cordes and Gelman (2005) argue that 'give me *x*' provide a more accurate assessment of the cardinal principle than the 'how many?' question. This is because 'give me *x*' tasks are believed to be more challenging because the child has to create the required set of objects one object at a time, until they have created the value that corresponds to the one in their memory (Cordes and Gelman, 2005). It is also possible that children hear 'give me' as an expression more in real-life than 'how many'. However, unlike the 'how many' questions, the 'give me' questions may not be in a numerical context, for example, 'give me the ball' or 'give me the hat'.

2.6.3 Understanding of the cardinal principle

Most children younger than three and a half are not able to accurately respond to 'give me *x*' tasks with a small set of up to six items and the majority of two and a half to three and a half year olds grab the objects rather than counting them (Wynn, 1990, 1992). Research with three to four-year olds has also found that most children of this age were also more likely to grab

objects than count them (Fluck and Henderson, 1996; Montague-Smith, 1997). This supports the proposal that children first learn to count and then use their counting knowledge to develop their understanding of the principles. However, Bruce and Threlfall (2004) found that three and four-year olds were just as likely to count as to grab. Therefore, they argue that their study, whereby children reverted to grabbing having started counting, suggests that, even though they understand the significance of counting, children choose not to use their counting until they have developed the skills. They argue that this supports the 'principle before skills' perspective (Bruce and Threlfall, 2004).

Wynn (1992) reported a series of developmental levels that children go through in response to 'give me *x*' tasks. At the first level children do not distinguish between the meanings of different numerals with the number of objects and give an unrelated number of objects. Next, the child can correctly give one object when asked to give one but cannot give the correct number of objects when asked for any number other than one. After that, the child can correctly give one or two objects when requested but cannot correctly give three or more objects. The child then progresses through levels of being able to give three, then four, then five objects. Collectively, children at these levels have been termed 'subset-knowers' (Le Corre *et al.*, 2006; Le Corre and Carey, 2007). The child then seems to learn how to give numbers from five upwards in one stage. This understanding of the higher numerals appears to come all at once. At this stage, the child is known as a 'cardinal principle knower'. In a longitudinal study, it has been shown that on average it takes about one year for children to progress from being 'one-knowers' to cardinal principle knowers (Wynn, 1992).

Through their research Sarnecka and Lee (2009) explained the two types of error that children produce in the 'give me *x*' task; performance errors and guessing. Performance errors involve a child understanding the cardinal principle but making a mistake when counting. Guessing errors involve a child who does not understand the cardinal meaning of the number they are asked so they guess how many they should give. They found that children did not produce performance errors around the lower-numbers. They also found that children produced no guesses below the number the child demonstrated that they knew, so if a child was consistently able to 'give four' then any errors they made were with sets above four. In later research, it was found that if a child is a 'three-knower' they will not give the answer one, two or three to a 'give me five' question (Lee and Sarnecka, 2011). They argued that until children have learned the cardinal principle, they do not know the meanings, even approximately, of any higher number words. This research supports the argument that children first learn to count and then use their counting knowledge to develop their understanding of the cardinal principle.

Researchers in the field of cardinality have also made use of children's observations of the counting of others (Muldoon, Lewis and Berridge, 2007; Muldoon, Lewis and Francis, 2007). It has been demonstrated that if children can identify procedural errors in others' counting then they will be more likely to understand the significance of cardinal numbers when comparing sets (Muldoon, Lewis and Francis, 2007). Research has also shown that by asking children to explain their own reasoning about counting accuracy they make better progress in identifying inaccurate counts made by another and if children are sensitive to procedural accuracy then this supports an understanding of cardinality (Muldoon, Lewis and Berridge, 2007). Research has indicated that unnecessary recounting is an indicator of not grasping

cardinality (Bermejo, 1996). However, others have argued some children who do recount unnecessarily do grasp cardinality (Freeman, Antonucci and Lewis, 2000).

Gesture may be used as one way of emphasising cardinality. It has been shown that children have a better understanding of cardinality and are more successful when asked to 'give me *x*' items if they have learned to use a circular 'altogether' gesture on the final word of the count to indicate that the word referred to the whole set (Suriyakham, 2007).

2.7 Abstraction principle

The abstraction principle states that both tangible and intangible objects can be counted. To understand this principle children must understand that physical and non-physical entities, such as sounds, can be counted. The type of element being counted does impact on children's counting, with tangible objects being easier to count than intangible objects (Baroody, Benson and Lai, 2003). Researchers argue that children's understanding of this concept develops over time, with children gradually learning that abstract objects can be counted as well as concrete objects (Baroody, Wilkins and Tiilikainen, 2003).

2.8 Order-irrelevance principle

The order-irrelevance principle involves understanding that items can be counted in any order. Gelman and Gallistel (1978) propose that a child understands this principle when they know that: the tags assigned to objects are arbitrary and temporary and do not apply to the object once the count is over and that, regardless of the order of enumeration, the cardinal number remains the same.

Research has shown that children are able to count objects in a different order from a young age. Two-thirds of 5-year olds and almost half of four-year olds were able to do this with sets of four to five objects (Gelman and Gallistel, 1978). However, children found it more challenging to understand that counting in any order would result in the same cardinal number (Ginsburg and Russell, 1981). When watching counts made by others, half to two-thirds of three to five-year olds thought that a mistake had been made when the counter started in the middle of a row or counted alternate items (Mierkiewicz and Siegler, 1981). More recent research has demonstrated that eight and nine year olds still demonstrate difficulty in understanding the order-irrelevance principle because they argue that counts which do not follow the conventional count order of, for example, left to right are incorrect (Rodríguez *et al.*, 2013). Kamawar *et al.* (2010) argue that understanding of the order-irrelevance principle does not play a significant role in children's development of conceptual understanding of counting. They found that children aged between five and eleven years old argued that the order objects were counted was relevant. Only some ten and eleven year olds accurately applied the order-irrelevance principle and this was not linked to their numeration skills (Kamawar *et al.*, 2010)

2.9 Subitising

Subitising is determining the numerosity of a set quickly, confidently and accurately (Kaufman *et al.*, 1949). Subitising is distinct from counting because of the speed involved in the recognition of the numerosity and is distinct from estimating because of the accuracy required. Subitising is not yet fully understood (Sophian, 1998) so there are several alternative theories offered. Gelman and Gallistel (1978) argue that subitising is unconscious counting and that for small sets counting precedes subitising. Others argue that subitising precedes

counting and that it is within the subitising range that children initially begin to understand the quantitative meaning of counting (Klahr and Wallace, 1976). Therefore, there seems to be some disagreement about whether children should be taught and encouraged to subitise.

A relationship has been found between subitising, spontaneously focusing on numerosity and object counting skills (Hannula, Räsänen and Lehtinen, 2007). The researchers argued that this could be because those children who spontaneously focus on numerosity get more practice at enumerating sets of objects which develops their subitising and counting skills. It has been suggested that subitising is the development pathway through which children acquire the meaning of the first few number words as children begin to associate number words (e.g. 'two') with numerosities they can recognise (Klahr and Wallace, 1976; Benoit, Lehalle and Jouen, 2004).

Research into reaction times has found that for one to seven objects the response is fast and accurate. It is argued that this is because up to seven objects can be held in mental consciousness (Mandler and Shebo, 1982). However, another theory offered is that subitising is not a unique numerical ability and that the increasing reaction times reflect the visual attention having limited capacity (Balakrishnan and Ashby, 1992). An alternative theory is that subitising involves the items being processed simultaneously rather than in succession (Sophian, 1998). The links between subitising and counting are not clear. It has been argued that there is not a clear continuity between the ability to subitise and count (Le Corre *et al.*, 2006; Le Corre and Carey, 2007) and between the ability to subitise and solve nonverbal addition problems (Huttenlocher, Jordan and Levine, 1994).

2.10 Procedural and conceptual understanding of counting

Judging when a child understands counting is challenging because counting is made up of many different concepts (Sophian, 1997). A sound grasp of counting involves the mastery and interplay of *procedural* and *conceptual* understanding (Gelman, Meck and Merkin, 1986; Hiebert and Lefevre, 1986). For example, a child has a *procedural* understanding of the one-to-one principle if they can accurately count a set of five objects, applying the one-to-one principle to each object in the set. However, for a child to have a *conceptual* understanding of the one-to-one principle they would need to demonstrate an understanding that when this principle is violated then the count is inaccurate. This may be demonstrated by a child spotting a mistake in their own application of the one-to-one principle or spotting a mistake made in another's counting (Rittle-Johnson and Siegler, 1998). As discussed in the introduction, there are a number of researchers who have used judgements about others' counting to explore children's understanding of counting (Briars and Siegler, 1984; Frye *et al.*, 1989; Canobi, Reeve and Pattison, 1998; Canobi, 2004).

There are historic and on-going debates about the theories concerning what order children develop procedural understanding of counting and develop conceptual understanding. Procedural understanding may precede conceptual understanding, or vice versa, or both may emerge concurrently (Rittle-Johnson and Siegler, 1998). However, others argue that procedural knowledge of counting appears to develop in a straightforward way with age and with overall mathematical skill whereas conceptual knowledge appears to develop in a more complex trajectory (LeFevre *et al.*, 2006). It has also been argued that even by the age of ten children have been shown to have not fully developed a conceptual knowledge of counting (Geary *et al.*, 2004).

A child may have a procedural and conceptual understanding of counting but may still perform poorly on a counting task. They may not understand what they are being asked to do, so will be unable to demonstrate *utilization skills* (Greeno and Riley, 1984). This may be because the context is unfamiliar or because the question is not understood. When learning to count children learn concepts, meanings and number words that are embedded in the context of the count (Donaldson, 1978). Therefore, each of the three competences can be dependent on the context of the count. Through a detailed study of the development of one child's understanding of number between the ages of 12 to 38 months it has been demonstrated that this understanding is heavily dependent on the context (Mix, 2002; Mix, Huttenlocher and Levine, 2002). This context dependency and the need for children to practise counting mean that the world around the child has a huge impact on their understanding of counting. This is in contrast with Gelman and Gallistel's (1978) 'principles first' view of counting.

2.11 The development of counting skills

Understanding of the development of counting skills still needs to be developed further. Although there have been several recent studies into the development of reading skills, less is known about the development of mathematical skills (Aunola *et al.*, 2004). A recent report into mathematics in the early years recommended that there should be more research into how young children learn mathematics and this research could then inform teaching methods (All Parliamentary Group for Maths and Numeracy, 2014).

Researchers suggest that counting skills develop in a hierarchical manner (Gelman and Gallistel, 1978; Nesher, 1986; Entwisle and Alexander, 1990). Researchers have also found that children demonstrate different development trajectories in mathematics dependent on

their mathematical performance (Aunola *et al.*, 2004). It is argued that there is a developmental relationship between the counting principles with children understanding the stable order principle and one-to-one principle prior to the cardinal principle (Gelman and Gallistel, 1978). However, researchers have identified that one of limitations in the testing procedure used by Gelman and Gallistel (1978) was in their identification of the order of the development of the principles (Frye *et al.*, 1989) and have since found that this developmental relationship only applies to very small sets of objects (Fuson, 1988). By definition the cardinal principle requires an understanding of the stable order and one-to-one principle and research has indicated that the cardinal principle is the most difficult of the three 'how to count' principles (Fuson, 1988; Butterworth, 2005). However, more recent research has found that a higher proportion of children understood the cardinal principle than the stable order principle at the end of Dutch kindergarten (five to six year olds) (Stock, Desoete and Roeyers, 2009). This has implications for those teaching young children to count because there does not appear to be a set sequence in which the principles need to be taught.

It has been argued that early mathematical skills appear to develop in overlapping phases (Purpura and Lonigan, 2013) with children progressing through levels of mathematical thinking (Clements and Sarama, 2004). As children's mathematical skills develop they integrate to become a mastered skill (Nesher, 1986). The particular way the skills involved in counting develop has been described as a *learning trajectory* with the child's knowledge progressing in a systematic way (Simon, Martin and Tzur, 2004). These research findings, rooted in the constructivist approach, have led to the development of a 'hypothetical learning trajectory' approach to mathematical teaching (Simon, 1995). As the learning trajectory might proceed along a different path to that predicted by the teacher the learning trajectory is

'hypothetical'. Also, individual children may proceed along different, although often similar, learning paths. These trajectories are referred to as a 'cognitive tool' which aim to generate knowledge of learning and teaching (Clements and Sarama, 2004).

2.12 Theories about how children learn to count

Counting may mean different things to different children (Maclellan, 2008) but is fundamentally a means of quantifying or measuring consisting of several components (Sophian and Kailihiwa, 1998). It is one of the first mathematical skills that children acquire and forms a foundation for other mathematical activities (Briars and Siegler, 1984). Academics from the two differing fields of psychology and education have researched counting. The origin of counting knowledge has been the interest of developmental psychologists whereas mathematics education researchers have focused on the teaching of counting in school (Sophian, 2007). The early view of counting was established by Piaget and Bruner who argued that number concepts are like any other concept and are learned over time, through experience and gradual introduction; a constructivist approach (Piaget and Szeminska, 1952; Bruner, 1966, 1973).

2.12.1 Gelman and Gallistel's 'principles-first' view

An alternative theory to the constructivist approach, the 'principles-first' view, was proposed by Gelman and Gallistel (1978) who argue that there are innate knowledge structures, number-specific principles, which are implicitly understood before children master counting. They argue that Piaget obscured children's understanding of counting because his counting tasks were too excessive and focused on what children could not do. For example, Piaget suggested that children understood conservation of number (i.e. that the number of items in a set remains the same when they are rearranged) at the age of seven (Piaget and Szeminska,

1952). However, researchers have since found that children can succeed at the Piagetian experiments at a younger age if they are set in more meaningful contexts (McGarrigle and Donaldson, 1974). A meaningful context is one in which some aspects of the child's everyday experiences mathematics in which mathematics can be embedded (Haylock, 2007). It is suggested that a meaningful context supports the development of mathematical skills (Bryant and Nunes, 2002) and embedding a task in a meaningful context supports children in evidencing their knowledge of number (Donaldson, 1978). Therefore, recent early years practice has focused on providing children with meaningful contexts in which to learn and practise counting skills (Early Education, 2012).

Gelman and Gallistel (1978) support their 'principles first' view through citing examples of children who do not count correctly but still apply the principles. As a child is unlikely to have seen an adult counting incorrectly they argue that the child must learn counting through an innate structure rather than by learning it from other people. They also support their claims by likening this to children's over-generalisation of rules in language (e.g. I goed home). They support their theory by citing examples of children who count in the wrong list (e.g. a, b, c). However, these children may have heard people counting in a list (e.g. 1, 2, 3) and thought that counting was about reciting a list. Gelman and Gallistel (1978) inferred their findings primarily from observations of children performing counting tasks correctly. Therefore, it is difficult to know if the children simply knew how to execute the counting procedure correctly, or whether they understood the underlying counting principles. Gelman and Gallistel (1978) argued that children understood the act of counting prior to being able to count accurately. Any mistakes made by children in their counting were attributed to them not

being able to execute the counting procedure rather than not understanding the counting principles (Mierkiewicz and Siegler, 1981).

Researchers have approached the 'principles first' view from a different perspective to Gelman and Gallistel (1978). It was argued that if children did possess the counting principles then they would be able to distinguish between conventionally correct counting, unconventional but correct counting, and incorrect counting in counts performed by a puppet (Mierkiewicz and Siegler, 1981; Gelman and Meck, 1983; Briars and Siegler, 1984; Gelman, Meck and Merkin, 1986; Frye *et al.*, 1989). The findings of these studies were contradictory, highlighting the complexity of this debate. Gelman and Meck (1983) demonstrated that children as young as three understand the counting principles. They found that three-year olds correctly rejected double counting, skipping objects, using the incorrect number sequence, and using an incorrect cardinal number to represent a set of objects for set sizes up to 20. Mierkiewicz and Siegler (1981) argued that executing the counting procedure is better characterised as following a few specific rules rather than a few general principles. Briars and Siegler (1984) argued that children learn to execute the standard counting procedure early on then gradually learn what typical aspects of counting are essential.

2.12.2 'Principles after' or 'alongside' view

The 'principles after' or 'alongside' view of counting argues that children imitate early counting from adults, with children learning different counting skills and applying these to different contexts in order to generate the counting principles after or alongside this early imitation (Fuson and Hall, 1983; Briars and Siegler, 1984). Briars and Siegler (1984) argued that counting skills come before knowledge of the counting principles because they found that three, four and five-year olds could correctly count on their own before they could distinguish

between unconventional but correct counts and incorrect counts. However, Gelman, Meck and Merkin (1986) argued that Briars and Siegler (1984) asked the children to count sets of objects on their own prior to evaluating the puppet's counts, which they claim meant the children incorrectly rejected more unconventional counts.

It is argued that because the children in Briars and Siegler's (1984) study accepted both the non-conventional and the incorrect counts, there is no evidence that they distinguished between them (Le Corre *et al.*, 2006). Le Corre *et al.* (2006) propose that Briars and Siegler (1984) may have underestimated children's knowledge of the counting principles by excessively demanding their utilization skills. The children's metacognition of the counting principles, rather than their ability to use the principles, is being tested when they are asked to judge if a count is acceptable. Other researchers agree and state that children may not have the explicit knowledge of counting principles that these tasks require until later (Ewers-Rogers and Cowan, 1996). Le Corre *et al*. (2006) attempted to address this by varying the utilization and procedural demands of the tasks children were asked to do. However, they found that those children who failed to demonstrate an understanding of counting in the harder tasks, also failed to demonstrate this understanding in the easier tasks (Le Corre *et al.*, 2006).

2.13 Teaching and learning counting in the nursery

2.13.1 The nursery curriculum

Researchers have argued that the early years curriculum needs to provide young children with the opportunity to develop their understanding of the world alongside their own experiences and interests (Athey, 1990; Nutbrown, 1994). Early Years Foundation Stage (EYFS) practice was, until relatively recently, founded upon Piagetian thinking, with a focus on sorting and

matching. However, advances in theoretical work on early mathematics (for example, Gelman and Gallistel, 1978 and Fuson, 1988) have led to a reinstatement of the role of counting in the EYFS curriculum. In the nursery where this research took place the curriculum taught was based on Development Matters (Early Education, 2012). This non-statutory guidance provides nursery staff with the objectives that should be taught and gives examples of activities and resources that can be provided and modelled to support the teaching of the objective.

Mathematics is divided into two sections in the current curriculum guidance; 'Number' and 'Shape, Space and Measure' (Early Education, 2012). In the previous curriculum guidance for early years practitioners, 'Problem Solving, Reasoning and Numeracy' (PSRN), was the overarching title given to mathematics (Department for Children, Schools and Families, 2008). This was then broken down into three sub-sections; 'Numbers as labels and for counting', 'calculating', and 'shape, space and measures' (Department for Children, Schools and Families, 2008).

Current statutory government guidance does not specify how teachers must teach in the EYFS (Department for Education (DfE), 2014). However, the current non-statutory guidance for EYFS teachers recommends they offer playful opportunities for teaching and learning (Early Education, 2012). Defining play is challenging but after carrying out a review of the definitions offered by a range of psychologists and behaviourists, Rubin, Fein and Vandenberg (1983) concluded that play behaviour has the following features; it is intrinsically motivated, it is controlled by those playing, it is not concerned with the outcome (more the process), it is not literal, it is free from externally imposed rules, and the players have to be actively engaged in the activity (Rubin, Fein and Vandenberg, 1983). Learning through play

links with constructivist theories of learning because the individual interprets the world through their personal experiences and thus constructs their own perspective of the world. The child is then able to make 'human sense' of the world (Donaldson, 1978).

However, research has raised concerns about the amount of mathematical activity children engage in when in the EYFS environment. In a large-scale study of EYFS provision in England researchers found that four-year olds only spent five percent of their total time in the EYFS environment engaged in any mathematical activities (Siraj-Blatchford *et al.*, 2002). Research across three different countries also failed to find evidence of young children involving numbers in their independent play. For example, when playing in 'fast food' scenarios children used literacy skills but not any numbers (Ewers-Rogers and Cowan, 1996). A study of two and three-year olds in ten Scottish nurseries observed no mathematics in independent role play and found that it was very rare for children to engage in the use of numbers without adult involvement (Munn and Schaffer, 1993). Four-year olds playing independently in a nursery setting were recorded for 70 hours and were found to use mathematical skills only 1.6% of the time (Young-Loveridge, Carr and Peters, 1995). Gifford (2005) found, in informal observations, little evidence of children making use of mathematics in their role play. She proposed that this is because mathematical knowledge is socially constructed so requires adult involvement (Gifford, 2005). In contrast to these findings, other researchers argue that children do use numbers when engaged in free play. In an observational study of young children engaged in their usual day-to-day activities, it has been shown that, for the three-year olds observed, numbers are as much a part of everyday life as letters (Tudge and Doucet, 2004). Also, researchers have found that children carry out a significant amount of mathematical activity, such as enumerating, comparing magnitudes and exploring patterns

and shapes in the EYFS (Seo and Ginsburg, 2004). Children in the foundation stage have also been found to use a range of mathematical metalanguage during their play (Coltman, 2006). More recently, a small-scale study involving three and four-year olds in a nursery setting in England, found evidence of children engaged in many play episodes that included mathematics. This study also found that the number of play episodes involving mathematics increased throughout the year (Worthington and van Oers, 2016). These different findings indicate that the EYFS environment, the resources provided and the input of the adults in the setting may all impact on the amount of number play that children engage in.

2.13.2 Teaching counting skills

Researchers in the US found that counting skills were one of the aspects of mathematics that teachers of young children focused on (Engel, Claessens and Finch, 2013). The researchers argued that kindergarten teachers focused on basic counting skills even though many of the children they were teaching showed an understanding of counting prior to starting kindergarten. Although this research is with older children than my research (kindergarten pupils in the US are aged five to six, the equivalent of year one in England) the researchers did find that, on average, this exposure to basic counting teaching negatively impacted on the children's achievement in mathematics. They also found that the children with the lowest skills in mathematics at the start of the study benefitted the most from this teaching, whereas the children with the highest skills at the start of the study benefited when teachers taught more advanced content (Engel, Claessens and Finch, 2013). However, further research is needed as to the explicit instruction needed by those children with the lower mathematical skills (Hinton, Stroizer and Flores, 2015).

Development Matters (Early Education, 2012) emphasises key teaching points, based on the counting principles for children working within the age-range of 30-50 months. With regards to verbal counting and the stable order principle, nursery staff are encouraged to use number language in a variety of situations. Teaching of the one-to-one principle is emphasised through providing children with models of counting objects in a random layout and only counting each object once. The cardinal principle is emphasised as nursery staff are encouraged to ask questions such as 'how many are there altogether?' and children must know that numbers identify how many objects are in a set. The abstraction principle is specifically mentioned with staff encouraged to support children's developing understanding of this principle by counting hops, jumps, clicks or claps (Early Education, 2012: 33).

2.13.3 The learning environment

The importance of the environment in which children are taught the EYFS curriculum has been highlighted by researchers (Hutt *et al.*, 1989; Moyles, 1989). The environment is a key aspect of the most recent curriculum guidance which emphasises that 'children learn and develop well in enabling environments' (Early Education, 2012:2) and goes on to emphasise the need to respond to individual children's needs and build a strong partnership between the setting and carers (Early Education, 2012).

Over the last ten years there has been a renewed focus on the benefits of learning outside the classroom (Department for Education and Skills, 2006). The current curriculum guidelines for EYFS provision in England actively promote the use of the outdoor environment to support children's learning (Early Education, 2012). Children appear to benefit from being outdoors and when outside have more space to move freely (Rivkin, 2000). However, despite research detailing the benefits of outdoor learning (Fjørtoft, 2001; Borge, Nordhagen and Lie, 2003;

Maynard and Waters, 2007), teachers' understanding of outdoor learning may need further development with some teachers believing the 'real work' still takes place inside the classroom environment (Maynard, Waters and Clement, 2013).

2.13.4 Adult involvement in teaching counting

Gelman and Gallistel (1978) do not dismiss the role of society in teaching counting and still believe that number concepts are at least partly constructed from environmental input. Recent thinking on learning has emphasised the involvement of adults in the learning process and the social context in which the learning takes place (Vygostky, 1986; Siraj-Blatchford *et al.*, 2002). New research from neuropsychology also informs our understanding of both brain development and the need for supportive environments to nurture it (Blakemore and Frith, 2005). The EPPE project found that the quality of the provision provided by the adults in a nursery setting are critical to the impact the setting has on children's outcomes. The project found that the advantages to a child's development of attending a particularly 'effective' preschool setting were evident up to the age of seven (Sylva *et al.*, 2004).

There is debate around what kind of adult involvement is most effective. Frequent adult interactions with children are necessary but research has found that, even in the most effective settings, these interactions are not happening as frequently as they should be (Munn and Schaffer, 1993; Stephen and Wilkinson, 1999; Siraj-Blatchford *et al.*, 2002). Effective teachers are able to intervene with the different strategies children bring to school without replacing them entirely (Askew *et al.*, 1997) and are competent at developing their own strategies for helping children to apply mathematics in different contexts (Hughes, Desforges and Mitchell, 2000). Researchers have identified approaches to 'scaffolding' which involve simplifying and breaking down the problem into steps (Wood, Bruner and Ross, 1976).

Vygotsky's (1986) 'Zone of Proximal Development' has generally been emphasised and encourages adults to 'scaffold' learning to lead the child to be able to do what they could not do. Researchers have found that mothers seem to intuitively adopt this approach when completing puzzles with their children (Saxe *et al.*, 1987). A play based approach to learning number skills, through the playing of games with adults, has been shown to have significant effects on five-year olds' early number skills (Peters, 1998; Aubrey and Godfrey, 2003; Young-Loveridge, 2004). In fact, research has shown that children's play increases in complexity just by having an adult nearby (Sylva, Roy and Painter, 1980). This is significant in planning adult roles in the EYFS classroom.

2.13.5 Assessment of mathematics

Assessment is used for a range of different educational purposes including: making comparisons between schools and countries, giving individuals a 'level' or 'grade', planning interventions, improving teaching and learning, and providing feedback to individuals (Newton, 2007). There are two key types of assessment. The first of these is summative assessment which is an assessment of the learning that has taken place. The second of these is formative assessment which is an assessment for learning (The Partnership Management Board, 2007). Black and Wiliam (1998) describe formative assessment as any assessment undertaken by teachers and pupils which is then used to modify the teaching so as to meet the needs of the pupils. Through their extensive research it was found that assessment for learning led to quantifiable learning gains in primary classrooms (Black and Wiliam, 1998). In the nursery, assessment for learning is carried out by staff who observe the children and use this information to inform their assessment and future planning. It is argued that careful observation of children can be used to identify 'children's pathways of learning' (Nutbrown, 1994:148). The observations of number are made through a mix of adult-led and child-

initiated play. Nursery practitioners need to use their own judgement to ensure a balance between adult-led and child-led activities (Department for Education (DfE), 2014).

There are several statutory requirements placed on state primary schools in England regarding the reporting of children's outcomes in mathematics. They are required to report their pupils' mathematical outcomes at the end of Reception, Key Stage One and Key Stage Two (Standards and Testing Agency, 2018a, 2018b, 2018c).

With regards to summative assessment in the Nursery, staff use Development Matters to assess the children's understanding in each area of learning (Early Education, 2012). This document has age-bands containing statements describing what a child showing 'typical' development for their age may be demonstrating. The children in nursery are described as having either an emerging, developing or secure knowledge of each age band depending on how many statements they have demonstrated. A 'best-fit judgement' is then used to decide whether a child is showing typical development for their age (Early Education, 2012). At the end of Reception children are then assessed against the Early Learning Goals (ELG) informed by observations of the child using Development Matters (Early Education, 2012). Schools are required to report whether a child is working at the 'emerging', 'expected' or 'exceeding' level at the end of the Early Years Foundation Stage (Standards and Testing Agency, 2018a). Researchers have found that, throughout their schooling, those children born in the summer months tend to not perform as well as their autumn born peers, with the gap being at the widest the younger the children are, and narrowing as they get older (Crawford, Dearden and Greaves, 2013). The use of age-bands would appear to support the assessment of these summer-born children in the class, who may be nearly a whole year younger than some of

their peers. However, the assessment at the end of the Reception does not take into account children's month of birth, with all children assessed against the same ELGs.

Key Stage One outcomes are informed by national tests and teacher assessment (Standards and Testing Agency, 2018b). Teachers are provided with a framework of 'I can' statements against which to judge whether a child is working at the expected standard for their age in mathematics (Standards and Testing Agency, 2018d). Schools are required to report whether a child is 'working towards the expected standard', 'working at the expected standard' or 'working at greater depth within the expected standard' (Standards and Testing Agency, 2018b). Key Stage Two outcomes are informed by national testing only with this national testing determines whether a child is working at, below or above the expected standard (Standards and Testing Agency, 2018c).

The previous National Curriculum provided assessment levels for years one to six and descriptors of each level for mathematics (Department for Education and Employment and Qualifications and Curriculum Authority, 1999). However, the introduction of the current National Curriculum in 2014 saw the removal of these levels (Department for Education, 2013). A Commission on Assessment without Levels (CAWL) was established by the government who argued that by removing levels teachers would be able to spend more time on in-depth teaching and using formative assessment approaches to support pupils progress, rather than tracking progress towards numerical targets (McIntosh, 2015). However, in a qualitative study reviewing the effect of assessment without levels most respondents reported that teachers were still spending a similar amount of time on assessment as they were prior to the removal of national curriculum levels, with some schools even reporting they were now

spending more time on assessment (Poet *et al.*, 2018). The commission also argued that the removal of levels would lead to the better use of formative assessment by teachers (McIntosh, 2015). In the review of the implementation of assessment without levels it was found that teachers were now focusing more on formative assessment than prior to the removal of levels (Poet *et al.*, 2018).

2.14 Parental involvement in counting

Parental involvement in education has changed and developed over the years. The educationalists' views of parents are argued to range from *parents as problems*, to *parents as partners*, to *parents as consumers* (Hughes, Wikeley and Nash, 1994). Athey (1999) argued that a parent-teacher partnership was crucial to support the development of young children. Research shows that there are great individual variations in the mathematical knowledge of children by the age of four (Fuson, 1988; Aubrey, 1993; Starkey, Klein and Wakeley, 2004; Sarnecka and Lee, 2009). This indicates that there is a relationship between children's preschool experiences and their mathematical knowledge at the start of school. Parents play a key role in this preschool experience.

2.14.1 Knowledge on entry to school

Children's mathematical knowledge on entry to school is significant because there is increasing evidence that this knowledge indicates subsequent success in mathematics later on in schooling (Aunola *et al.*, 2004; Aubrey, Godfrey and Dahl, 2006; Clements and Sarama, 2008; Hannula-Sormunen, Lehtinen and Rasanen, 2015). The EPPE project found that those children who had preschool experience showed an intellectual advantage in early primary school when compared to those children who had no preschool experience (Sylva *et al.*, 2004). Research in Finland found that if children entered preschool with a high level of

mathematical skills they made faster progress in mathematics at school over a three-year period (Aunola *et al.*, 2004). Research in England found that if children began school with mathematical knowledge they showed better mathematical progress through primary school than those who began school with little or no mathematical knowledge (Aubrey, Godfrey and Dahl, 2006). In the United States early interventions in mathematics for pre-schoolers helped them to develop mathematics knowledge and score higher in mathematical assessments than those who had received no early intervention (Clements and Sarama, 2008). In their longitudinal study about how early numeracy skills of different performance groups develop during the Finnish kindergarten year, Aunio *et al*. (2015) found differences in mathematical skills between children were already visible before formal mathematical education began. This study measured children's early numeracy skills at three points during the kindergarten year with children having an average age of six at the start of the study. They also found that although children with low performing counting skills improved during the kindergarten year, they did not catch up with their peers (Aunio *et al.*, 2015). In fact, using the data from six longitudinal studies, it has been shown that mathematical skills on entry to school are one of the three strongest predictors of later achievement, alongside reading and attention skills (Duncan *et al.*, 2007). Even though causality has not yet been proven this research indicates the need for effective preschool provision in mathematics and the key role parents play in supporting their children's preschool mathematical development.

2.14.2 Parental input

The Froebel Early Education Project (Athey, 2007) had a significant impact on the role of parents in young children's education. The project linked three key aspects of young children's education; parents, professional educators and pedagogy (Nutbrown, 2011). Through the project professional educators supported parents in identifying schemas and

developing ways to support these schemas at home. The research indicated that children's development could be supported by parents and early years settings working together in a number of ways. These included sharing the children's interests at home and in the setting, sharing records kept on children and planning together to enhance learning, jointly planning the experiences that will be provided at home and in the setting, parents borrowing resources from the setting, and by parents joining children on visits planned by the setting (Athey, 2007).

Research has been conducted in a number of countries to explore the impact of different types of parental input in mathematics. In Canada, parental reports of preschool exposure to formal home number activities (e.g. practising calculations), informal number games, and parents' enjoyment of numeracy all had a positive impact on mathematical outcomes for children one year after starting kindergarten (Skwarchuk, Sowinski and LeFevre, 2014). Similar results were found in a study in Greece (Manolitsis, Georgiou and Tziraki, 2013) and in the Netherlands (Kleemans *et al.*, 2012). More recent research with nine to thirteen-year olds in Spain found that parental involvement, such as showing an interest in children's progress and school work, improved children's confidence and motivation in mathematics (Rodríguez *et al.*, 2017). However, each of these studies relied on parental reports through questionnaires. The parents may not have been accurate with their reports or may have misunderstood the questions they were being asked.

Other researchers have used observation as a method to explore parental input in number at home. For example, Durkin *et al*. (1986) carried out a longitudinal study of the early number reference used by a small group of primary care givers with their children, at three-month

intervals, from their ninth to their 36th month. They found that the first few numbers were primarily used. Although the parents did try to teach their child counting, the input was not always consistent or clear, due to the linguistic system and social interaction. They also found that the use of number changed as children became older, with more explicit teaching of number and less nursery rhymes and songs (Durkin *et al.*, 1986).

How parents engage with their child at home has been shown to impact on early mathematical development. For example, Gunderson and Levine (2011) researched the quality of parent number talk in the home environment and found that not all types of number talk had an equal impact on children's development in number knowledge. They found that counting and labelling sets of 'higher' numbers of items (4-10) rather than smaller sets was the strongest predictor of a child's later cardinal-knowledge (Gunderson and Levine, 2011).

Researchers have argued that mathematics is taught less frequently at home than literacy skills (Fluck, Linnell and Holgate, 2005; Cannon and Ginsburg, 2008). However, research has indicated that parental teaching of literacy at home predicts children's early mathematical acquisition as strongly as parental teaching of numeracy at home (Manolitsis, Georgiou and Tziraki, 2013). One reason put forward by parents for teaching literacy more frequently than mathematics at home was a lack of personal interest and strength in mathematics (Fluck, Linnell and Holgate, 2005). However, other researchers have found that counting is an area of mathematics parents can help with relatively easily at home. For example, Jones (1998) found that Somali parents in England were able to help their child at home with counting. These children experienced 'formal' teaching at home, through learning by rote, as well as informal learning through play with older siblings (Jones, 1998). As already discussed in the

introduction, this informal learning is a vital step in the development of more formal mathematical skills. When the children then began learning mathematics in Reception class, the Somali children and parents had difficulty identifying the mathematics in the play-based curriculum.

2.14.3 Social and economic circumstances

The significant disparities between children's mathematical knowledge has been shown to be associated with social and economic circumstances. Research indicates that children from a lower socioeconomic status have less mathematical understanding than their more affluent peers (Hughes, 1986; Young-Loveridge, 1991; Jordan, Huttenlocher and Levine, 1992; Wright, 1994; Shonkoff and Phillips, 2000; Denton and West, 2002; Jordan, Hanich and Kaplan, 2003; Van de Rijt *et al.*, 2003; Starkey, Klein and Wakeley, 2004; Sylva *et al.*, 2004). This could be because, according to parental reports, middle socioeconomic status (SES) children engaged more frequently in activities at home which supported mathematical development than lower SES children (DeFlorio and Beliakoff, 2015). Middle SES children also appear to acquire the cardinal principle earlier than those with a lower SES (Ginsburg and Russell, 1981). The reasons for this have been explored by researchers. In the 1980s it was shown, when comparing mathematical activities in the home environment, middle SES mothers engaged their children in more complex number activities than lower SES mothers (Saxe *et al.*, 1987). Young-Loveridge (1989) interviewed parents of children who were exceptions to the general pattern of association between SES and achievement to achieve greater insights into the ways home experiences affect achievement. Although this was a small sample of only six parents, Young-Loveridge found that high achievers from low SES backgrounds seemed to enjoy a rich variety of number experiences which contrasted markedly with the lack of number experiences found for the two low achieving children from

high SES families. The children's achievement also seemed to be dependent on the mother's attitude to mathematics rather than the fathers' occupations or mothers' education levels (Young-Loveridge, 1989). Although causality cannot be drawn from the findings of this small study, it does highlight the importance of looking closely at home environments rather than generalising due to social status. For example, researchers in Germany studied the impact of the 'Home Numeracy Environment' (HNE) on the development of mathematical understanding while controlling for other variables, including socioeconomic status. They found that the 'Home Numeracy Environment' was an important predictor of mathematical understanding at the end of kindergarten and beyond (Niklas and Schneider, 2014). In the UK, the large scale EPPE project concluded that the quality of the home learning environment was more significant to children's outcomes than parents' social class or educational background (Sylva *et al.*, 2004). Researchers in the US found that proficiency in mathematics at the start of kindergarten accounted for the greatest decrease in the gap in achievement in mathematics between low and high SES families (Galindo and Sonnenschein, 2015).

2.15 Language and culture of counting

The role of language and culture is significant in my study because all of the children in the study are bilingual and from an ethnic minority background. Therefore, this section supports the understanding of the context of my study.

2.15.1 The language of counting

Counting is a culturally transmitted formal system (Resnick, 1989). It is a simplified view to see the language of counting as merely learning the counting words. Language is more than just the vocabulary used, it is also the order of the words and the way the words inflect each other. Researchers have argued that language issues are an important focus in the teaching of

mathematics because of the 'language-like' nature of the subject (Pimm, 1987; Moschkovich, 2010). This means that the learning of mathematics requires a variety of different linguistic skills (Adetula, 1990). To be able to participate and understand mathematics children need to have competence in communicating in mathematical discourse. Even children who are monolingual can have difficulty learning the language of mathematics because it contains many words which have slightly different uses in mathematics to everyday conversation (Hughes, 1986). Learners have to understand not only the words but also their meanings and the ways they are used. Therefore, in my study this situation is intensified because the children are speaking a different language at home and at school.

Mathematical language is significant to the development of mathematical knowledge. Klibanoff *et al*. (2006) found dramatic differences in the amount of mathematical talk provided by preschool teachers in the US. Their results indicated that there is a significant relationship between the amount of mathematical talk a preschool teacher provides, and the growth of children's conventional mathematical knowledge over the school year. They argue that acquiring mathematical language is an important tool in the acquisition of mathematical concepts (Klibanoff *et al.*, 2006). This supports the claim by Donaldson (1978) that in order to be able to generalise from various mathematical experiences and develop abstract ideas children must understand mathematical language.

Links between children's general language development and their knowledge of number words have been explored (Negen and Sarnecka, 2012). The theory behind this is that if a child has a better knowledge of nouns then they will be able to better understand a noun phrase which contains a number word. The child will be able to identify the number words

because they would understand the other vocabulary in the sentence. Negen and Sarneck (2012) found a strong correlation between overall vocabulary score and number word knowledge in monolingual children aged between two years and six months and four years and nine months. These findings are relevant to this study because bilinguals have been shown to have a smaller vocabulary in each of the languages they speak than monolinguals (Pearson, 2002; Perani *et al.*, 2003; Mahon and Crutchley, 2006; Portocarrero, Burright and Donovick, 2007). Also, research indicates that there is a strong correlation between a child's vocabulary score and their parents' vocabulary score, with children from lower socioeconomic status (SES) families being exposed to a smaller vocabulary because their parents use a smaller vocabulary (Hart and Risley, 1995). The use and explanation of more complex vocabulary is strongly associated with acquisition of a larger vocabulary (Beals, 1997). The children in this study are both bilingual, and from lower SES families. Therefore, this research indicates that they could have a smaller vocabulary than children from higher SES families and this may then impact on their knowledge of number words.

The vocabulary and grammatical structure used in counting in different languages have been explored to look for any impact this has on how children develop counting knowledge. As previously discussed in section 2.3, there are irregularities in the pattern of the sequence of the English counting system that make it difficult for children to learn the counting sequence. Therefore, children have to memorise parts of the sequence (Fuson, Richards and Briars, 1982; Siegler and Robinson, 1982). This is different to other number-word sequences, for example, the Chinese counting system has a pattern which appears to make it easier for Chinese children to learn (Miller and Stigler, 1987).

Sarnecka *et al*. (2007) looked for links between the child's native language and how they acquire understanding of cardinality. English and Russian learners, where the languages mark singulars and plurals, were compared to Japanese learners, where the language does not mark singulars and plurals. Researchers found that English and Russian learners knew the cardinal meanings of the words 'one', 'two' and 'three' earlier than Japanese learners, even when the singular and plural cues were removed from the task (Sarnecka *et al.*, 2007). It is proposed that this is because the number-word meanings of these first number words are learned through the conceptual framework of grammatical number. Therefore, when a child learns the number 'one' they understand that it means singular and think that all other numbers mean plural. They then learn the number 'two' but still think that all other higher numbers still mean plural. Then they learn the number 'three' and know that three items are referred to as 'three'. All other number words refer to sets bigger than three.

How a language positions number words in a sentence has been shown to impact on children's understanding of number. Ramscar *et al*. (2011) found that when the number is in a prenominal position (e.g. those four cars), as is the case in English, then the time taken to acquire the number words was lengthened when compared to languages that have a postnominal position for the number word (e.g. those cars, all four of them). It is argued that this is because in postnominal positions, the item being counted is discriminated prior to the use of the count word so the child is more easily able to isolate the number word (Ramscar *et al.*, 2011).

2.15.2 Bilingual learners

It is proposed that the language we use and hear controls and structures our thoughts (Vygostky, 1986). Therefore, language is important in constructing mathematical knowledge.

This is relevant to the children in my research as they have a different home language to the language used in school. Within schools these children are defined as having English as an additional language (EAL) because their first language is not English.

Research on the effects of bilingualism in mathematics education has been taking place since the 1970s (Austin and Howson, 1979; Cuevas, 1984; Secada, Walter, 1991). In the UK in particular the impact of bilingualism is becoming a more prevalent issue. The percentage of pupils with a first language other than English has been rising over recent years. In 1998 8.5% of primary school pupils and 7.8% of secondary school pupils had a first language other than English (Blair *et al.*, 1998). This percentage has risen to 18.7% of all pupils in compulsory schooling in England (Department for Education, 2014). This figure is different across England with Inner London recording the highest percentage of 55.8% compared to the lowest percentage of 6.4% in the north east of England (Department for Education, 2014).

The government advocates support of the child's home language to support progress. The Statutory Framework for the Early Years Foundation Stage in England states that:

> *For children whose home language is not English, providers must take reasonable steps to provide opportunities for children to develop and use their home language in play and learning, supporting their language development at home.* (Department for Education (DfE), 2014: 9)

The same document also states that providers must give children sufficient opportunities to reach a good standard in English language (Department for Education (DfE), 2014). Also, throughout the non-statutory guidance for practitioners in the EYFS in England there is guidance on the support that should be offered to bilingual learners (Early Education, 2012). For example, the mathematics section advises practitioners to encourage parents to talk in

their home language about quantities and numbers (Early Education, 2012: 32). This is necessary because language, culture and identity are all closely interwoven so it is important that children feel that their own language and culture are recognised and valued (Siraj-Blatchford, 1996; Chen and Gregory, 2004; Conteh and Brock, 2006). The most recent National Curriculum in England refers to bilingual learners in the 'inclusion' section of the document (Department for Education, 2013). It requires teachers to take into account the pupil's age, length of time in the country, previous educational experience and ability in other languages when monitoring their progress. It also advises teachers to plan opportunities to help pupils develop their English and to provide the support pupils need to take part in all subjects (Department for Education, 2013). With regards to assessment, the Statutory Framework for the Early Years Foundation Stage in England states that assessments of communication, language and literacy skills must take place in English. Where children do not have a strong grasp of English language the child's skills in their home language must be explored to find out if there is a concern about language delay (Department for Education (DfE), 2014). A bilingual child can be disadvantaged because it can be difficult to distinguish whether they have any special educational needs if staff in the setting do not speak the child's home language.

2.15.3 Culture

Language is not merely a set of words and phrases; it reflects differences in culture too. This research focuses on the development of counting skills and the language used by the children involved. However, it is important to consider the impact of the children's culture on their learning because their cultural group is the shared framework of communication that includes not just spoken and written words, but also facial actions, gestures, actions and tones of voice (Fawcett, 1996).

Children form their sense of identity, community and belonging through the languages they speak and through how these languages are perceived (Siraj-Blatchford, 1996). Moschkovich (2010) considers not just the language used but also the social and cultural participation in language practices and communities as an aspect of bilingualism. In a classroom where children are bilingual each child will be bringing a different 'toolkit' with them (Bruner, 1990).

The language we use is instrumental in helping us to form our sense of belonging to a community and our identity (Siraj-Blatchford, 1994; Bialystok, 2001). Kenner (2005), who conducted research with bilingual three to seven-year olds living in London, found that children 'hybridised' the two cultural worlds they were living in simultaneously. That is, they connect the world based around English at school and the other based around their home language and culture (Kenner, 2005). However, some researchers argue that one cannot generalise about children's learning and development and that it is dangerous to impose ideas from one culture onto others, because it is important to take account of the context-dependent nature of children's understandings (Singer, 1992; Dahlberg, Moss and Pence, 2007).

Children's understanding of counting can be linked to their home language from infancy. Researchers studied infants' language preference by exposing them to a correct count and a count that violated the one-to-one principle in their own language, in a foreign language, and using beeps (Smidt, 2008). The results showed that infants did not show an understanding of the one-to-one principle in a foreign language but did in their own language. This indicates that exposure to their cultural counting routine supports children in learning the one-to-one principle. Bilingual learners will have also developed an internal dialogue in their home

language and may have experienced nursery rhymes, songs and stories in this home language. This may prove confusing when they begin school and start speaking in a different language.

2.16 Positioning this research

My review of the literature has revealed that there is still ongoing debate regarding how children learn to count and how best to support them in learning to count. There appears to be a gap in the research regarding tracking the same child's understanding of counting over an extended period of time. As discussed in section 2.11, a recent all party parliamentary group even recently highlighted the need for more research into how young children learn mathematics so that teaching methods can be informed (All Parliamentary Group for Maths and Numeracy, 2014).

The literature has revealed the significant impact that children's early understanding of counting can have on their outcomes in mathematics later on in their schooling (Aunola *et al.*, 2004; Sylva *et al.*, 2004; Aubrey, Godfrey and Dahl, 2006; Clements and Sarama, 2008; Hannula-Sormunen, Lehtinen and Rasanen, 2015). However, although it is recognised that support for those children who arrive at school working with lower skills in counting is required (Engel, Claessens and Finch, 2013), further research is needed into what this explicit instruction should involve (Hinton, Stroizer and Flores, 2015). Therefore, this research aims to support our knowledge of how children's understanding of counting develops during their year in nursery.

2.17 Summary of chapter

In this review of the literature I have explored what is known about verbal counting and each of Gelman and Gallistel's five counting principles (1978). I have discussed what is already

known about the development of understanding of counting and have explained the competing discourses. I reviewed the different theories about how children learn to count and what is already known about how children's counting skills develop. Finally, I have reviewed three areas of literature relevant to the context of my research: teaching and learning counting in the nursery; parental involvement in counting; and language and culture of counting. I have then positioned my research in the context of the current literature. In the following chapter, I discuss how I used this literature review to arrive at my research questions and how I then developed a research methodology in order to address them. This review of the literature is then applied to my analysis of the data in chapter four.

CHAPTER THREE - RESEARCH DESIGN AND METHODOLOGY

3.1 Research Questions

Through my review of the literature, discussed in the previous chapter, I identified a gap in the current research around how individual children's understanding of counting develops over time. This led to the overarching research question:

How does a child's counting develop during the preschool nursery year?

The three sub-questions, which have guided the study are:

1. *What does the development in understanding of counting look like for a child during the preschool nursery year?*
2. *How does a child's baseline attainment and their reported previous experience in counting relate to their development in understanding of counting during the preschool nursery year?*
3. *How does reported teaching relate to the development in understanding of counting during the preschool nursery year?*

My research offers a new perspective on children's understanding of counting because it focuses on the same children over a one-year period. My research also focuses on using meaningful contexts in the questions asked. In the rest of this chapter I explain and justify the

research position taken and the methodological approach used to address this research question.

3.2 Research Position

Burrell and Morgan (1979) offer a continuum upon which to position social science research, with a subjective approach at one end of the continuum and an objectivist approach at the other end of the continuum. The ontological, epistemological and methodological positions are all informed by the assumptions I made. I have taken a subjective approach to research because I hope to generate socially and culturally constructed information about the individual participants. I aim to track the participants' understanding, rather than improve it, with the objective of learning from and improving current practice. I am not aiming to generalise my findings and have taken the position that social reality is formed by each individual's consciousness; therefore, the ontological position of this research is nominalist (Cohen, Manion and Morrison, 2007). This leads to an interpretive epistemological position because knowledge is viewed as personal and unique to each individual (Burrell and Morgan, 1979). This position has led to the idiographic methodological approach taken in this research, whereby I have chosen to emphasise the particular case being studied and the individuals forming the case rather than on generalising (Burrell and Morgan, 1979). However, I aim for the research to produce findings that are relatable to schools in similar settings.

It is important for researchers to understand their own role in the creation of knowledge (Berger, 2015). I am positioned within the research and I believe that the researcher can never be independent of the researched (Pring, 2000). Therefore, research reflexivity was

considered throughout the research process whereby my own experiences informed the research process and outcomes (Etherington, 2004). My own position as both researcher and Deputy Headteacher at the school, and my own personal views and beliefs guided not only my topic of research but also my choice of paradigms and methods (Crotty, 1998). Merriam *et al*. (2001) describe advantages of being positioned within the research: easier access, being able to ask more meaningful questions over the course of the study, and being able to have a more authentic understanding of the research setting than an outsider would have. However, it is possible to be too close to the research setting to ask provocative questions (Merriam *et al.*, 2001).

The knowledge constructed is dependent on the situation of the research, is subjective and is based on the individuals' perspectives (Cohen, Manion and Morrison, 2000; Pring, 2000). However, throughout the research I refer to and draw upon research material and knowledge that is outside the subjective world of the researcher. I had regular interaction with the subjects of the research. The constructivist paradigm also lent itself to using a range of research methods in order to acquire multiple perspectives (Robson, 2002).

3.3 Pilot Study

My ontological and epistemological position has moved since my pilot study in which I adopted a more positivist approach and attempted to look for evidence of impact of an intervention using an experimental, quantitative approach. In my pilot study, I aimed to find out if an intervention to support parental involvement in counting over a six-week period in nursery affected children's conceptual understanding of counting. The parents attended a weekly workshop where they were given a counting activity to take home and complete with

their child over the week. I had an intervention group and a control group. I assessed each of the children's understanding of counting before and after the six-week intervention period in a task-based interview using the same instrument as Briars and Siegler (1984). This instrument and the modifications I made to this for my main study are discussed later in this chapter. I found little difference in the progress made between the control and intervention group. I concluded that it was possible that the timescale was too short for the intervention to have any significant impact. I also concluded that it would be difficult to attribute any progress made by the children to the intervention and not to the teaching they were receiving at school. When interviewing the parents during the pilot study the issue of speaking English as an additional language was raised by several of the interviewees. I probed them more and found that despite not speaking English as their first language, the parents all taught their children to count in English. This research process led me to becoming more interested in what the development in counting looked like for the individual children in this setting. It also led me to change my position to a more interpretive approach.

3.4 Qualitative research

As previously explained, my research position is one where I have chosen to focus on the uniqueness of the individuals involved in the case study rather than focusing on producing generalisable findings. This research position fits with an interpretive qualitative research approach because this type of approach is focused on the individual context at a particular point in time (Merriam, 2002). Qualitative research aims to understand a particular situation and the unique interactions that occur within a context (Patton, 1990). This matches the aims of my own research. I aim to generate a theory and look for the variables that arise, rather

than negate them. My research questions will be best addressed through using a case study approach. In the following section, I explain this decision in more detail.

3.5 Case Study

3.5.1 Rationale for a case study approach

As detailed in section 3.2, my own position as both researcher and Deputy Headteacher, and my own experiences, guided how I chose to approach this research and the methods used (Crotty, 1998). Therefore, one of the key reasons I adopted a case study approach is because of the emphasis on studying the complexity of a real-life situation (Simons, 2009). Another key reason was because a case study approach gave me the opportunity to present the research through my eyes (Donmoyer, 2000). Case study research sits within the 'social-constructivist' paradigm because it assumes that 'social reality' is created through social interaction (Stark and Torrance, 2005). By conducting a case study, I was able to develop a 'triadic overview' of each child's case study story, with the child being at the heart of the triad with the family, teachers and peers surrounding the child (Pollard, 1996). Another reason I chose a case study approach is because of the focus on in-depth study (Stark and Torrance, 2005). This meant that I could look at the subject from many different angles to draw rich information about how and why something might have happened (Thomas, 2011). Some researchers argue that case studies should not disturb the ordinary activity of the case at all, and include no tests or interviews (Stake, 1995). However, I chose to include these more structured methods of data collection in my case study, because I considered they would provide me with the opportunity to collect the richest data in order to meet the aims of my research. These methods of data collection will be discussed later on in this chapter.

Two other common types of social research were considered for this research: the experiment and the social survey (Hammersley and Gomm, 2000). It is useful to draw comparisons between a case study and these other types of research to justify the use of a case study to answer my research question. Firstly, the aim of this research was to find out how children's understanding of counting developed. I needed to study the situation in-depth, looking at the relationship and processes within its real-life context (Yin, 2009). This is achieved by focusing on the particular details of a case (Denscombe, 2010). Therefore, a case study, rather than an experiment or social survey, was an appropriate research strategy to meet this aim. An experiment would have been more appropriate if I was aiming to study causation, and a social survey would have been more appropriate if I was aiming for statistical generalisability (Thomas, 2011). Secondly, I needed to focus on the particular details of the case in order to answer the research question so it was more suitable to study just one case in-depth. Therefore, a case study was the most suitable strategy because social survey research focuses on a relatively large number of cases whereas case study research can focus on just one case (Gerring, 2007; Thomas, 2011). A third reason for selecting a case study over other types of social research is that multiple sources of evidence needed to be collected in order to answer the research question. Case studies rely on multiple sources of evidence (Yin, 2009) and many methods can be used to collect the data (Merriam, 1988; Robson, 2002; Punch, 2009; Hamilton and Corbett-Whittier, 2013). A case study was more suitable because experiments and social surveys tend to use just one method (Hammersley and Gomm, 2000).

A final reason for selecting a case study over other types of social research is that in order to address the research question it was important to study the phenomenon within its real-life context (Robson, 2002; Punch, 2009; Yin, 2009). The aim of the research was not to identify

causation or generalisability so it was not necessary to control the variables to answer the research question.

3.5.2 The case

There is no commonly agreed definition of a case although there are some common features of what a case must be. The case must be a 'bounded system' (Punch, 2009) with fairly distinct and identifiable boundaries (Gerring, 2007; Denscombe, 2010; Hamilton and Corbett-Whittier, 2013). Thomas (2011) describes this boundary using the metaphor of a suitcase whereby the case is the study of everything bounded within the suitcase.

In this study, the boundary was the nursery class in the primary school for the year that the data was being collected. However, the parents and local community will also influence the case. Therefore, in this study the case included the parents because they have such a strong influence on the children's understanding of counting. The school context is explained in more detail in section 1.5. This school was selected for two reasons. Firstly, the case presented a group of children who had just begun their first year of full-time schooling in the English education system. This case provided the opportunity to find out how their understanding of counting developed over that first year in school. Secondly, the case was in a school where I worked full time as the Deputy Head Teacher. This meant that the case was of professional interest to myself and was intrinsically interesting to me (Stake, 1995). I was involved and interested in the development of the children in the school and had access to the children, parents and teachers. However, this accessibility was a subordinate reason for selecting this case (Denscombe, 2010).

The year-long timeframe was an important feature of the data collection because it meant that differences could be revealed over a defined time period (Gerring, 2007; Thomas, 2011). However, studying a case over a period of time did provide some of the challenges detailed by Hamilton and Corbett-Whittier (2013). Firstly, it required me to be persistent and show continuous effort. Secondly, it required me to be flexible and adaptable as unexpected events occurred over time. Finally, it was challenging to bring the research to a conclusion and share the findings with the participants (Hamilton and Corbett-Whittier, 2013).

3.5.3 The theoretical framework

The theoretical framework provided the case study with a purpose and was an essential component of the study (Yin, 2009; Thomas, 2011). A theoretical framework provides a guide on what data to collect and how to analyse it (Yin, 2009). The theoretical framework for case study research is a continuum with theory or hypothesis building at one end and theory or hypothesis testing at the other end (Gerring, 2007; Thomas, 2011).

Theory or hypothesis building involves generating a framework of ideas to explain the subject you are researching (Thomas, 2011). This study sits at this end of the continuum, focusing on describing what is happening in the setting, exploring the key issues, or, in case studies with multiple cases, comparing the settings to learn from similarities and differences between them (Denscombe, 2010). The review of the literature has revealed that Gelman and Gallistel's (1978) five principles of counting provide an appropriate theoretical framework to study the development of children's understanding of counting. Therefore, this study uses Gelman and Gallistel's (1978) five principles of counting as a theoretical lens to study and explore children's understanding of counting. This study also applies Briars and Siegler's (1984) proposal that children learn how to count prior to understanding the counting principles. The

study uses children's assessments of others' counting to build on knowledge about how children's understanding of counting develops. The review of the literature has revealed a gap in knowledge about how the children's understanding of counting, when tracking the same children, develops over an extended period of time. Therefore, this case study focused on building on Gelman and Gallistel's theory in a meaningful setting with a specific focus on how children's understanding of counting developed over time rather than testing an existing theory (Merriam, 1988).

This theoretical framework impacted on the type of case study chosen. Case studies can be divided into three main types: intrinsic, collective, and instrumental (Stake, 1995). If the purpose of the case study had been to understand the case more fully by capturing the whole case then an intrinsic case study would have been most appropriate. If the case study had aimed to learn more about a population, phenomenon or general condition then a collective case study would have been used. A collective case study is an instrumental case study using multiple case study design. However, this case study focused on a particular aspect, the development of understanding of counting, so an instrumental case study was most appropriate.

As I was positioned within the research I kept a research diary that supported me in distinguishing between things I saw and my own reflections (McNiff and Whitehead, 2006). This helped me to reflect on my research and the learning so far. As findings emerged, I was able to read about these findings and adapt my thinking.

3.5.4 The number of cases

The case study design I chose to address my research questions was an embedded case study (Yin, 2009) because it involves individual cases, or subunits, that fit into a larger unit (Thomas, 2011). Children were selected as individual cases, or subunits, which were part of the larger unit of the nursery class of 2014-2015. By choosing this design and having eight cases, more powerful analytical conclusions could be drawn because they could be drawn from more than one case (Yin, 2009). The children were studied in parallel rather than sequentially. Therefore, each case was receiving the same teacher input in their class. If the cases were studied over different years then the teacher may have changed and it is possible that the curriculum being taught may have been changed by the government.

3.5.5 Choosing the individual cases

The selection of the eight embedded cases was done purposefully and with the aim of providing as much relevant information to answer the research question as possible. The individual cases were not selected as 'sampling units' representative of the wider population because I was not trying to achieve statistical generalisation (Merriam, 1988; Yin, 2009; Thomas, 2011). I wanted a range of counting and language levels on entry to nursery to capture the variation within the nursery. I also wanted to provide an equal representation of both genders to ensure equality in the research. Therefore, children were selected based on their language and counting levels on entry to nursery, their predominant home language, and their gender. All children selected also attended the nursery on a full-time basis and were in the same nursery class to ensure consistency in the class teaching and the amount of time spent in school. I did not select any children who had been identified as having a special educational need. All children selected were from a Bangladeshi background because this was the dominant cultural background of children in the school. There were not any other

significantly sized ethnic groups represented in the school. However, after beginning the research one of the girls selected left the school. She left at the point when I had already conducted the first round of data collection so I concluded that it was too late to select another child to replace her in the study. Therefore, seven children took part in the study. Information about the seven children is shown in table 1.

***Table 1**: Information about the seven participants*

Child's Alias	**Gender**	**Month and Year of Birth**	**Age at start of study**
Ridwan	M	August 2011	37 months
Safwaan	M	July 2011	38 months
Ayesha	F	June 2011	38 months
Maryam	F	June 2011	39 months
Sadia	F	March 2011	41 months
Abdul	M	February 2011	43 months
Musa	M	September 2010	48 months

3.5.6 Strengths of this research approach

Using a case study approach to this research provided me with the opportunity for a rich, detailed, and whole description and analysis of the case (Geertz, 1973; Merriam, 1988; Gerring, 2007; Denscombe, 2010; Thomas, 2011). This in-depth data dealt with the subtleties and intricacies of complex social situations (Denscombe, 2010). I found the approach to be holistic so the interconnected relationships and processes between the child, parent and teacher were looked at (Denscombe, 2010). As I was positioned within the research as both researcher and Deputy Headteacher, the case study strategy gave me the opportunity to represent nursery children's counting from the participants' perspective (Stark and Torrance, 2005) whilst also presenting the research through my eyes (Donmoyer, 2000). Through the case study approach, I was able to explore why certain outcomes happened rather than just finding out what the outcomes were (Denscombe, 2010). As this strategy was carried out in a

setting where the case already existed not all of the data needed to be artificially generated (Gerring, 2007; Yin, 2009; Denscombe, 2010).

3.6 Data Collection Methods

I used three different methods of data collection, with each method serving a purpose towards answering my research questions. Each research method is described in more detail in the following sections of this chapter. The three methods of data collection are:

- Task-based interviews with children;
- Documentary evidence; and
- Interviews with parents.

Table 2 summarises the data collection points during the nursery year. The interviews with parents were carried out first because I needed to find out about children's home experiences of counting before they started nursery. I conducted these within the first two weeks of the children starting in the nursery because I wanted to capture the children's home experiences before the nursery setting had influenced the parent. The nursery teachers invested a lot of time supporting parents with activities to do at home and this may have impacted on the home experiences if I had waited longer to interview the parents.

The task-based interviews began five-weeks into the school term so that children had settled into the nursery setting. Ten task-based interviews were carried out at monthly intervals. I collected documentary evidence six times throughout the year, at half-termly intervals. I collated all of the planning completed by the teacher and all of the observations made by the nursery staff of the children in this study. As part of this documentary evidence I also

collected the assessment data produced by the class teacher for each child. This was collected at the beginning and end of the nursery year. This data was also collected at the end of the Reception year.

***Table 2**: The data collection points during the nursery year*

	Task-based interview	**Documentary evidence**	**Interviews with parents**
September		✓	✓
October	✓		
November	✓	✓	
December	✓		
January	✓	✓	
February	✓		
March	✓	✓	
April	✓		
May	✓	✓	
June	✓		
July	✓	✓	

3.7 Task-based interviews with children

3.7.1 Overview of the task-based interviews with children

The aim of the task-based interviews was to address research questions one and two, about children's development of understanding of counting and how the baseline levels and reported prior experience in counting relate to this development. I worked one-to-one with each child and asked them a series of questions to try to establish their current level of understanding of counting. In this section, I explain the overarching principles around the design of the questions asked. An example of an interview schedule can be found in appendix one and the detail regarding the decisions about each interview question are found in appendix two.

In my pilot study, I had based my research on that of Briars and Siegler (1984) and had asked children to count counters pasted onto a cardboard strip. However, I found that children had not been engaged with this type of questioning so for my main study I aimed to make the interview more purposeful, relevant and interesting to the child. I adapted the research by Briars and Siegler (1984) by setting the questions in a meaningful context. As discussed in section 2.12.1, research has shown that if a task is 'embedded' in a meaningful context it supports children in showing evidence of their number knowledge (Donaldson, 1978). I used a more meaningful context for my questions because research suggests that children can demonstrate more knowledge in meaningful contexts than in artificial contexts (Hughes, 1986). The context of each interview reflected the text being taught in the nursery class at the time of the task-based interview so that it was familiar to the children. The stories were selected to give a meaningful context to the mathematics, based on children's engagement in their school lives. The first three task-based interviews had an 'Owl Babies' context (Waddell and Benson, 1994), the next four task-based interviews were based around the text 'Brown Bear, Brown Bear, what do you see?' (Carle and Martin Jnr, 2007), and the final three task-based interviews were based around the text 'The Very Hungry Caterpillar' (Carle, 1994). This context was then used as a setting for purposeful questions that would engage the children, for example, with the children needing to help Owl Mummy count to prepare a nest and food for her Owl Babies. As discussed in the review of the literature, children need a meaningful context to support their mathematical development (Bryant and Nunes, 2002) and show better mathematical attainment in purposeful, meaningful contexts (Donaldson, 1978; Hughes, 1986).

The key aspect of the literature which framed my design of the task-based interviews was Gelman and Gallistel's (1978) five principles of counting. I structured the interview in such a way as to assess the children's understanding of each of the principles. I then made use of Rittle-Johnson & Siegler's (1998) research regarding procedural and conceptual understanding of counting to frame my questions so as to assess children's procedural and conceptual understanding of each counting principle.

Section 2.3 of my literature review revealed the importance of verbal counting on children's understanding of counting (Fuson and Hall, 1983). Researchers argue that practicing verbal counting should be emphasised when working with young children (Donaldson, 1978; Hughes, 1986). Research has also revealed a high variation in the length of an accurate verbal counting sequence produced by children between the ages of 3½ and 6 years old (Fuson and Mierkiewicz, 1980; Fuson, Richards and Briars, 1982). Therefore, the aim of the first question was to find out how high the children could verbally count.

The next question allowed me to assess children's understanding of the one-to-one principle and cardinal principle. Children were asked to count a set of four objects for a puppet. The puppet was used to make the counting activity more meaningful (Donaldson, 1978). For example, the children were told that Owl Mummy was not very good at counting so needed their help. Four objects were chosen because the first mention of being able to count a set of objects in the developmental framework for children working in the Early Years Foundation Stage states that children should be able to count three or four objects (Early Education, 2012). I did not line the objects up but put them in a group on the table. This is because I was interested to see how the children would count the items and also to see if the child used any

gestures when counting (Graham, 1999). If the child counted the group inaccurately, I then put the items in a line and asked the child to count again. This was to allow me to see any development in their counting depending on the arrangement of the objects. The context of each interview determined the objects that were used for counting. For example, children were asked to count leaves in the task-based interviews focused on 'The Very Hungry Caterpillar'. If children were able to accurately count four objects, in the following interview I increased the number of objects they had to count by two each time because this allowed me to track children's progress in their ability to count larger sets of objects.

Section 2.6 of the literature review revealed that many academics argue that, to establish whether a child understands the cardinal principle, they must be able to accurately respond to the 'give me *x*' question (Schaeffer, Eggleston and Scott, 1974; Fuson, 1988; Frye *et al.*, 1989; Wynn, 1990, 1992). Therefore, in the next task-based interview question, children were asked to give a puppet *x* objects from a set of objects. For example, I asked the children to give Mummy Owl three conkers from a set of six because the developmental framework for children working in the Early Years Foundation Stage states that children should be able to count three or four objects (Early Education, 2012). If children had been able to respond accurately to this question, I would have increased the number of objects in the set and the number of objects they were requested to give in the following interview. However, no children responded accurately to this question.

The first three task-based interview questions focused on children's procedural knowledge of counting. However, the review of the literature (section 2.10) revealed that there is debate regarding the order in which procedural and conceptual understanding of counting are

acquired (Rittle-Johnson and Siegler, 1998). Therefore, conceptual understanding of counting was assessed in the rest of the task-based interview by asking children to identify unusual but correct counts or counting errors in a puppet's counting. The questions asked were based on research by Briars and Siegler (1984), which is discussed in section 1.2, who assessed children's understanding of counting by asking them to judge whether a puppet had counted correctly or not. The puppet performed a range of counts, which contained errors, unusual correct counts, and correct counts. The counting errors used by Briars and Siegler (1984) indicate some of the common mistakes made by children in the early stages of conceptual understanding of counting. The counting errors and unusual correct counts were linked to Gelman and Gallistel's (1978) five principles of counting. For the rest of the interview a puppet was used to provide model counts to the children because I wanted to assess the children's understanding of another's counting as the literature indicates that this frees children from the performance demands of counting (Rodríguez *et al.*, 2013). I kept the number of objects counted by the puppet the same in each task-based interview throughout the school year because I wanted to track children's progress in their understanding of the principle. If children had shown clear understanding of a counting principle then I did plan to increase the number of objects counted by the puppet to see if children could apply their understanding of the principle to a larger set, however, this situation did not arise in the research.

The next two questions were designed to assess children's understanding of the one-to-one principle. Based on the research of McGarrigle and Donaldson (1974) I aimed to assess the children's understanding of the one-to-one principle through the counting of another. However, rather than using a 'naughty teddy', I used a puppet who did not know how to count

(McGarrigle and Donaldson, 1974). As discussed in section 2.5.1, there are several mistakes that can be made when applying the one-to-one principle (Fuson, 1991). However, I chose to focus on missing out an object and double counting an object because these two mistakes clearly illustrated whether children understood the one-to-one principle. The first question involved the puppet missing out one item when counting and the second involved the puppet double counting one object. The 'missing object' question provides a clear example of the meaningful questions I asked:

> **Next Owl Mummy collected some twigs for the nest. She needs to count out the twigs.**
>
> *Put 7 twigs out in a line. Start counting from the same end used as the child. Point to each twig and say the number name as you point. Count each twig but skip one twig, neither pointing to it nor labelling it with a number word.*
>
> **Does this way of counting get the right answer?** *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Children's understanding of the cardinal principle was assessed through their observations of the counting of others (Muldoon, Lewis and Berridge, 2007; Muldoon, Lewis and Francis, 2007). The puppet correctly counted the objects but gave the wrong number to describe how many objects were in the set. Then, to assess children's understanding of the order-irrelevance principle I asked two questions based on previous research to find out if children had difficulty accepting counts which do not follow the conventional order (Rodríguez *et al.*, 2013). Firstly, the puppet produced a correct but non-standard count by counting every alternate object. Secondly, the puppet produced a correct but non-standard count by starting in the middle of the row of objects.

The final two questions were designed to assess children's understanding of the abstraction principle. These questions aimed to find out if children found counting intangible objects more difficult than tangible objects (Baroody, Benson and Lai, 2003). Children were asked to count how many jumps the puppet did and to give the puppet *x* claps to say well done. The 'jumping' question provides another clear example of the meaningful questions I asked:

> **Owl Mummy is very excited that she has everything ready for the Owl Babies, she is so excited that she jumps up and down. Can you count how many jumps she does?**
>
> *Owl Mummy jumps 6 times.*

To conclude this section, table three summarises the questions asked and the particular principle each question focused on.

***Table 3**: How each question given to the children relates to Gelman and Gallistel's (1978) principles of counting (errors adapted from Briars and Siegler, 1984)*

Question number	**Gelman and Gallistel's principles**	**Category**	**Explanation**
1	Verbal counting (part of stable-order)	Procedural	How high can you count?
2	Verbal counting One-to-one Cardinal	Procedural	How many?
3	Verbal counting One-to-one Cardinal	Procedural	Give me…
4	Verbal counting One-to-one Cardinal	Standard correct count	Count from left to right, point to each object once, assign one number word to each object
5	One to one	Counting error – skipped object	Object neither pointed to nor labelled with a word
6	One to one	Counting error – doubly counted object	Object assigned two words and two points
7	Cardinal	Counting error	Count objects correctly but give the *n*th + 1 value when stating how many are in the set
8	Order irrelevance	Unusual correct count – non-adjacent	Start counting from the same end as the child, then count every alternate object, and then reverse direction when the end of the row was reached
9	Order irrelevance	Unusual correct count – start in the middle	Number one was assigned to the middle chip, then the count continued to the end of the row, in the same direction used by the object, when the end of the row was reached resume the count at the other end of the row in the same direction
10	Abstraction		Count the jumps
11	Abstraction		Claps

3.7.2 Procedure for the task-based interviews with children

As shown in appendix one, the interview schedule contained a scripted introduction, questions and closing comments (Robson, 2002). The task-based interviews followed a structured

format with a predetermined list of questions (Thomas, 2011). The same questions were used in every task-based interview, but, as previously discussed, the context changed each time depending on the children's focus book in nursery. I prepared the wording of the questions and order they were asked to provide a consistent structure to the interviews and to maximise the comparability between the task-based interviews (Punch, 2009). However, I did use my judgement as an experienced teacher to adapt the wording of the questions or repeat the questions if I felt this were necessary. The aim of the interview was to find out what the child was able to do and rewording and repeating questions was sometimes necessary to achieve this.

Where children were absent on the day I carried out the task-based interview I would carry out the interview on the day of their return. However, if children were absent for a prolonged period of over two-weeks I missed out that interview as the interview would then end up taking place just before the next task-based interview.

3.7.3 Why use task-based interviews?

An interview typically involves a researcher asking a range of questions and receiving responses from those being interviewed (Robson, 2002). In the field of mathematics education, a task-based interview is used by researchers to gain knowledge about a participant's mathematical knowledge (Maher and Sigley, 2014). A task-based interview is a particular type of clinical interview. Clinical interviews were first used by Piaget as a method of gaining a deeper understanding of children's cognitive development (Maher and Sigley, 2014). The clinical interviews used by Piaget have been described as verbal interviews because concrete objects were not used and the questioning used with the children was on a completely verbal level (Ginsburg *et al.*, 1983). I chose a refined version of the clinical

interview because I used concrete objects when describing the mathematical problem, therefore, the data I collected was both verbal and non-verbal (Ginsburg *et al.*, 1983). This task-based interview was more appropriate than a traditional interview to address my research question because I was able to carefully design the task to find out about children's understanding of counting. The task-based interview followed a similar format to a traditional interview where I asked questions and the participant responded. However, the questions were based around specific counting activities so that I could evaluate each child's understanding of counting (Ginsburg *et al.*, 1983). During the task-based interview I chose specific counting tasks for the children to do that addressed research questions one and two. The task-based interviews were also conducted on a one-to-one basis which meant that the children were working independently and were not being influenced by their peers.

3.7.4 The interviewer

As previously discussed, in a case study the role of the researcher is key because all data collected is analysed by them. Within the task-based interview the data collected relied on me asking the right questions and making sure the children felt comfortable enough in the interview situation to respond. I was aware of the natural power imbalance between the adult and the child (Shaw, Brady and Davey, 2011). I attempted to reduce this power imbalance by spending time in class with the children, prior to the interview, so that they could get to know me, and by being friendly and welcoming towards the children during the interview. I also used lots of positive praise during the interviews to keep the children motivated during the task. However, I did not use any positive praise until children had answered each question because I did not want to lead them in any way. Another way I attempted to reduce the natural power imbalance was to sit next to the child and at the same level as them during the interview.

3.7.5 The location of the task-based interviews

The environment where the data were collected was an important consideration because of the effect it may have had on the participants (Shaw, Brady and Davey, 2011). The children were interviewed within the nursery setting, but in a quieter room, where there would be no interruptions. The children were familiar with this room because it was where they ate their lunch every day. I hoped that this familiarity with the environment would reduce any inhibiting factors.

3.7.6 Recording the task-based interviews

Due to my involvement in the task-based interviews I decided that digitally recording the interview for later analysis was essential (Denscombe, 2010). I was unable to take notes during the interview because I was focused on working with the child and asking them questions. Therefore, I had a choice between audio and video recording.

I chose to use video recording rather than audio recording for several reasons. Firstly, video recording allowed non-verbal behaviour to be recorded (Merriam, 1988). I thought that this was essential because I knew that the children would use non-verbal behaviours, such as pointing, during the task-based interview. Secondly, although video recording can be distracting for adults, I had identified during my teaching experience that children are less conscious of this type of distraction and still act in the same way, whether there is a video recording or not. The ethical issues regarding recording are discussed in detail in section 3.10.

3.7.7 Strengths of task-based interviews with children

There were several strengths to using task-based interviews as a method of data collection. Firstly, the prepared wording of the questions and the order of the questions meant that the

data were standardised (Denscombe, 2010). I was still able to clarify answers and reword or repeat the question but the children's responses were still easier to code than they would have been if a less structured data collection method had been used (Thomas, 2011). This made the analysis of the data much easier. However, there was an element of flexibility in the choice of whether to proceed with the next question or repeat the question with a small number. This meant I could tailor the task to each individual child. Secondly, the task-based interviews gave me the opportunity to review children's counting in a one-to-one situation. This meant that the data collected was from the child being studied only. Data collected in the classroom was likely to be influenced by other children. Finally, task-based interviews enabled me to focus on children's understanding of counting. As discussed in section 2.13, observation of children in their nursery classroom may have led to no observations of them counting, and therefore, would not have improved my understanding of counting.

3.7.8 Limitations of task-based interviews with children

The type of task-based interview selected has several limitations as a method of data collection. I chose to follow a structured design to improve comparability across the time frame but it is possible that the children may have responded differently than if I had used a more flexible design. However, I thought that a fixed design was more appropriate to answer the research questions because it allowed comparability over the time period and between children. I was also aware that during the task the child went through a decision-making process about what actions to take and that these actions may not be a complete demonstration of their understanding of number concepts (Lee and Sarnecka, 2010).

3.8 Documentary evidence

3.8.1 Overview of documentary evidence

At six points throughout the nursery year I collected the planning produced by the class teacher and all assessment information produced about the focus children by the nursery staff. I went through each document and found the information that was relevant to the child's understanding of counting. There is an example of the teacher's planning in appendix three and examples of observations made by nursery staff in appendices four and five. This data was collected to address research question three, about how teaching relates to children's understanding of counting, and as a source of evidence to support answering research questions one and two.

3.8.2 Why use documentary evidence?

Documents can provide a rich source of data to researchers (Punch, 2009). Within education vast amounts of documentary evidence are produced to provide evidence to support the assessment of children. In the school studied in this case study the documentary evidence collected about each child includes a 'special book', assessment records, and notes from teaching sessions. The 'special book' is used to record observations of the child's learning, samples of their work, and photographs of their learning in class. An example of a page of Maryam's special book is shown in appendix four and Safwaan's special book is shown in appendix five. Assessment records are summative records of what age-related level the child is working at and are recorded each half term. Notes from teaching sessions are records kept by the adult leading a group session about how well the children did in a teaching activity.

3.8.3 Strengths of documentary evidence

Documentary evidence has several strengths. Firstly, the documents are permanent so can be reviewed if necessary (Hodder, 2000; Yin, 2009; Denscombe, 2010). Secondly, the documentary evidence would have been created whether or not this case study took place (Yin, 2009). This meant that the analysis of the documents was unobtrusive because the documents were not altered by the fact I was using them (Robson, 2002). Also, it was easy for me to access the documents as I work within the school (Hodder, 2000; Denscombe, 2010).

3.8.4 Limitations of documentary evidence

There were several potential limitations to using documentary evidence. Firstly, as the documents contain the observations and recordings of the class teacher and support staff, this means that the data is secondary data, so I was relying on information that was produced for a purpose different to the purpose of the research (Robson, 2002; Denscombe, 2010). It is also important to note that the class teacher was aware of the research that was taking place and had attended training I had delivered on counting in the early years, so her planning and teaching may have been influenced by this. Secondly, it was difficult to find the information needed to answer the research questions within the documents (Yin, 2009). As previously discussed, this is because the documents were written for a different purpose to the research (Robson, 2002; Denscombe, 2010). A final potential limitation is that the analysis of the documents was open to interpretation and depended on my position (Denscombe, 2010). The documents can also be reread and different meanings could be potentially seen in them on each different reading (Hodder, 2000).

3.9 Interviews with parents

3.9.1 Overview of interview with parents

A parent of each child who participated in the research was interviewed at the beginning of the study. As previously explained, the interviews with parents were carried out within the first two weeks of the nursery year. This was because I wanted to capture information about the children's home experiences of counting before they started nursery and before the parents may have been influenced by the activities they were encouraged to do by the nursery staff. As discussed in section 2.14 children arrive at school with a wide range of mathematical understanding. I hoped, by interviewing the parents, that I would find out more about children's experiences at home and any experiences they had had in education. This could then be used to address research question two, about how children's baseline levels and their prior experience of counting relate to their understanding of counting.

I prepared the interview schedule including introductory comments, key questions, a set of associated prompts and closing comments (appendix six). A full explanation of the design of the questions is shown in appendix seven. I carefully considered the wording of the questions because language can be ambiguous (Fontana and Frey, 2000). Specific words in the questions may have meant different things to different respondents depending on their background (Davies, 2007). I knew that putting the questions in a straightforward, clear and non-threatening way would help me to gather the data I needed (Kvale, 1996). An issue that was specific to the language used in my questions was the fact that the respondents spoke English as an additional language. To address this issue I avoided long questions, double-barrelled questions and any jargon (Breakwell, 2006) and ensured that a translator was available for each of the interviews.

In order to build rapport and co-operation with the parent, I began with an open question about how their child had settled in to nursery. I then moved on to questions which aimed to obtain factual information about the child's language background and information about any siblings they have.

Next, in order to gather information about the child's experience of counting in the home environment, I asked questions specifically about counting and the languages used to count with the children at home. I then wanted to find out if any counting games were played with the child in their home life so asked:

> **Do you play any counting games at home or when you are out with your child?**

For this question, I had prepared a probe to ask respondents. This probe was designed to ask for more details or for an example (Denscombe, 2010).

> If they answer yes ask - **what games do you play?**
> and - **What language is used when these games are played?**

I then asked a question to find out about the child's experiences of counting songs at home. Finally, I asked questions to find out if anything specific had been done to prepare the child for nursery with regards to counting. The interviews lasted between 20 and 35 minutes and were audio recorded because I needed a full, accurate and permanent record of the interviews (Oppenheim, 1992; Davies, 2007; Denscombe, 2010). This allowed me to conduct the analysis at a later date and allowed me to focus fully on the respondent during the interview (Robson, 2002). I had paper to take notes of any non-verbal behaviour I thought to be

significant. I then typed up a transcript of each interview, an example of which can be found in appendix eight.

3.9.2 The structure of the interview

The interviews with parents had a specific purpose and were constructed (Cohen, Manion and Morrison, 2007). I chose a semi-structured approach because I was studying the individual respondent's perceptions of the phenomenon being researched and their particular meaning of it (King, 1994). This approach was chosen because it was important that I had some control over the questions and I needed some consistency in the data collected from the interviews in order to have similar amounts of background data on each of the children (Breakwell, 2006). This approach also gave me flexibility in the order of the delivery of these questions depending on what seemed most appropriate (Robson, 2002). I had the opportunity to follow-up points raised by the respondents when I thought it would provide me with more relevant information, which would not have been possible if I had adopted a structured format (Thomas, 2011). Therefore, I could be open to information which emerged during the interview rather than having to determine all the variables in advance (Young-Loveridge, 1989).

3.9.3 The interviewees

I held an information session about the research project which all parents involved attended. From this information session, they knew that they would be interviewed and that the general topic of the interview would be their child's counting. I explained that the interview was their opportunity to share their interpretations of their child's early counting (Cohen, Manion and Morrison, 2007). When each of the interviewees consented (see appendix nine) to take part

they agreed to their interview words being treated as ‘on the record’ and knew that the agenda for the interview would be set by me (Denscombe, 2010).

3.9.4 Rationale for using an interview

The interview is one of the most prominent methods of data collection in qualitative research (Fontana and Frey, 2000; Punch, 2009). In my research, I needed to find out background information about the individual children and their prior counting experience in order to be able to answer research question two. As parents are the primary educators, interviewing them provided the data from their perspective and allowed an insight into their child’s preschool experiences.

I decided that one-to-one interviews where I met each respondent individually and face-to-face were most suitable in order to obtain the best data. This type of interview provided me with the opportunity to probe the respondents to give more information and to understand their position in more detail, which is something I would not have been able to do if I had used a questionnaire to collect the data. The information being collected was about personal experiences that take place in the family home, so it was important to collect this privileged information in the more personal setting of a one-to-one interview (Fontana and Frey, 2000). As the respondents did not speak English as a first language, in face-to-face interviews it was easier to identify any language barriers and misunderstandings than in a phone call or in written form. It was also possible to have a translator present, which would have been more difficult to manage in a phone call. The one-to-one interview also made data analysis easier (Denscombe, 2010) because transcription was more straightforward with only up to three people involved in each interview.

3.9.5 The interviewer

As previously mentioned, in a case study the role of the researcher is key because all data collected is analysed by them. Within the interview situation the quality of the data collected relied heavily on the performance of the interviewer (Powney and Watts, 1987; Davies, 2007). The responses given depended on the trust developed between the interviewer and respondent (Cicourel, 1964; Powney and Watts, 1987). Therefore, I took into account three key concepts when planning and conducting the interviews: power, social position and value. To try to avoid these three concepts impacting on the data collected I was friendly, welcoming and attentive towards the interviewees to try to make them feel as comfortable as possible (Denscombe, 2010). I remained passive and neutral throughout the interviews because I was there to learn from the respondents (Denscombe, 2010). I also ensured that I did not signal approval or disapproval to any of the answers given by the respondents (Arksey and Knight, 1999). I conducted the interviews in the nursery department, an environment familiar to the parents, rather than in my office that was in a different part the school. I listened more than I spoke in order to reduce the impact of the power structure and differences in social position and to increase the value of what the respondent said (Robson, 2002). In two of the interviews a translator was present. The translator was a member of staff who was familiar to the parents. I explained the interview purpose, process and questions to the translator prior to the interview to ensure the meaning was conveyed as accurately as possible.

3.9.6 Strengths of interviews with parents

Collecting data using the type of interview I chose had several strengths. Firstly, the interview was targeted specifically to address the research questions (Yin, 2009; Newby, 2010). I was able to design the interview in a way that addressed each research question and I was able to adapt the design during the interview to suit each respondent through prompts and probes.

Secondly, the interviews were flexible and adaptable (Robson, 2002; Bell, 2010). I was able to clarify and develop the responses from the participants immediately to ensure I had the information I needed to answer my research questions (Bell, 2010; Newby, 2010). Also, the interviews required simple equipment (Denscombe, 2010). All I needed to record the interviews was an audio recording device. Finally, the interviews had high validity because the information came directly from the respondent (Denscombe, 2010).

3.9.7 Limitations of interviews with parents

The data collected through the interviews with parents was limited by the amount of information the respondent shared (Powney and Watts, 1987). Therefore, it was important that I asked the right questions to gather the information required and built trust with the parents. Concerns about the reliability of the data may arise because the semi-structured approach meant that there was a lack of standardisation across the interviews (Robson, 2002). However, I aimed to improve the standardisation by preparing an interview schedule and by having just one interviewer (Bell, 2010). Another potential limitation is that respondents may have given inaccurate answers accidently due to poor recall or they may have deliberately given inaccurate answers because they thought that is what the interviewer wanted to hear. It can be difficult to rule out inaccuracies in the responses given (Yin, 2009) but I aimed to reduce these through the manner in which I conducted the interviews.

3.10 Ethics

In planning and conducting this research I adhered to British Education Research Association (BERA, 2011) guidelines and followed all relevant University procedures.

3.10.1 Informed consent

Prior to beginning the research, I sought and gained consent from the Headteacher of the school and from the class teacher involved in the study. After the selection of the participants a letter was sent to their parents inviting them to an information session during which the research was explained and any questions or concerns were answered (appendix nine). At this meeting, and in the project information sheet which was given to parents (appendix ten), it was made clear that whether or not they agreed to their child's participation in the research, it would not affect their child's normal nursery provision and what they were taught in school. The lessons would carry on as usual whether or not their child participated. If any parents had decided that they did not want their child to participate I would have selected another child and gone through the same process of meeting the parent and explaining the research to them. Following the information session parents were asked to sign a consent form (appendix 11) and were given the information sheet (appendix ten) to take away with them. I ensured a bilingual member of staff was available at the information session to translate the information for any parents who required this.

On-going consent was sought from the children at the beginning of each task-based interview. I asked children if they were happy to participate and to be filmed in age appropriate language. If any child had not wanted to participate at that moment then they would not have been forced to do so. However, all children were happy to participate when asked. On-going consent was also sought from the parents at all parental interviews.

3.10.2 Non-participants

At the beginning of the school year a meeting was held to welcome new nursery parents. At this meeting, all parents were told about the research and those parents of children who had

not been selected were informed that their child would not be disadvantaged and that all children would have equal access to the mathematical teaching provision provided in the nursery.

3.10.3 Confidentiality

The data collected remained confidential throughout the project. All electronic data was stored on a password-protected laptop and USB. Any recorded data was locked away, with only myself and my supervisor having access to it. The data was not shared with any of the staff in school. The data has remained confidential because the school and participants have not been named. All of the data will be destroyed after a ten-year period from September 2014.

3.10.4 Sharing the findings

I offered a feedback session to parents once the research was completed. This session broadly outlined my findings to the parents. I also fed back to the children about their counting and what changes I saw in their counting in an age appropriate way. I did plan to share the findings with the nursery teacher but she had left the school before the research was concluded.

3.10.5 Professional ethics

Throughout my research I was also aware of professional ethical issues. If any child protection issues arose, I would have reported them in line with the school policy. Also, if any professional issues arose regarding the staff involved in the study, I would have addressed these in line with the school policies.

3.11 How I analysed the data

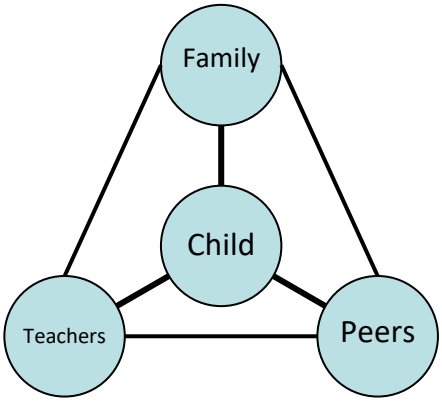
In this section, I describe how I analysed the data collected in order to address my research questions. I describe the overriding approach to analysis, then describe in detail the different stages of analysis.

3.11.1 Approach to analysis

The methods of analysis were carefully selected based on the aims of this research and my research position. This research aimed to expand the current literature by exploring how counting develops for the children in this study over the preschool nursery year. Therefore, I began my analysis with a deductive approach with the intention of developing a hypothesis based on existing theories about the understanding of counting. As with the data collection, I used a structured approach to the analysis of the data because I considered this to be the best approach in order to meet the aims of my research. At the first stage, I analysed the children's responses in the task-based interviews; coding these responses based on the counting principles (Gelman and Gallistel, 1978) and wider literature (appendix 12), which is discussed in more detail later in this section. I then constructed five matrices, one for each of the counting principles, using the coded responses. Each matrix included the children's names down the left-hand side, and then detailed their response to each of the questions in the task-based interviews month by month. An example of a completed matrix is shown in appendix 13. I then compared the matrices of the children to develop overlapping phases of development in counting. At the second stage in my analysis I used an inductive approach to address my second and third research questions. These questions looked at how baseline attainment, previous counting experience, and teaching and learning related to children's understanding of counting. An element of grounded theory (Corbin and Strauss, 2015) was used to establish themes which relate to children's understanding of counting.

Three different types of data were collected; task-based interviews, documentary data, and interviews with parents. This meant that I was able to collate a triadic overview of each child's case study story, shown in figure 1 (Pollard, 1996). The outer triangle represents the social context with the child at the centre of this. The inner connections represent the dynamic relationship between each child and their family, peers, and teachers. The information from the family was collected through the interviews with parents. The information from the teacher was collected through the task-based interviews and the teacher's planning, observations and assessment of the children. The information regarding children's peers was collected through the observations made by the nursery staff of the children in the nursery environment interacting with their peers. This range of data meant that my approach to analysis required a detailed process of reducing a large number of open codes, looking for patterns and relationships, and identifying key themes. I now offer a more detailed overview of each stage of analysis.

***Figure 1**: Triadic overview of each child (Pollard, 1996)*



3.11.2 Stage one - Deductive analysis

The first stage of my analysis aimed to address the first research question, about how children's understanding of counting develops during the nursery year. I began analysis of the data alongside subsequent rounds of data collection. This meant that the data analysis took place over an extended period of time which allowed me to continuously review the analysis that had taken place alongside new data being added. I structured the analysis using Gelman and Gallistel's (1978) five principles of counting and wider literature to code the individual children's responses in the interviews (see appendix 12).

In order to reduce the data (Miles and Huberman, 1984), I prepared matrices for each principle and tracked each child's development in that principle over the ten task-based interviews, an example of which is shown in appendix 13. This allowed me to look for patterns in the development of each principle over time. Miles and Huberman (1994) legitimised the use of matrices as a method of reducing the data and identifying patterns. Whilst watching the video recordings, I coded children's responses (appendix 12). I then logged them on to the appropriate matrix, depending on the principle of counting involved. For each question, I also coded the gestures used by the children and any other verbal responses as these have shown to be significant by other researchers (Gelman and Meck, 1983; Suriyakham, 2007). I colour coded the responses according to the children's success in answering a question. Green indicated that the child had correctly answered the counting question or had accurately identified the mistake made by the puppet and could explain what the mistake was. Orange indicated that the child had made an attempt at the counting question, but had made a mistake, or had identified the mistake made by the puppet but could not explain what the mistake was. Red indicated that the child had not attempted the counting

question or had not identified the mistake made by the puppet. Finally, I recorded whether children made progress compared to the previous task-based interview.

An example to illustrate how I coded the data is given for the responses to question two:

> **This is Owl Mummy.** *Show the puppet.* **Mummy Owl is learning to count so she needs your help. Can you help her?**
>
> **Owl Mummy has got some conkers**. Put 4 conkers on the table in a small pile.
>
> **How many conkers has Owl Mummy got?**

I recorded whether children had answered the question correctly and recorded the numbers the child said aloud when they counted the objects. As my review of the literature indicated that gesture can be significant in children's understanding of the one-to-one principle, I recorded any gestures made by the child (Saxe and Kaplan, 1981; Alibali and DiRusso, 1999; Graham, 1999). Where children made mistakes regarding the one-to-one principle, I coded the mistakes discussed in section 2.5.1, for examples, skim errors and flurry errors (Fuson, 1991). I also compared children's response to that given in the previous task-based interview to see if children had given the same response or made improvements or declined in their response.

Once the matrices were complete, I used 'constant comparisons' (Corbin and Strauss, 2015) between the matrices for each child to see if there was any pattern in the progress they made. I looked for significant shifts in understanding and I compared the progress made by the children to identify if there was a consistent trajectory for the understanding of counting. I compared the children's matrices to see if there was any pattern to the hierarchy in

understanding of the principles and to see if children needed to understand one principle before they could understand another principle (Miles and Huberman, 1984).

At the next stage of analysis, I used the literature to support me in defining what response children needed to give in order to show an understanding of each principle. This is presented in table four. As discussed in section 2.10, researchers argue that children's understanding of aspects of counting can be broken down into procedural and conceptual understanding (Gelman, Meck and Merkin, 1986; Hiebert and Lefevre, 1986). Therefore, I broke down the one-to-one principle and the cardinal principle into procedural understanding and conceptual understanding. This allowed me to identify if children showed procedural and conceptual understanding of these principles at the same time or if one came before the other. A procedural understanding was assessed as a child demonstrating an understanding of the principle in their own counting. A conceptual understanding was assessed as a child demonstrating an understanding of the principle in the puppet's counting. The abstraction principle is about understanding that things other than objects can be counted, so I did not divide this into a procedural or conceptual understanding. The order-irrelevance principle was only demonstrated in the counting of others in the task-based interviews so this was defined as a conceptual understanding.

***Table 4**: The responses children needed to give to the questions asked in order to be judged to have some understanding of Gelman and Gallistel's principles of counting (1978)*

Gelman and Gallistel's Principle (1978)	**Procedural or conceptual?**	**Question asked**	**Response**
Verbal counting (part of stable-order principle)	Procedural	How high can you count?	To at least 3
One-to-one principle	Procedural Conceptual Conceptual	How many objects are there? Puppet misses out an object Puppet double counts an object	Counted at least 4 objects Spots the mistake Spots the mistake
Cardinal principle	Procedural Conceptual	Can you give the puppet *x* claps? Puppet gives the wrong number for total items in the set	Matched the count word to the clap and stopped at *x* Spots the mistake
Abstraction principle	Procedural	Can you count how many jumps the puppet does? Can you give the puppet *x* claps?	Matched the count word to the jump Matched the count word to the clap
Order irrelevance principle	Conceptual Conceptual	Puppet starts counting in the middle Puppet counts alternatives	Identifies that the count is unusual Identifies that the count is unusual

As research indicates that children's counting develops in a hierarchical manner (Gelman and Gallistel, 1978; Nesher, 1986; Entwisle and Alexander, 1990), the final stage of my analysis was to compare the matrices and look for this hierarchical development across the counting principles. I looked at the months in which children showed an understanding of each principle and identified that there was a pattern to their understanding of the principles. In line with Gelman and Gallistel's (1978) assertion that there is a developmental relationship

between the counting principles, it appeared that the children in the study showed an understanding of certain principles before others and that understanding of other principles occurred concurrently. I then mapped out the trajectory through the principles for each child and compared them. An example of Ayesha's progression is shown in appendix 14 and shows that Ayesha first showed an understanding of verbal counting, the one-to-one principle and the cardinal principle, followed by the order-irrelevance principle and abstraction principle. Using the trajectories for each child it was possible to see that there were points in children's development that they made significant 'shifts' in their understanding of different aspects of counting. I have organised these 'shifts' into 'phases of development'. Each 'phase of development' appears to build on children's previous knowledge so demonstrates how children continuously build and consolidate their understanding of counting. These 'phases of development' are discussed in more detail in the following chapter.

Also, I used my research diary to identify if there were any significant issues that had arisen during the research process that needed to be explored in more detail. This led to me identifying that the age gap between the children involved in the study may have been significant. I therefore prepared a matrix to compare the children's understanding of the principles at 48 months old. This is shown in table 10 in the next chapter.

3.11.3 Stage two - Generating themes

The second stage of my analysis aimed to address research questions two and three, about how baseline levels, prior counting experience, and teaching and learning relate to children's understanding of counting in the nursery year. I was therefore looking for significant features of the children's home and school experiences which related to their development in the understanding of counting. At this stage I analysed the data from the interviews with parents,

the teacher's planning and assessment and the observations of the children made by the nursery staff.

In order to draw these significant features from my data I used a process termed 'constant comparisons' (Corbin and Strauss, 2015), a structured approach to analysis, which I deemed to be most appropriate for addressing my research questions. This involved reviewing the data repeatedly, and comparing each of the different elements to look for emerging themes. As I am positioned within the research, I wanted to be involved in my data so chose this method because it required analysis by hand. I followed guidelines for coding data when engaged in analysis (Corbin and Strauss, 1990). This is explained in more detail in section 3.11.3.1.

During the research process I recorded memos in my research diary. The memos involved recording analytical interpretations of the data (Bryant and Charmaz, 2007). The memos led to me identifying new phenomena as it emerged. I then used these phenomena to theorise and guide my research. For example, through my memo writing I began to notice that the children appeared to apply the gestures used by the teacher when counting to their own counting. This was found in both the observations by the nursery staff and in the task-based interviews. These gestures included holding up their fingers when they recited the counting string and touching each item as they counted a set. I then used this finding to guide my future research and particularly focus on the use of gesture in the task-based interviews.

3.11.3.1 Interviews with parents

As explained above, I followed guidelines for coding data (Corbin and Strauss, 1990). There were three stages to these guidelines which I followed with each of my data sources. I began by transcribing each of the interviews and was able to transcribe the interviews manually

because they were not excessively long. I also checked transcriptions against the original recordings for accuracy. An example of a transcription of an interview with a parent is in appendix eight. At the first stage of analysis, described by Strauss and Corbin (1990) as 'open coding', I reviewed the data and highlighted the common, recurring themes, such as children's home language and details of what counting was done at home. These are referred to as *temporary constructs* (Thomas, 2016). Then, at the next stage, I identified a key theme which appeared to be the most common across all of the parental interviews. I labelled the theme; previous experience of counting. This theme is discussed in section 4.4.

3.11.3.2 Documentary evidence

The documentary evidence included the teacher's planning, the nursery staff's observations of the pupils and the teacher's assessment data of the children. These different types of documents provided data to address different aspects of the third research question:

> *How does reported teaching relate to the development in understanding of counting during the preschool nursery year?*

The teacher's planning provided data for the input the children had received, and the observations and assessment data provided data about how this teaching related to children's understanding of counting. Therefore, I analysed the documents in different ways.

3.11.3.2.1 Teacher's planning

At the first stage of analysing the teacher's planning, open coding, I reviewed the planning and coded the key teaching points using Gelman and Gallistel's (1978) principles of counting. These principles were used to code the data because they had been used to develop the phases

of development. At the next stage, I mapped the teacher's planning onto a yearly plan (see table 11 in the next chapter). This yearly plan showed the teaching of each aspect of the phases of development and the months in which they were taught. I could see when and how frequently they were taught, if at all. I was then able to compare table 11 to the significant shifts in children's development identified in response to research question one.

I was then able to move on to the third phase of analysis, selective coding, to look for connections between the teaching input and any significant shifts in children's understanding of counting through the phases. From this, I identified the following significant themes, each of which are discussed further in section 4.5:

- The language of counting;
- One-to-one principle and gesture; and
- Cardinal principle.

3.11.3.2.2 Observations by nursery staff

With regards to the nursery staff's observations of children, at the first stage of analysis, I reviewed the observations and coded them using Gelman and Gallistel's (1978) principles of counting. At the next stage, I recorded these observations on to a yearly plan (appendix 15). I was then able to see what point in the school year the children were demonstrating an understanding of the different phases of development that I had identified. I could then compare the information I had gathered in the task-based interviews to that gathered by the nursery staff. Finally, I looked for connections between the nursery staff's observations of the children's counting and any significant shifts in children's understanding of counting through the phases. From this analysis, I was able to conclude that there were significant differences

between the counting skills demonstrated by the children in the nursery environment and the task-based interviews. This is discussed further in section 4.5.

3.11.3.2.3 Teacher's assessment data

The teacher's assessment of the children at the beginning and end of the nursery year was collected. The end of year assessment of the children following their second year in school, the end of Reception data, was also collected. These assessments were completed by the teacher using Development Matters (Early Education, 2012). Following the completion of the analysis of the task-based interviews, I compared the phases of development I had identified to the assessment tool used by the class teacher, Development Matters (appendix 16).

3.12 Summary of chapter

In this chapter, I have explained how I have addressed my research questions. I have explained my research position and have positioned my research within a methodological framework. I explored why a case study was the best approach for addressing my research questions. I have then explained each method of data collection in detail including how the review of the literature was used to design the data collection methods. Next, I explored the ethical implications of the research. Finally, I described my approach to data analysis and how this was used to draw out the findings of my research.

In the next chapter, I address each of the research questions and present the findings of my analysis.

CHAPTER FOUR - PRESENTATION OF FINDINGS AND DISCUSSION

4.1 Introduction

In this chapter, I describe the outcomes of my analysis of the data using the methods described in the previous chapter. Each research question is addressed in turn. I begin with a description of the phases of development of counting that I have identified through my analysis. During this explanation I include 'thick description' (Geertz, 1973) of the children's counting, through specific examples, so as to clearly exemplify the phases. I then illustrate a child's development through these phases by describing the development of one child, Ayesha, who provided a complete data set because she moved through each phase. I also include information about other children's progression through the phases to illustrate similarities and differences between their progression. Next, I move on to describe the themes which emerged from the interviews with parents and from the documentary evidence in order to address research questions two and three. Throughout the chapter I explain how my findings relate to previous research and how my research contributes to existing knowledge.

4.2 The phases of development

In this section, I address the first research question:

> *What does the development in understanding of counting look like for a child during the preschool nursery year?*

I describe the phases of development that I have identified through my analysis of the data. An overview of the phases is given, followed by a description of the features of each phase in turn.

4.2.1 Overview of the phases

The analysis of the data led me to conclude that the learning trajectories of the children in this study suggest that there are four phases of development in counting. Within a phase, there were specific skills which the children in the study appeared to demonstrate at a similar point on their developmental trajectory. The phases are a continuum with each phase building and consolidating the understanding demonstrated in the previous phases. As discussed in the previous chapter, because my task-based interviews were structured using the principles of counting (Gelman and Gallistel, 1978), I have used these principles and their names to describe the counting skills demonstrated by the children.

Each phase I have identified builds on the counting skills demonstrated in the previous phase. This means that the majority of the children in this study did not demonstrate the counting skills of a later phase without demonstrating all of the counting skills of the previous phases. So, for example, children did not demonstrate the elements of understanding of counting identified as phase three without already demonstrating the features of phase one and phase two.

Table 5 summarises the counting skills demonstrated at each phase of development. This table also summarises the context of the task-based interview in which the counting skill was demonstrated. The context is relevant because some counting skills were demonstrated in

some contexts prior to others. This will be discussed further in the following sections, where each phase is described in more detail.

***Table 5**: Summary of the counting skills demonstrated in each phase and the context these skills were demonstrated*

Phase	Counting skills	Procedural or conceptual	Context
1	Verbal counting	Procedural	How high can you count?
2	One-to-one principle Cardinal principle Abstraction principle	Procedural Procedural	How many? How many? How many jumps?
3	Abstraction principle One-to-one principle Order irrelevance principle Order irrelevance principle	 Conceptual Conceptual Conceptual	Claps (give me) Missing objects Starting in the middle Counting alternatives
4	Cardinal principle Cardinal principle One-to-one principle	Procedural Conceptual Conceptual	Abstract (give me *x* claps) Puppet's count Double count

4.2.2 Phase one

Within the first phase children demonstrated that they could accurately count verbally to at least three. For example, in October, when Sadia (42 months) was asked 'How high can you count?' she responded with 'one, two, three, four', then stopped counting and smiled at me. I encouraged her to continue counting if she could but she shook her head so I moved on to the next question. I found that all children in this study except Safwaan (39 months) were able to recite the sequence of numbers accurately to at least four in the first task-based interview. Safwaan (40 months) was able to demonstrate this recited the number sequence to three in the second task-based interview. In the first task-based interview he did not demonstrate that he could recite the count sequence, shaking his head when he was asked 'how high can you count?'. In this study, there was no occasion when a child either said 'one' or 'one, two' when counting aloud or when counting a set of objects. The shortest sequence of numbers recited was 'one, two, three'. Therefore, in this study I recorded a child as being able to count

verbally when they recited the count sequence to at least three. This finding is similar to those of Gelman and Gallistel (1978) who, although working with two-year olds, found that 15 out of 16 children studied produced a number word sequence beginning '1, 2, 3', continuing in various ways.

This study supports research by Donaldson (1978) and Hughes (1986) because it identifies verbal counting as the first phase in the development of counting. This highlights a need for an emphasis on verbal counting in early years provision. Accurately reciting the counting sequence beyond ten emerged gradually over time for the children in this study. For example, in October, Maryam (40 months) demonstrated that she could recite the count sequence to five. By February, Maryam (44 months) could recite the count sequence to eight. Then, by July, Maryam (49 months) could recite the count sequence to 24. For the majority of children in this study they first demonstrated they were able to count to ten and beyond when they were also showing an understanding of the counting skills detailed in phase two, although Safwaan did not demonstrate this until he was showing an understanding of counting skills detailed in phase three.

4.2.3 Phase two

Within the second phase there were three aspects of understanding of counting which were demonstrated by the children. All three were demonstrated in the context of 'how many?' questions. The first aspect was showing a procedural understanding of the one-to-one principle. The second aspect was showing a procedural understanding of the cardinal principle. To illustrate these first two aspects, in October, in response to being given four conkers and asked 'how many conkers has Owl Mummy got?', Abdul (44 months) responded by accurately counting the four conkers, touching each conker as he counted. The final aspect

was demonstrating an understanding of the abstraction principle, whereby children were asked how many jumps the puppet does. For example, in October, Maryam (40 months) counted each of the puppets jumps, so she understood that the jumps could be counted. However, she continued to count after the puppet had stopped jumping so did not yet understand that cardinal principle in this context.

Most of the children in this study demonstrated a procedural understanding of the one-to-one principle and cardinal principle in the same task-based interview. However, there was no clear pattern about whether they showed an understanding of these two aspects or an understanding of the abstraction principle first. The children in this study either showed an understanding of all three aspects in the same task-based interview or in two different task-based interviews one or two months apart from each other. However, Maryam did not appear to fit into this pattern with there being four months between her showing an understanding of these three aspects of counting.

Within phase two the children in this study demonstrated an understanding of the one-to-one principle and the cardinal principle when counting a set of four objects which were not set out in a linear arrangement (Graham, 1999). This was more challenging than if the objects had been in a linear arrangement (Alibali and DiRusso, 1999). However, this allowed the children to demonstrate what technique they used to keep track of which items had been counted and those which had yet to be counted. Children either did this by touching, moving, pointing to, or tracking by eye (Fuson, 1988). For example, in all ten task-based interviews, Ridwan (38 months in October) touched each object as he counted but did not move the objects. However, in March, May, June and July, when there were eight or more objects in the set, Sadia (47

months in March) moved the objects into a line before counting them, touching each object as she counted. As discussed in section 3.7, four objects were chosen because the first mention of being able to count a set of objects in the developmental framework for children working in the Early Years Foundation Stage states that children should be able to count three or four objects (Early Education, 2012). If the children were able to show an understanding of the one-to-one principle and cardinal principle with this set of four objects, I judged them to be demonstrating an understanding of the aspects in phase two, even if they struggled to apply this principle to a larger set of eight objects. This is because they had shown that they could apply their understanding of the one-to-one and cardinal principle to a small set of objects, but not yet a larger set of objects. Most children demonstrated that they could apply their understanding of the one-to-one and cardinal principle to a larger set of eight objects when they were showing an understanding of the aspects in phase three.

Within phase two, children showed an understanding of the abstraction principle, one-to-one and cardinal principle in the context of the 'how many?' questions. It is significant that this was prior to them showing an understanding of these principles when asked 'give me *x*' questions. This appears to support researchers who argue that children find 'give me *x*' questions more difficult (Schaeffer, Eggleston and Scott, 1974; Wynn, 1990, 1992; Sarnecka and Gelman, 2004; Le Corre *et al.*, 2006; Le Corre and Carey, 2007; Sarnecka *et al.*, 2007; Condry and Spelke, 2008). For example, in July, Maryam (49 months) demonstrated that she could count a set of ten objects but when she was asked to 'give 6 objects' she correctly matched the counting words as she gave each object, but then did not stop at the requested number of six.

Within phase two, the children demonstrated that they had an understanding of the abstraction principle when asked 'how many jumps does the puppet do?'. For example, in October, Musa (49 months) counted each of the puppet's jumps, matching the count word to the jump, but then continued counting once the puppet had stopped jumping. This is evidence of children understanding the one-to-one principle but not yet understanding the cardinal principle in this context. They did this in a task-based interview before they demonstrated any understanding of the abstraction principle when asked to 'give the puppet *x* claps'. This supports research which argues that 'give me *x*' tasks are more challenging because children have to create the required set of objects one object at a time (Cordes and Gelman, 2005). However, my research appears to extend this by applying it to the abstraction principle. In the context of my research the child had to create and count the 'claps' whereas they only had to count the jumps which could explain why they found the 'give me *x* claps' more challenging.

4.2.4 Phase three

During phase three the children demonstrated four different aspects of understanding of counting. Firstly, they showed an understanding of the abstraction principle in the context of 'give me *x*' claps. For example, in November, when asked to give the Owl Mummy four claps, Maryam (41 months) showed that she understood the abstraction principle by clapping and counting accurately as she counted. However, she continued clapping and counting to six so did not yet show an understanding of the cardinal principle in this context. Secondly, they showed a conceptual understanding of the one-to-one principle in the context of the missing object. For example, in May, Safwaan (46 months) commented 'you missed that one', when an object was missed out during a count. The final two aspects demonstrated during phase three involved children beginning to show an awareness of the conventions involved in counting regarding the order-irrelevance principle in two different contexts; starting in the

middle, and counting alternatives. For example, in January, when the puppet counted alternative objects, Maryam (43 months) immediately pointed to the first missed object and said ‘he didn’t do that one’. In the same interview, when the puppet started counting from the middle, Maryam immediately pointed to the first item in the row and said ‘he didn’t do that one’. In both examples it appears that Maryam was beginning to be aware of the conventions of counting such as counting along a row, starting at the end and counting each item in order.

It appeared that the children showed an understanding of the abstraction principle when they were asked to ‘give the puppet *x*’ claps. The children were asked:

Can you give the Owl Mummy four claps to say well done?

In response to this question, children clapped and counted, matching the counting word to the clap, but continued clapping and counting beyond the requested number of claps. For example, Musa clapped and counted, matching the count word to the clap, but continued to ten claps. The children had already shown an understanding of the abstraction principle within phase two so it is possible that they were demonstrating a deeper understanding of the abstraction principle in the context of ‘give me *x*’ claps. However, this finding is tentative because it is possible that the children in this study just knew that they were being asked to clap and did not relate this to being asked a question about counting.

Interestingly, children showed an understanding of the one-to-one principle in this phase in the context of the missing object prior to the context of the double count which they demonstrated within phase four. This supports previous research findings which found that

three, four and five-year olds were more likely to reject a missing object count than a double count (Briars and Siegler, 1984). As it was not until this third phase that children began to identify that adjacency and starting at the end of a count are optional, my research appears to support the findings of other researchers who argued that these are the most difficult features of counting to recognise as optional (Briars and Siegler, 1984).

4.2.5 Phase four

During phase four the children demonstrated three different aspects of understanding of counting. Firstly, they showed a procedural understanding of the cardinal principle in the context of giving the puppet claps. When asked to give the puppet *x* claps they accurately clapped and counted, matching the count word to the clap, and stopped counting at the requested number. For example, in February, Abdul (48 months) was asked to 'give the puppet five claps' and accurately clapped and counted five times. Secondly, they demonstrated a conceptual understanding of the cardinal principle in the context of the puppet counting. When the puppet accurately counted a set of objects but then gave an incorrect number as the number of items in the set the child spotted the mistake and gave the correct answer. For example, in April, Ayesha (45 months) spotted that the puppet had made an error when the puppet counted a set of seven objects accurately and then stated there were eight objects. Finally, they demonstrated a conceptual understanding of the one-to-one principle in the context of the double count. When the puppet double counted one item in the set, they spotted the mistake and corrected the puppet. For example, in July, Ayesha (48 months) spotted that the puppet had made an error when the puppet counted one object twice. However, no children in this study demonstrated all three aspects of phase four. Therefore, as with Gelman and Gallistel's (1978) finding that children acquire the cardinal principle last,

despite showing that they could count a set of objects, no child in this study showed that they fully understood the cardinal principle.

4.2.6 Summary of phases of development

I have identified four phases that the children in this study moved through as their counting developed. The phases are a continuum, with each phase building and consolidating the understanding demonstrated in the previous phase. Within phase one children demonstrated an understanding of verbal counting. Then, within phase two they began to show an understanding of the one-to-one, cardinal and abstraction principle. Next, within phase three they continued to develop their understanding of the one-to-one and abstraction principle whilst also showing an understanding of the order-irrelevance principle. Within phase four, they continued to demonstrate an understanding of the one-to-one, cardinal, abstraction and order-irrelevance principle.

By the end of my study no children demonstrated a secure understanding of the cardinal principle. Even though the children in my study had demonstrated that they understood how to accurately count a set of items in response to the 'how many?' question, none of the children accurately responded to the 'give me *x*' question. Some children did start counting out objects, but then reverted to grabbing and giving a pile of objects. It may be interesting to explore Wynn's (1992) proposal that children develop their understanding of cardinality one step at a time by exploring if they can give one object first, then moving on to two, then three objects. This may be an area for further study and may reveal that giving one or two objects may fit in with the earlier phases of development. A fifth phase of development may be a secure understanding of the 'give me *x*' question demonstrated through an ability to give larger sets of objects.

The identification of these phases supports the 'hypothetical learning trajectory' approach to mathematics teaching (Simon, 1995). This is because it appears that the children in this study proceed along similar learning paths. In particular, children's knowledge of counting appears to progress in a systematic way (Simon, Martin and Tzur, 2004). I have developed my hypothetical learning trajectory using the nursery data. It would have been interesting to track the progress of the children in the study over a longer period of time to see if all children moved through the phases by the end of the Reception year. As shown in section 4.4.4, I do have the end of year Reception data for six children in this study but did not follow the children's progress through continued task-based interviews during the Reception year due to time constraints.

The phases I have identified do not exactly match the assessment system used by the nursery teacher to assess the children's understanding of number. However, if at the end of nursery, a child is working securely in the 30 to 50-month phase of Development Matters (Early Education, 2012) then they will have demonstrated the aspects detailed in phase one and two. My assessment of children's counting within phase three and four is different to that in Development Matters (Early Education, 2012). Teachers are not encouraged to assess children's understanding of others' counting so it is not possible to say if children have a conceptual understanding of the one-to-one and order-irrelevance principle as identified in phase four. Children must show an understanding of the cardinal principle in order to be identified as securely working within the 30 to 50-month phase. For a child to have been assessed as reaching the Early Learning Goal in Number by the end of Reception they would need to show an understanding of all four phases (Early Education, 2012). These criteria

include children demonstrating an understanding of cardinality because they are asked to ‘count up to six objects from a larger group’.

The sequence of development identified in this study supports the claim that counting skills develop in a hierarchical manner (Gelman and Gallistel, 1978; Nesher, 1986; Entwisle and Alexander, 1990). Gelman and Gallistel (1978) argued that children demonstrate the stable order and one-to-one principle prior to the cardinal principle. I have found something similar because children demonstrated an understanding of the stable order and one-to-one principle prior to demonstrating an understanding of the cardinal principle in the ‘give me *x*’ context. They also argued that even very young children can apply the abstraction principle. My research supports this finding and in addition to this, my research also indicates that children demonstrate an understanding of the abstraction principle at a similar time to the one-to-one principle and that children demonstrate an understanding of the order-irrelevance principle prior to the cardinal principle in the ‘give me *x*’ context.

The developmental trajectory I have identified indicates that learning to count is a constructive process and supports Nesher’s (1986) proposal that skills integrate progressively until they become mastered. The phases I have identified do overlap, supporting findings by other researchers who argue that early mathematical skills appear to develop in overlapping phases (Purpura and Lonigan, 2013). The phases also demonstrate a development in understanding of each principle of counting. For example, children take time to develop their understanding of the one-to-one principle, so that eventually, they are able to demonstrate an understanding of this principle in different contexts. This supports the findings of researchers

who argue that children progress through different levels of mathematical thinking (Clements and Sarama, 2004).

4.3 Patterns in development

In this section, I continue to address the first research question:

> *What does the development in understanding of counting look like for a child during the preschool nursery year?*

I have chosen to structure the analysis of children's development through the phases by describing the case study of one child, Ayesha, and illustrating her development through the phases. I have chosen to do this because there appears to be a typical learning trajectory which the children in this study follow, demonstrating an understanding of the aspects of each phase in turn. Ayesha was selected because she is the only child who demonstrated an understanding of aspects of all four phases by the end of the period of time the children were studied. A limitation of this study is that at the point in time when it ended, at the end of the nursery year, not all of the children had moved through all of the phases. However, as discussed in section 4.2.6, if children had achieved the Early Learning Goal in Number by the end of Reception (Early Education, 2012) I could assert that they had moved through all four phases.

4.3.1 Overview of development

Table 6 shows the points in the year each child demonstrated an understanding of the aspects of each phase. This table clearly shows that children spent different amounts of time

demonstrating an understanding of the aspects of each phase. Within phase four, I have indicated whether children had demonstrated an understanding of one or two of the three aspects because no child demonstrated an understanding of the whole of this phase by the end of the study.

***Table 6**: The points in the nursery year when children showed an understanding of the aspects of each phase. Children's age in months in October is shown under their name*

Ridwan								4	4
38								3	3
					2	2	2	2	2
1	1	1	1	1	1	1	1	1	1
Safwaan									
39							3	3	3
				2	2	2	2	2	2
	1	1	1	1	1	1	1	1	1
Ayesha						4	4	4	4 4
39					3	3	3	3	3
		2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1
Maryam									
40					3	3	3	3	3
	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1
Sadia									
42									
			2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1
Abdul				4	4	4	4	4	4
44									
2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1
Musa									
49									
2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1	1	1
October	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**

4.3.2 Ayesha's development

4.3.2.1 Ayesha within phase one

Ayesha demonstrated the aspects of phase one in the first task-based interview (39 months). She was able to recite the counting sequence accurately to four. As mentioned in section 4.2.2, like most of the other children in this study, Ayesha demonstrated that she could accurately count to ten when demonstrating the aspects of understanding in phase two. In June (47 months), when reciting the count sequence, Ayesha completed the count sequence

by saying '…twenty-nine, twenty-ten'. This supports research that children use the set of rules they have acquired when learning the sequence to twenty to generate the higher numbers (Ginsburg, 1977). This also appears aligned to research that children memorise the number words up to 29, despite the patterns because Ayesha had almost accurately recited the sequence to 29 and was not able to accurately recall the number 30 (Munn, 1997).

My research supports Butterworth's (1999) findings because most of the children used their fingers to count, even when they were not explicitly instructed to do so. For example, in more than half of the task-based interviews, when asked the question 'how high can you count?', Ayesha spontaneously held up her fingers one at a time as she counted. She did this accurately on some occasions but inaccurately on others. This is discussed further in section 4.5 in the context of how teaching relates to children's development in understanding of counting.

My findings support those of researchers who argue that there is a high variability in the length of an accurate verbal counting sequence produced by children between the ages of three and a half and six years old (Fuson and Mierkiewicz, 1980; Fuson, Richards and Briars, 1982). I also found that there was variability in the length of an accurate count sequence produced by individual children from one task-based interview to the next. For example, Ayesha accurately recited the count sequence to ten in January when asked 'how high can you count?' but then in February only recited it accurately to six. This emphasises the importance of the counting sequence being embedded and overlearned before children are able to apply it to counting objects accurately (Fuson, 1991). This finding also reinforces the guidance offered in Development Matters (Early Education, 2012) and the National Curriculum

(Department for Education, 2013). Development Matters states that children aged 30-50 months should be able to recite the numbers in order to ten and children should be provided with reasons to count to allow them to practise this (Early Education, 2012). The National Curriculum for five-year olds states that children should practise counting as reciting numbers until they are fluent (Department for Education, 2013).

Ayesha made some of the common mistakes in the counting sequence identified by previous researchers (Threlfall and Bruce, 2005). Firstly, there were several occasions where she continued a counting sequence beyond the correct string. Secondly, in April, Ayesha recited the numbers in an incorrect order, '1,2,7,4,1,6,8'. Also, in June and July, Ayesha omitted some number words from the number sequence. Finally, in June, Ayesha continued the counting sequence in an idiosyncratic way, '…twenty-nine, twenty-ten'. It is interesting that Ayesha continued the counting sequence beyond the correct string in the task-based interviews towards the end of the nursery year. It is possible that she had become more confident with her counting by this point and was trying out different sequences using the counting skills she had acquired over the year.

4.3.2.2 Ayesha within phase two

Ayesha demonstrated an understanding of the aspects of phase two in December (41 months). She had demonstrated an understanding of the aspects of phase one at the initial task-based interview so it is not possible to say how long she had understood the aspects of phase one prior to the start of this study. All children in the study had demonstrated an understanding of the aspects of phase two by March of the nursery year. Ayesha, like most of the other children in the study, demonstrated that she had a procedural understanding of the one-to-one and cardinal principle either in the same task-based interview or in the task-based interview prior

to beginning to show that she understood the abstraction principle when asked to count how many jumps the puppet did.

When working within phase two Ayesha was able to count a small set of three or four objects, thereby demonstrating a procedural understanding of the one-to-one and cardinal principle. In the earlier task-based interviews (October to December at 39 to 41 months), when asked to count a set of four objects, Ayesha confidently demonstrated an understanding of the one-to-one principle, by moving or touching the objects as she accurately counted them. However, in later task-based interviews (April to June at 45 to 47 months), when asked to count larger sets of objects, Ayesha was not able to demonstrate this understanding of the one-to-one principle, though she could still demonstrate this understanding on smaller sets of objects (Bermejo, 1996; Sarama and Clements, 2009). For example, in July she was asked to count nine leaves which were given to her in a pile. Ayesha arranged the leaves into a row and started counting. Instead of pointing to each object she skipped items without counting them. As explained above, I have coded Ayesha as still working within phase two even when she could not apply the one-to-one principle to a larger set of objects because she was still able to show an understanding of the one-to-one principle when applied to a smaller set of objects. This is in line with research by Fuson (1988) who argued that the developmental relationship of the counting principles only applies to very small sets of objects.

Within phase two, Ayesha was able to demonstrate an understanding of the abstraction principle by showing that she understood that the movements made by the puppet can be counted. However, Ayesha, like all of the other children in the study was able to apply the one-to-one principle when counting a set of tangible objects prior to when counting a set of

jumps or claps. This supports the findings of researchers who argued that there is a relationship between the type of element being counted and how well children appear to demonstrate an understanding of counting (Baroody, Benson and Lai, 2003).

Ayesha used the gestures of moving, touching and pointing to objects as she counted a set. There was no clear pattern in development over time in her use of gestures. It is argued that touching gestures support children in counting more accurately than pointing at a distance (Gelman and Meck, 1983) although I did not find evidence of this in the case of Ayesha. Interestingly, I did see a clear progression in the use of gesture in the case of Abdul which supports what Fuson (1988) refers to as 'progressive internalisation'. When counting a set of four objects, Abdul moved from touching the objects (October, 44 months), to pointing to the objects (November, 45 months), to counting the objects using eye fixation only (December, 46 months).

At the point where Ayesha demonstrated that she had moved to within phase two she demonstrated her understanding of the counting sequence by counting forwards to five, then counting back again to one. Ayesha had not been asked or prompted to do this. As she could produce the number words and could work in both directions Ayesha was beginning to demonstrate that she was working at what has been referred to as the 'bidirectional chain level' (Fuson, Richards and Briars, 1982). Ayesha was the only child to spontaneously demonstrate that she was able to count backwards and it may be interesting, in future research, to include this aspect when establishing children's understanding of counting.

4.3.2.3 Ayesha within phase three

Ayesha moved to within phase three in March, after three months within phase two. Of the other three children in the study who also moved to within phase three before the end of the study, they all spent either three or four months within phase two prior to this.

Within phase three, Ayesha was able to co-ordinate her understanding of the counting sequence, the one-to-one principle, the cardinal principle, and the abstraction principle. This is clearly illustrated by the progression in Ayesha's response to the 'give the puppet *x* claps' question. In the first two task-based interviews (October to November, 39 to 40 months), prior to phase three, she did not clap at all. In the next task-based interview (December, 41 months), she clapped but did not count. At the next stage (February to March, 43 to 44 months) she clapped and counted, but did not match the count word to the clap, the one-to-one principle. By the time she was working within phase three (April, 45 months), Ayesha was able to match the count word to the clap for the first three claps, followed by a flurry of other claps with no counting. By the final task-based interview (July, 48 months), she was able to match the count word to the clap up to ten claps. However, Ayesha had been asked to give the puppet four claps. She did not give the requested number of claps and continued past this number to ten, so was not yet showing an understanding of the cardinal principle in this context.

Within phase three Ayesha was beginning to show an awareness of the conventions of counting regarding the order-irrelevance principle. This is illustrated when Ayesha thought the puppet had made a mistake when the puppet started counting in the middle of the row or counted alternate items in a row. This supports the findings of researchers who identified that

more than half of three to five-year olds thought that a mistake had been made when the counter started in the middle of a row or counted alternate items (Mierkiewicz and Siegler, 1981). It is interesting that Ayesha and her peers began making this observation during this phase of their understanding of counting. In previous task-based interviews Ayesha had not made any comment or gesture when the puppet started counting in the middle of the row or had counted alternatives. Therefore, it is possible that as Ayesha's own counting skills developed and through the models of counting provided in the nursery classroom, she began to realise the conventions involved in counting.

Within phase three Ayesha's understanding of the one-to-one principle had become more embedded and she was able to apply this knowledge when watching others count. Within this phase, Ayesha was able to spot that the puppet had made a mistake when she missed out an object when counting a row of items. This demonstrates a conceptual understanding of the one-to-one principle because the understanding is being applied to the counting of another person.

4.3.2.4 Ayesha within phase four

Ayesha had shown that she could count a set of objects within phase two so had begun to show a procedural understanding of the cardinal principle. However, it was not until April, one month after moving to within phase three that Ayesha (45 months) demonstrated one aspect of understanding of counting detailed within phase four, a conceptual understanding of the cardinal principle in the context of the puppet making a mistake. Ayesha spotted that the puppet had made an error when the puppet counted a set of seven objects accurately and then stated there were eight objects.

A second aspect of phase four was demonstrated by Ayesha in July (48 months). She showed a conceptual understanding of the one-to-one principle in the context of the double count. Ayesha spotted that the puppet had made an error when the puppet counted one object twice. Only one other child, Ridwan, also spotted the puppet's double count mistake. He spotted this in June (46 months).

A final feature of a child working within phase four is that they demonstrate an understanding of the cardinal principle in the context of giving the puppet a set number of claps. Ayesha did not demonstrate an understanding of this during the task-based interviews but Abdul did. In February, Abdul (48 months) was asked to 'give the puppet five claps' and accurately clapped and counted five times. However, Abdul did not show any understanding of the aspects of understanding of counting detailed within phase three by the end of the nursery year.

4.3.3 Abdul and Musa

There were two children in the study who did not appear to follow the same pattern of development as the other five children. Abdul and Musa both started and ended the study demonstrating that they were working within phase two. However, Abdul did show an understanding of one aspect of phase four in February. Interestingly, these two children had the highest levels in number and language on entry to nursery when assessed by the classroom teacher, and both demonstrated that they had understanding of the aspects of both phases one and two in the first task-based interview.

The progress they showed in the task-based interviews related to their ability to recite the counting sequence to higher numbers as the study progressed and their ability to count larger sets of objects (nine) in response to the 'how many?' question by the end of the study. Both

children also showed progress in the nursery classroom and, according to their teacher's assessment of them, had made expected progress by the end of the nursery year. As detailed in section 4.2.4, this would suggest they were working within phase three by the end of the nursery year.

However, these two children did not demonstrate any progression in their understanding of the other counting principles during the task-based interviews. There are a number of reasons why this is possible. Firstly, both children were very quiet and shy during the task-based interviews in comparison to the other children in the study. They may have been nervous in the task-based interview and not felt comfortable demonstrating their knowledge. Secondly, they may not have understood the questions I was asking them. Despite their language being assessed as just above the level of the other children in the study, they may not have fully understood what I was asking them. Thirdly, their progression in counting did not fit the phases that I have identified which were demonstrated by the other children in the study. Therefore, further research with a larger sample of children would be required to find out whether the phases are an accurate reflection of the children's learning trajectory.

4.3.4 Procedural and conceptual understanding

The difficulties in establishing children's understanding of the different aspects of counting highlighted above supports Sophian's (1997) assertion that judging a child's understanding of counting is challenging because counting is made up of many different concepts. My research also supports the argument that learning to count involves the interplay of procedural understanding and conceptual understanding (Gelman, Meck and Merkin, 1986; Hiebert and Lefevre, 1986). As with research by LeFevre *et al.* (2006), I found that the conceptual understanding of counting develops in a more complex trajectory than procedural

understanding. I found that children tended to demonstrate a procedural understanding of a principle prior to a conceptual understanding of the same principle. Therefore, my research seems to support the suggestion to give children the opportunity to reflect on the counting of others rather than just practising so as to develop their conceptual understanding (Muldoon, Lewis and Berridge, 2007).

None of the children in my study demonstrated a fully developed conceptual knowledge of counting by the end of the nursery year. However, this does not appear to be unusual because it is argued that even by the age of ten children have been shown to have not fully developed a conceptual knowledge of counting (Geary *et al.*, 2004).

4.4 How baseline attainment, reported previous experience in counting and age relate to children's development in understanding of counting

In this section, I address the second research question:

> *How does a child's baseline attainment and their reported previous experience in counting relate to their development in understanding of counting during the preschool nursery year?*

In this section, I discuss the findings of the interviews with parents and how the outcomes of the analysis of the children's baseline data relate to the children's development in understanding of counting during the preschool nursery year. I begin with the key theme which emerged from the analysis of the interviews with parents: previous experience of counting. I then move on to discuss how children's age of entry to nursery and their baseline

levels relate to their understanding of counting throughout the nursery year. Next, I discuss children's outcomes at the end of both nursery and Reception and conclude by taking children's age into consideration when looking at their development in counting.

4.4.1 Previous experience of counting

I found a variation in the amount of counting activities parents had done at home prior to their children starting nursery. This is significant because the opportunity to learn and rehearse the counting sequence is vital and the process of memorising is strongly affected by children's opportunities to practise this sequence (Fuson, 1991). This was evident in my study because the parents of the two children with the lowest baseline levels, Safwaan and Ridwan, reported that they had not done any counting activities at home to prepare their child for starting nursery. There are many possible reasons for this. For example, the parents may have not felt confident to support their child with counting or there may have been a language barrier for the parent in supporting their children.

My findings appear to support research that there is a positive relationship between some preschool number activities and children's mathematical skills on entry to nursery and their mathematical skills throughout their first year in school (Kleemans *et al.*, 2012; Manolitsis, Georgiou and Tziraki, 2013; Skwarchuk, Sowinski and LeFevre, 2014). The two children whose parents reported doing the most preparation in counting with their children prior to starting nursery, Maryam and Ayesha, started the study within phase one. However, they moved to within phase three earlier than the other children in the study. Therefore, it is possible that the counting activities the parents did at home did relate to children's progress through the phases. For example, Maryam's mother reported that both she and Maryam's older sister counted at home with Maryam. She also noted that Maryam asked to help when

her sister did her homework. She reported that they had numbers all around the house and Maryam always wanted to join in when her sister was counting. They also counted fruit at home and counted when Maryam helped with the cooking. For example, Maryam's mother would ask Maryam to get five onions or potatoes. This is a good example of a 'give me *x*' question in the home context.

A limitation of this study is that I did not interview parents throughout the school year to find out if they had begun to do work at home with their children on counting or changed the practices that they had put in place before the children started nursery. Therefore, I do not know if the activities done at home increased, decreased or stayed the same throughout the school year.

4.4.2 Age on entry and baseline levels

In this section I consider children's age on entry to nursery and their baseline levels because research indicates that those children born in the summer months do not perform as well as their autumn born peers (Crawford, Dearden and Greaves, 2013). Table 7 shows children's age on entry to nursery and their number and language level as assessed by the nursery teacher using Development Matters (Early Education, 2012). In the final column, the phase of development the children were working within during the first task-based interview is recorded.

***Table 7**: Children's age on entry to nursery, their teacher assessed level in number and language at the beginning of the nursery year, and the phase they were within at the beginning of the nursery year*

Name of child	**Age on entry to nursery**	**Number level**	**Language level**	**Phase in first task-based interview**
Ridwan	37 months	emerging 22-36 months	emerging 22-36 months	1
Safwaan	38 months	secure 16-26 months	emerging 22-36 months	0
Ayesha	38 months	developing 22-36 months	secure 22-36	1
Maryam	39 months	developing 22-36 months	secure 22-36	1
Sadia	41 months	emerging 22-36 months	developing 22-36 months	1
Abdul	43 months	secure 22-36 months	developing 22-36 months	2
Musa	48 months	secure 22-36 months	developing 22-36 months	2

Table 7 shows that the children's age appeared to correspond with their levels in number and language and the phase they were working within. That is, the youngest children had the lowest levels and were working within the lower phases, and the oldest children had the highest levels, and were working within a higher phase. This is aligned with research that children who are born in summer months tend not to perform as well as their autumn born peers (Crawford, Dearden and Greaves, 2013). The relationship between children's age and their outcomes is explored further in section 4.4.

4.4.3 Outcomes at the end of the nursery year and Reception year

Table 8 shows the children's teacher assessed outcomes in Number and Language using Development Matters (Early Education, 2012) and the phase of counting the children were working within at the end of the nursery year.

***Table 8**: Children's age on entry to nursery, their teacher assessed level in number and language at the end of the nursery year, and the phase they were within at the end of the nursery year*

Name of child	**Age on entry to nursery**	**Number level at end of nursery**	**Language level at end of nursery**	**Phase at end of nursery**
Ridwan	37 months	Secure 22-36 months	Developing 30-50 months	Part of 4
Safwaan	38 months	Developing 30-50 months	Developing 30-50 months	3
Ayesha	38 months	Developing 30-50 months	Secure 30-50 months	Part of 4
Maryam	39 months	Developing 30-50 months	Secure 30-50 months	3
Sadia	41 months	Developing 30-50 months	Secure 30-50 months	2
Abdul	43 months	Secure 30-50 months	Secure 30-50 months	2 and part of 4
Musa	48 months	Secure 30-50 months	Developing 30-50 months	2

My research did not show evidence that children working within higher phases at the start of nursery made better progress than those who started within lower phases. In fact, the opposite appeared to occur. The children who started nursery working within phase one all made better progress through the phases than those children who started nursery working within phase two. For example, Ayesha, who started nursery within phase one, moved to within phase four by the end of nursery. In contrast, Abdul, who started nursery within phase two, did not show any evidence of phase three by the end of nursery, but did show some evidence of phase four. In fact, the only child who started the study working below phase one, Safwaan, appeared to make better progress through the phases than those children who started within phase two. It is possible that this is because Safwaan had not had much experience of counting prior to starting nursery. Therefore, when he was exposed to counting activities he made more accelerated progress through the phases.

My results of the task-based interviews differed from the teacher's assessment of children's number levels. For example, my findings showed that Musa was working within a lower phase than Safwaan and Ridwan. However, the class teacher's assessment records showed Musa as working at a higher level than both Safwaan and Ridwan in number. This could indicate some issues in the assessment process used by the teacher. The teacher is responsible for the assessment of all the children in her class. When part-time and full-time children are included this amounts to 34 children. Due to time constraints and the size of the curriculum, it is very difficult for the teacher, even with the support of the nursery team, to spend time assessing each child. The differences between the assessment made in the task-based interviews and those made by the class teacher could also be evidence that the children were able to count more competently within the context they were taught (Donaldson, 1978). The assessment of Musa suggests that children may show different evidence of their understanding of counting in the classroom environment, where they feel more comfortable.

Table 9 shows the children's levels in 'Number' and 'Language' at the end of the Reception year. Children were assessed as having an emerging or expected understanding of the Early Learning Goals (ELG). One child had left the school prior to this assessment so I have end of Reception data for six children.

***Table 9**: Children's teacher assessed outcomes in number and language at the end of the Reception year*

Name of child	**Age on entry to nursery**	**Number level at end of Reception**	**Language level at end of Reception**
Ridwan	37 months	Data not available	Data not available
Safwaan	38 months	Emerging (ELG)	Emerging (ELG)
Ayesha	38 months	Expected (ELG)	Expected (ELG)
Maryam	39 months	Expected (ELG)	Expected (ELG)
Sadia	41 months	Expected (ELG)	Expected (ELG)
Abdul	43 months	Expected (ELG)	Expected (ELG)
Musa	48 months	Expected (ELG)	Expected (ELG)

Table 9 reveals that all children reached the age-expected level at the end of Reception, the Early Learning Goal, except Safwaan, who was one of the youngest children in the study. No children had exceeded the ELG. Safwaan had the lowest baseline levels and was working below phase one on entry to nursery. This appears to support the findings of other researchers who argued that although children with lower baseline mathematical skills did make progress during their early years in school, they did not catch up with their peers who had higher mathematical skills on entry to school (Aunio *et al.*, 2015).

4.4.4 Taking children's age into consideration

My research appears to support the findings that there is a gap in attainment between summer born and autumn born pupils (Crawford, Dearden and Greaves, 2013). As previously noted, children's age on entry to nursery related to children's baseline attainment in counting. The youngest children had the lowest levels on entry to nursery and the oldest children had the highest levels. The age of the children in the study varied by ten months at the start of the study. Therefore, I decided to make a comparison of the children's levels when they were all at the same age, to see if this difference in age accounted for the difference in their understanding of counting. I compared the phases they were working within at 48 months, the age of the oldest child at the beginning of the study. This eldest child had received no school

teaching at this point but the youngest child had received a school year of teaching by the time they had reached 48 months. Table 10 shows the phase children were working within when they were 48 months and their age in the first task-based interview. The eldest child had just turned 49 months by the time of the first task-based interview and the youngest child turned 48 months the month after the final task-based interview.

***Table 10**: The phase children were working within when 48 months old*

Name of child	**Age on entry to nursery**	**Month they turned 48-months**	**How many months they had been in nursery at 48-months**	**Phase they were working within when 48-months**
Ridwan	37 months	August	11	Part of 4
Safwaan	38 months	July	11	3
Ayesha	38 months	July	11	Part of 4
Maryam	39 months	June	10	3
Sadia	41 months	April	8	2
Abdul	43 months	February	6	2 and part of 4
Musa	48 months	September	0	2

Table 10 shows the children who were working within a higher phase when they were 48 months were the younger children. These children had been in the nursery for a longer period of time when they were 48 months. This indicates the possible relationship between nursery teaching and children's understanding of counting. This is discussed in more detail in section 4.5. This also demonstrates that children's age needs to be taken into consideration when making assessments of children's understanding of number.

4.4.5 Summary of how baseline attainment, reported previous experience in counting and age relate to children's development in understanding of counting

It appears that my research contributes to the argument some preschool number activities relate positively on children's mathematical skills throughout their first year in school (Kleemans *et al.*, 2012; Manolitsis, Georgiou and Tziraki, 2013; Skwarchuk, Sowinski and LeFevre, 2014). This is because the two children whose parents reported the most preschool counting moved to within phase three earlier than the other children in the study. However, it is possible that there is a relationship between ongoing experiences of counting at home and movement through the phases.

When children's ages and outcomes were explored, my findings appear to support research claims that children who are born in the autumn months tend to outperform their summer born peers (Crawford, Dearden and Greaves, 2013). I also found that those children who had the least counting experience prior to starting nursery made accelerated progress through the phases in comparison to some children who had more counting experience prior to starting nursery. It is possible that this is because those children who had little previous counting experience made faster progress once they were exposed to counting activities in the nursery.

This research also contributes to existing literature regarding the relationship between baseline mathematical skills and children's development in understanding of counting. My findings appear to support the argument that although children with lower baseline skills do make progress during their nursery year, they do not catch up with those children who had higher baseline skills (Aunio *et al.*, 2015). This appears to support the findings of the EPPE

project which found that children's preschool experiences relate to their intellectual development throughout the early years of primary school (Sylva *et al.*, 2004).

4.5 How teaching relates to children's development in understanding of counting

In this section, I address the third research question:

> *How does reported teaching relate to the development in understanding of counting during the preschool nursery year?*

My findings regarding children's assessments at 48 months old, discussed in 4.4.5, appear to indicate there is a relationship between the reported nursery teaching and children's development in understanding of counting during the preschool nursery year. Those children who had spent the most time in nursery by the time they were 48 months old were working at a higher phase at this age than the older children.

To identify the possible reasons for this relationship between the reported nursery teaching and children's development in understanding of counting, I reviewed the teacher's planning and mapped it onto a yearly plan. Table 11 shows the aspects of each phase which were being taught in each month. In December, there was a focus on shape, space and measure which explains the blank boxes for that month.

***Table 11**: The aspects of each phase which were being taught in each month*

2 & 4		Cardinal principle		Cardinal principle	Cardinal principle	Cardinal principle	Cardinal principle	Cardinal principle	Cardinal principle	
3								1:1 principle – missing object		
2	1:1 principle	1:1 principle		1:1 principle	1:1 principle	1:1 principle	1:1 principle	1:1 principle	1:1 principle	1:1 principle
1	Verbal counting	Verbal counting		Verbal counting	Verbal counting	Verbal counting	Verbal counting	Verbal counting	Verbal counting	Verbal counting
Phase	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**

As explained in section 3.11, this review revealed several key themes regarding how the reported teaching relates children's development in understanding of counting. Table 11 was linked to the progression made by the children in order for me to identify these themes:

- The language of counting;
- One-to-one principle and gesture; and
- Cardinal principle.

4.5.1 The language of counting

All children in the study started in the nursery with language levels below the expected level for their age group. As all children in the nursery spoke English as an additional language there were no 'expert' English speakers in the children's peer group. Therefore, the only 'expert' English speakers were the nursery staff.

The planning did indicate use of mathematical language every day and the nursery classroom provided a mathematically rich environment, with mathematical language displayed. Research has shown that this 'language rich' environment should have related positively on the development of children's mathematical knowledge (Klibanoff *et al.*, 2006).

My analysis revealed daily repetition of the counting sequence in the teacher's planning. This repetition is supported by research that argues that the number-word sequence needs to be embedded and overlearned by children (Fuson, 1991). When reviewing the teacher's planning it was evident that in October and November the focus had been on daily teaching of the number sequence up to ten, although this depended on children's different starting points. This links to the first phase of development I identified for most children in this study. In the first two task-based interviews, in response to the question 'how high can you count?', the majority of children in this study counted to a number less than ten. Most children began verbally counting to ten and beyond in later months, when the teacher had begun to model counting to numbers beyond ten.

The nursery staff used a range of gestures to support children's development in counting but it is also possible that these gestures supported their communication with the children (Sfard, 2009). My research appears to support the findings of O'Neill *et al*. (2005) who argued that gesture can scaffold communication. Within all phases of development, the children in my study showed they had learned through the gesturing of the staff because they imitated the gestures used by the adults. When verbally counting they held up their fingers and when counting a set of objects, they pointed to each object as they counted.

4.5.2 One-to-one principle and gesture

My findings seem to support the emphasis placed on the involvement of adults in the learning process and the social context in which the learning takes place (Vygostky, 1986; Siraj-Blatchford *et al.*, 2002). In my research, it was clear that the children had learnt the counting procedure by watching others. For example, children followed procedures taught by their

teacher such as holding up their fingers as they counted, counting from left to right and touching the objects.

With regards to the development of the one-to-one principle in the second phase, reviews of the teacher's planning indicated that during the first two months of nursery the teacher focused on teaching the children to touch one object as they said each number. This continued to be taught throughout the school year. The children applied what they had been taught when counting sets of objects in the task-based interviews. Within phase two, when asked the 'how many?' question all children counted the objects from left to right and nearly all touched or pointed to the objects. When given a set of objects to count in a pile, all children lined the objects up before counting them, and counted from left to right, exactly as they had been taught to in class. The children also applied this model of counting to the nursery environment. For example, in April, Safwaan counted five objects by touching each object and moving from left to right.

It is possible that this explicit teaching of counting skills may account for the difficulties the children had in understanding correct but unconventional counts. These skills started to be present within phase three when children began to notice that starting in the middle and counting alternatives did not follow the conventional counting procedure. The children were so used to observing and following a specific procedure when counting a set of objects that they were not yet able to identify which aspects of counting are essential and which are just following the conventions of counting. Briars and Siegler (1984) make a similar point by arguing that most of the counts children see are standard counts which include starting at the

end of a row and counting adjacent items. This is because these standard procedures help the counter to distinguish between counted items and those to be counted.

Children were provided with models of errors regarding the one-to-one principle. In May, the planning indicated that the teacher modelled a count but missed an object out. Children had to identify what mistake was made. This may explain why children spotted the missing object mistake by the puppet within phase three but did not spot the double count mistake until they were working within phase four. This finding may indicate the need for teachers to include models of counting errors and models of correct but unconventional counting in their teaching.

I also found evidence that the use of gesture was beneficial to the children's understanding of counting (Saxe and Kaplan, 1981). My observations revealed that the teaching of verbal counting was frequently taught alongside the gesture of holding up fingers as children proceeded along the count sequence. The teacher would model the count sequence and hold up her fingers one at a time as she proceeded to count to five or ten. This multisensory approach appeared to support children's understanding that each count word responds to a number of items, in this case, fingers. As discussed above, Ayesha applied this teaching when reciting the counting sequence throughout the phases of development in response to the question 'how high can you count?', as did other children in the task-based interviews. Another gesture used by children in the task-based interview was pressing down their fingers on the table as they counted.

4.5.3 Cardinal principle

My analysis of the teaching of the cardinal principle indicated that, in line with the age-related teaching framework (Early Education, 2012), there was a focus on the 'how many?' question when teaching children how to find out how many objects were in a set. From February, the planning did begin to indicate that the children were taught how to select a small number of objects from a larger set when asked, for example, 'please give me two'. Higher attaining pupils were extended with larger numbers. However, the majority of the planning focused on the 'how many?' question. This could, alongside the reasons given in section 4.2.3, provide a reason why children were able to accurately respond to the 'how many?' question in phase two, but were not yet able to accurately respond to the 'give me *x*' question by the end of the study.

It is interesting to note that, although children were taught to use gesture to support their understanding of the one-to-one principle and to keep track of what objects had been counted, the children were not taught a gesture to emphasise cardinality, such as the gesture proposed by Suriyakham (2007), of a circular 'altogether' gesture as a way of emphasising cardinality. The teaching of this gesture may have supported children's understanding of the cardinal principle.

4.5.4 Summary of how teaching relates to children's development in understanding of counting

My findings contribute to existing knowledge by supporting the argument that the counting sequence needs to be overlearned by children through daily repetition (Fuson, 1991). My research indicated that children had learned through the gesturing of staff because they imitated these gestures in their own counting. This finding supports the argument that gesture

can support and scaffold communication (O'Neill *et al.*, 2005; Sfard, 2009) and that it may be useful to introduce an 'altogether' gesture to support the teaching of the cardinal principle (Suriyakham, 2007). This finding also supports the emphasis researchers place on the involvement of adults in children's learning and the social context in which the learning takes place (Vygostky, 1986; Siraj-Blatchford *et al.*, 2002).

This research also contributes to existing knowledge because it supports the findings that children may find it difficult to identify correct but unconventional counts because they are explicitly taught the counting procedure and follow this procedure in their own counting (Briars and Siegler, 1984). Finally, my findings appear to support the argument that children use their own counting experiences to abstract the counting principles (Siegler, 1991). This is because, despite there being no explicit teaching of the abstraction or order-irrelevance principle, children still demonstrated an understanding of these principles.

4.6 Review of literature and how teaching relates to children's development in understanding of counting

There were two aspects of the literature review which I expected to see in the teacher's planning because of their reported significance on children's understanding of counting. These were subitising and the 'what to count' principles. Neither of these was explicitly detailed in the teacher's planning although it is possible that they were taught in an unplanned way by the nursery staff.

4.6.1 Subitising

In section 2.9 the review of the literature appeared to indicate that subitising is a significant aspect of understanding counting. During the research, I was aware of this and was looking

out for children making use of subitising. However, I found that the teacher's planning did not reveal any explicit teaching of the skill of subitising. Also, there was no evidence of the children using subitising in any of the task-based interviews. When presented with a small set of four conkers and asked 'how many conkers are there?' no child in this study appeared to use subitising. There was also no indication in the observations of the children in class that they were able to subitise or were using subitising to help with their counting. It is possible that children counted the objects rather than subitising because that is what they thought they were expected to do. I specifically asked children 'how many' rather than 'can you count' but it is still possible that they thought that counting is what was expected of them. However, it is possible that if different numbers were used and if objects were presented in a different way, the children may have used subitising. For example, if I had displayed the objects in a similar pattern to that seen on a dice rather than setting the objects out in a line or in a random arrangement, the children may have subitised.

4.6.2 Abstraction and order-irrelevance principles

My research supported findings by Siegler (1991), who argued that children do not receive specific teaching of the counting principles and therefore use their counting experiences to abstract the counting principles. This could explain why there was no evidence of children understanding the order-irrelevance principle until phase three. A review of the teacher's planning revealed that there was no explicit planning for the teaching of the abstraction principle or the order-irrelevance principle, despite the abstraction principle being specifically mentioned in Development Matters (Early Education, 2012). There were also no observations made by the nursery staff for any of the children with regards to these principles. It is possible that this is because the nursery staff were focusing on other aspects of counting during the nursery year and did not recognise the importance of these counting principles.

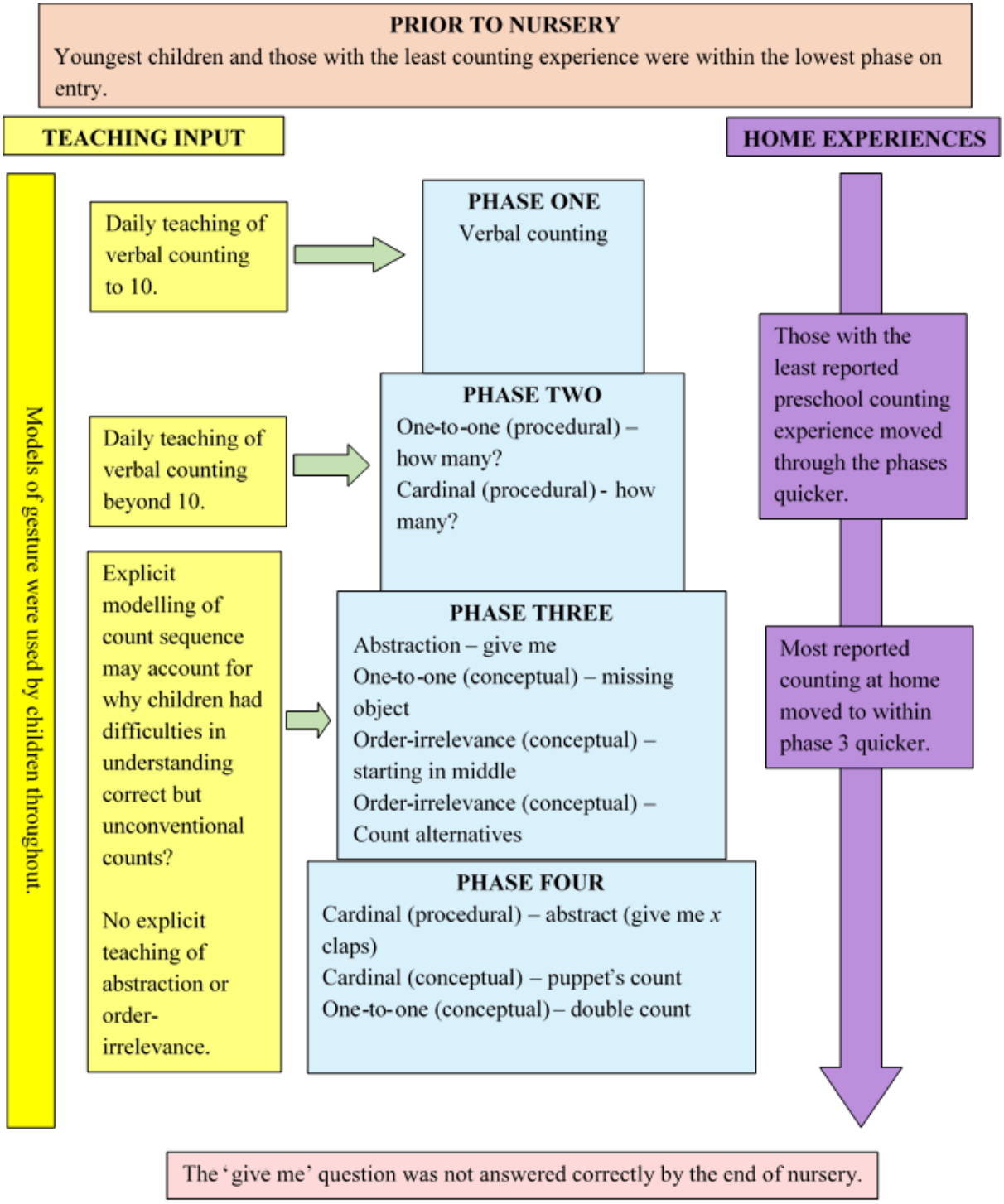
4.7 Differences in counting in the nursery environment and the task-based interviews

The analysis of the nursery staff's observations of the children revealed differences between the children's counting in the nursery environment and the task-based interviews. Despite the best efforts of the researcher to set the task-based interviews in a context familiar to the children, the situation of the interview was still different to the child's usual nursery experience. The task-based interviews were adult-initiated whereas the classroom teacher's assessment drew on a balance between child-initiated number activities and adult-led number activities (Department for Education (DfE), 2014). Therefore, several children demonstrated that they had more secure counting knowledge when in the nursery than in the task-based interview. For example, Safwaan, like other children in the study, demonstrated that he could count to a higher number in class than that demonstrated in the task-based interview. In April, he counted aloud to ten in class, but only counted to five in the task-based interview. Like Safwaan, Maryam demonstrated in the classroom that she could count higher than indicated in the task-based interview. The nursery staff observed that Maryam could count aloud to five in November and to 15 in January. As Donaldson (1978) points out, when learning to count, children learn concepts, meanings and number words that are embedded in the context of the count. This may, therefore, be a limitation of my research. However, it is also possible that Maryam was reciting the counting sequence with other children in the classroom so may have been supported by her peers in this counting aloud. Therefore, a suggestion for future research would be to study children's progression through the phases of development in the nursery setting. The role of researcher would need to be an adult who is based in the nursery class so that they could observe the child's progress in context.

4.8 Conceptual framework

In this research I have coded children's understanding of counting into matrices and have analysed these matrices to develop four, overlapping phases of development in counting, which each build on from the previous phase. In order to make these phases of development useful to practitioners it was important to develop a visual representation to summarise the key findings. I have done this by illustrating how my findings contribute to current research through a conceptual framework (figure 2). At the top of the conceptual framework I have summarised the preschool counting experience of the children in this study. Then, in the centre I have illustrated how children in this study moved through and built on each phase of development during the nursery year. To the left of the phases of development I have detailed the teaching at each phase. Finally, to the right of this conceptual framework I have detailed the home experiences at each of phase of development. This conceptual framework provides a useful summary of my findings and could potentially be a useful tool for teachers working with children at this early stage of understanding counting. This is discussed further in section 5.4.

***Figure 2**: Conceptual Framework*



4.9 Summary of chapter

In this chapter, I have detailed the key findings of my study. I found, through deductive analysis of the task-based interviews, that there appears to be a similar learning trajectory for the children in this study. From these similar learning trajectories, I have identified that there are four phases of development in counting, with each phase building on the previous phase. I have detailed these four phases and used a case study to illustrate what these phases look like. These phases support previous research because they appear to be overlapping (Purpura and Lonigan, 2013) and indicate that the development in counting is hierarchical in nature (Gelman and Gallistel, 1978; Nesher, 1986; Entwisle and Alexander, 1990).

With regards to how children learn to count, my research appears to support the 'principles alongside' position (Fuson and Hall, 1983; Briars and Siegler, 1984) because children appear to develop an understanding of the how-to-count principles gradually over time alongside learning to count. The phases of development of counting I propose suggest that, when set in a meaningful context, children's proficiency in counting appears to develop alongside their understanding of the counting principles. This supports the findings of Briars and Siegler (1984), Fuson (1988), Carey (2004), Le Corre *et al.* (2006) and Sarnecka and Carey (2008).

The sequence of development of counting I identified is aligned with the findings of Gelman and Gallistel (1978) because the stable order principle is demonstrated prior to the one-to-one and cardinal principle. However, I also found that the children in this study demonstrated an understanding of the abstraction principle at a similar time to the one-to-one principle. I found, through analysing the teacher's planning, that there was no explicit teaching of the abstraction or order-irrelevance principle. However, it is possible that this was taught to the

children but had not been included in the class planning. As discussed in section 5.2.4, this is one aspect of the research where it would have been useful to interview the class teacher to find out more about the informal aspects of mathematical teaching that took place. It appears that the children use their own experience of counting to develop their understanding of these principles. It is possible, that if these principles were explicitly taught, they would be evident in an earlier phase.

In this chapter, I have explained the themes that emerged through analysis of the baseline data, parent interviews and analysis of documentary evidence and how these themes related to children's development in understanding of counting. I have summarised my findings in a conceptual framework (figure 2). In the next chapter, I conclude my thesis by summarising my findings and detailing my contribution to both academic and professional knowledge. I also evaluate the research project and make recommendations for future research.

CHAPTER FIVE - CONCLUSION

5.1 Introduction

In this chapter I conclude this thesis by evaluating this research project and considering the trustworthiness and generalisability of the findings. I discuss the limitations of the research and detail changes I would make if I were to conduct the research again. I detail my contribution to current literature and to professional knowledge. I also describe the implications of these contributions. Finally, I make recommendations for future research based on the outcomes of this study.

5.2 Evaluation of research

5.2.1 Trustworthiness

Validity and reliability are 'problematic' concepts in case study research (Bassey, 1999). In a case study, the meaning of reliability and validity was less clear than if another type of research had been used (Thomas, 2011). This is because the quality of a case study is more dependent on the design and conduct of the study rather than the validity, sample or reliability (Thomas, 2011). Therefore, I have decided to use the alternative term 'trustworthiness', to describe the validity and reliability of this study instead (Lincoln and Guba, 1985).

Bassey (1999) simplifies and adds to the key questions posed by Lincoln and Guba (1985) in order to assess whether a case study is 'trustworthy'. I made use of these key questions when planning and reviewing my research to ensure it was 'trustworthy'. Firstly, I was engaged with the data sources for a prolonged period of time so that I was immersed in the issues, built the trust of the participants, and avoided misleading ideas. Secondly, I kept detailed records

throughout the research to ensure an adequate audit trail and carefully stored the raw data so that, in principle, other researchers can not only read the case study report, but can also review the data directly (Yin, 2009). I also collected three different types of data to address the research questions; task-based interview data, interviews with parents, and documentary evidence. Using these different data sources provided a chain of evidence (Yin, 2009), and improved the construct validity of this research (Patton, 2002). I made use of current literature to inform the design of the task-based interviews.

It is argued that for a case study to be deemed reliable, the investigator would arrive at the same findings and conclusions if the case study were conducted over again (Bailey, 1992; Denscombe, 2010). However, others argue that as a case study focuses on one or a small number of unique cases there is no assumption that if it were repeated it would produce similar results (Thomas, 2011). I agree with this argument, particularly when the case study involves young children. Each child's development is unique so it would be difficult to draw exactly the same conclusions from two different case studies involving young children. However, I took steps to improve the reliability of this case study by following case study protocol (Yin, 2009). I provided detailed information to identify those features of the case study that are unique to support reliability (Bailey, 1992). Therefore, the findings of this case study are a reflection of the understanding of counting of the children studied.

5.2.2 Generalisability

It is argued that a common misunderstanding about case study research is that it is not possible to generalise on the basis of an individual case, which implies that the case study cannot contribute to scientific development (Flyvbjerg, 2004). Some researchers argue that generalisation should not be a goal for qualitative research (Denzin, 1978) and others question

whether we want to be able to generalise from a case study (Punch, 2009).

This research project is situated within a particular context, with a particular set of circumstances, which does make generalising difficult. It is argued that generalisation can be applied to case study research by the individual reading the research and applying the tacit knowledge gained by reading the case study to another context, therefore, case studies need not make any claims about generalisation (Stake, 1995; Donmoyer, 2000; Lincoln and Guba, 2000). I have not aimed to produce generalisable findings but I have aimed to produce findings that are relatable to schools in similar contexts to the one in this study, with high levels of deprivation. It is argued that individuals form 'naturalistic generalisation' when reading a case study by identifying the similarities of issues or objects in their own contexts (Stake, 1995). Therefore, I have included details about the research context specific to this study, including details about the cultural context, because the 'transferability' will be based on the 'fit' or the similarity between the two contexts (Lincoln and Guba, 2000).

5.2.3 Limitations of this research

The case study approach used in this research has several potential limitations. Firstly, case study research has been criticised by Thomas (2011) for a lack of rigour. He claims this is because case study researchers have not always followed a systematic process in their research and they have allowed ambiguous evidence into their findings and conclusions. This lack of rigour is more common in case study research than in other strategies but this could be because there are less methodological texts about case study research (Yin, 2009). However, throughout my research I strived to be rigorous. For example, I analysed the data in a systematic manner by constructing matrices and drawing out significant features from my data using 'constant comparisons' (Corbin and Strauss, 2015).

A second limitation of a case study is that is difficult to replicate. In order to replicate the research different children would need to be studied because a different cohort of children would be starting nursery. This could lead to different research outcomes which could contribute positively to our overall understanding of counting. Another limitation of case study research is that it can take a long time to complete and produces huge amounts of data that can result in a large, unreadable report (Yin, 2009). I carefully considered this point when designing the research but there were limitations to the amount of data that could be collected due to personal time constraints.

The findings of my study are limited by the timeframe over which the research took place. Tracking the children's progress over a longer period of time would have potentially allowed for all of the children to move through the phases identified. It is also possible that further phases of development could have been identified. However, my time constraints meant this was not possible.

Another limitation of this research is that I did not interview the parents throughout the school year. Therefore, I was not able to find out if they had begun to do work at home with their children on counting or changed the practices that they had put in place before the children started nursery. As I did not interview parents throughout the school year I do not know if the counting activities carried out at home increased, decreased or stayed the same throughout the school year. For example, a parent who had reported little or no involvement in counting at home may have begun to regularly count with their child. This could have related to their child's development through the phases.

My analysis has focused on the data collected in the task-based interviews and this was analysed alongside the observations made in the nursery classroom by nursery staff. However, as previously discussed, there were differences in children's counting between the task-based interviews and the nursery classroom. Therefore, the findings of this study are limited because the children did not appear to demonstrate their full understanding of counting in the task-based interviews. It is possible that if I had interviewed the nursery teacher, which is discussed in the next section, I would have been able to explore the differences in the children's understanding in class and in the task-based interviews.

My findings supported prior research that children can respond more accurately to the 'how many?' question than the 'give me x' question (Frye *et al.*, 1989; Wynn, 1990; Sarnecka and Carey, 2008). This seems to support the argument that children first learn to count and then use their counting knowledge to develop their understanding of the cardinal principle (Schaeffer, Eggleston and Scott, 1974; Frye *et al.*, 1989). All children in the study were able to correctly answer the 'how many?' question prior the 'give me *x*' question. In fact, no child could accurately respond to the 'give me *x*' question by the end of the nursery year. The mistake most children made in response to the 'give me *x*' question was not stopping at *x* objects. This indicates that the children were beginning to understand the cardinal principle in the context of the 'how many?' question (phase two) but not yet in the 'give me' question (phase four). However, as also argued by Fuson (1988), a limitation of my research is that I have only been able to show that this developmental relationship applies to a small set of objects (up to 10).

5.2.4 Changes I would make to the study

If I were to conduct this study again there are several changes that I would make which I think would enhance the study and its contribution to the literature and professional knowledge. Firstly, I would utilise Wynn's (1992) findings regarding the understanding of cardinality where it is argued that children first become 'one knowers', then 'two knowers', then 'three knowers' and so on. In the task-based interviews I would first ask the children to 'give me one' object. Then, if they were able to demonstrate an understanding of this, I would ask them to 'give me two', and so on until they were unable to give the number of objects requested. I think reframing this question about cardinality would have further enhanced our knowledge of how children's understanding of cardinality develops.

If I were to repeat the study I would conduct interviews with the parents throughout the school year rather than once at the beginning of the study. I think this would have enhanced my knowledge of children's understanding through the phases because I would have been able to find out what counting activities the parents were carrying out throughout the nursery year, rather than prior to starting the nursery. I would also interview the nursery teacher because it would be useful to have her input into the children's understanding of counting. The nursery teacher had kindly agreed to me conducting research in her classroom and analysing her planning and assessments. Although this did not add to her current workload, it did add an extra element of pressure to her work because her teaching documents and practice were being constantly analysed by a member of the school leadership team. Therefore, I had decided against interviewing the nursery teacher because I did not want to add any extra pressure. However, on reflection, it would have been useful to gather her views about the

children's understanding of counting and to find out about any counting that took place which was not captured in the written assessments made by the nursery staff.

5.3 Contribution to current literature and its implications

The aim of my study was to expand the current literature by exploring how counting develops for the children in this study over the preschool nursery year. This overarching aim was addressed through answering three research questions:

1. *What does the development in understanding of counting look like for a child during the preschool nursery year?*
2. *How does a child's baseline attainment and their reported previous experience in counting relate to their development in understanding of counting during the preschool nursery year?*
3. *How does reported teaching relate to the development in understanding of counting during the preschool nursery year?*

In response to research question one, my analysis of the data led me to conclude that the learning trajectories of the children in this study suggest that there are four phases of development in counting. Each of the four phases contains specific counting skills and children appeared to demonstrate these specific skills at a similar point in their developmental trajectory. The four phases are a continuum with each phase building and consolidating on the understanding demonstrated in the previous phases. Within phase one children began to show an understanding of verbal counting. Within phase two they began to show an understanding of the one-to-one, cardinal and abstraction principle. Within phase three they continued to

develop their understanding of the one-to-one and abstraction principle whilst also showing an understanding of the order-irrelevance principle. Finally, within phase four, they continued to demonstrate an understanding of the one-to-one, cardinal, abstraction and order-irrelevance principle. The skills in each phase appeared to build on those demonstrated in the previous phase. Most children in this study did not demonstrate the skills of a later phase without demonstrating all of the counting skills of the previous phase.

My findings appear to add further empirical data to the current evidence base supporting the theoretical position that children learn to count alongside developing an understanding of the principles of counting, the 'principles alongside' argument (Fuson and Hall, 1983; Briars and Siegler, 1984). This is because the children in this study were able to demonstrate an understanding of how to count before and at the same time as showing an understanding of the counting principles. I did not find any evidence that children understood the principles of counting prior to being able to count a set of objects.

The identification of these phases of development contributes to several different aspects of existing research. Firstly, because it appears that the children in this study proceed along similar learning pathways, this supports the 'hypothetical learning trajectory' approach to teaching mathematics (Simon, 1995). The counting knowledge of the children in this study appears to progress in a systematic way, supporting the findings of Simon, Martin and Tzur, (2004). In addition to this, my findings build on current knowledge by indicating that children demonstrate an understanding of the abstraction principle at a similar time to the one-to-one principle.

The developmental trajectory I have identified adds further data to support the research of Nesher (1986) because it indicates that the process of learning to count is a constructive process whereby the skills progressively integrate until they are mastered. The phases I have identified indicate a development in the understanding of each principle over time, supporting the argument that children progress through different levels of mathematical thinking (Clements and Sarama, 2004). For example, children's understanding of the one-to-one principle develops over time until they are able to apply their understanding of this principle in different contexts. Finally, as the phases I have identified do overlap, my findings are consistent with previous research which argues that children's mathematical skills develop in overlapping phases (Purpura and Lonigan, 2013).

In response to research question two my research findings support existing literature regarding children's previous experiences of counting. My research aligns with the argument that preschool number activities relate positively to children's mathematical skills throughout their first year in school (Kleemans *et al.*, 2012; Manolitsis, Georgiou and Tziraki, 2013; Skwarchuk, Sowinski and LeFevre, 2014). I also found that, in my research context, those children who had the least counting experience prior to starting nursery made more accelerated progress through the phases when compared to some of the children who had more counting experience prior to starting nursery. With regards to children's baseline skills, my findings support existing literature because those children with the lower baseline skills did not catch up with those children who had higher baseline skills by the end of nursery (Aunola *et al.*, 2004). My research also supports existing literature surrounding children's ages and outcomes. Building on previous research, I found that children who are born in the

autumn months tend to outperform their summer born peers (Crawford, Dearden and Greaves, 2013).

In response to the third research question, my research indicates that there was a positive relationship between teaching the use of gesture when counting and children's understanding of counting. It appeared that children had learned through gesture because they imitated the gestures in their own counting. Therefore, my research contributes to existing literature by supporting the argument that gesture can support and scaffold communication (O'Neill *et al.*, 2005; Sfard, 2009). This finding regarding gesture is consistent with previous research regarding the importance of the role of adults in children's learning and the social context in which the learning takes place (Vygostky, 1986; Siraj-Blatchford *et al.*, 2002). My findings also build on the existing knowledge regarding the importance of overlearning the counting sequence (Fuson, 1991). This indicates that children need daily repetition of the counting sequence to support their development in understanding counting.

Another contribution this research makes to existing literature regarding the teaching of counting involves the models of counting that teachers provide to children. This research supported the argument that children may have difficulty in identifying correct but unconventional counts because they are explicitly taught the counting procedure and follow this procedure in their own counting (Briars and Siegler, 1984). My research indicates the need to provide models of unconventional, correct counts to support children's understanding of the one-to-one and order-irrelevance principle. My research also builds on the proposal that children abstract the counting principles from their own counting experiences (Siegler, 1991).

This was illustrated because, despite the lack of explicit teaching of the abstraction or order-irrelevance principle, children still demonstrated an understanding of these principles.

The findings of this research also contribute to current knowledge about children's understanding of counting because of the methodology used in this study. This approach differed from much previous research into young children's counting because it tracked the progress of the same children over a whole school year. Much of the previous research into this area of children's understanding of counting focused on groups of children's counting at various ages but did not track the same children's counting over an extended period of time (Nesher, 1986; Entwisle and Alexander, 1990).

5.4 Contribution to professional knowledge and its implications

The findings of this study contribute to current professional knowledge regarding the teaching and assessment of counting when working with young children. As discussed in the introduction, through this research I wanted to generate materials which support teachers of early mathematics, such as assessment tools and pedagogic aids. This is because, when I was a teacher in an early year's classroom, I found there was little support and few materials to support my teaching of mathematical skills when compared to my teaching of literacy skills. Therefore, using my findings, I have developed an assessment tool (table 12) and a flowchart to support teachers in planning and teaching a sequence of lessons on counting (figure 3).

The assessment tool was developed because the phases of development I identified do not match the assessment system used by early years teachers (Early Education, 2012). For example, the lack of reflection on others' counting means that it is not possible to assess

children's understanding of the other's counting so it is not possible to say if children have a conceptual understanding of the one-to-one and order-irrelevance principle as identified within phase four. I did find that if a child is working securely in the 30 to 50-month phase then they will have demonstrated that they have an understanding of the counting skills detailed within phases one and two. For a child to have been assessed as reaching the Early Learning Goal in Number by the end of Reception they would need to show an understanding of the counting skills detailed within all four phases (Early Education, 2012). However, understanding of cardinality is not emphasised in the current EYFS curriculum guidance (Gifford, 2014) although my research indicates that an emphasis on understanding cardinality should be encouraged. Therefore, an assessment tool for counting would be useful for teachers of young children (table 12). The aim of this tool is to allow teachers to assess which phase of development children are showing an understanding of. Each question needs to be set in a context familiar to the child. For example, the context could be based on the current book the children are reading in class.

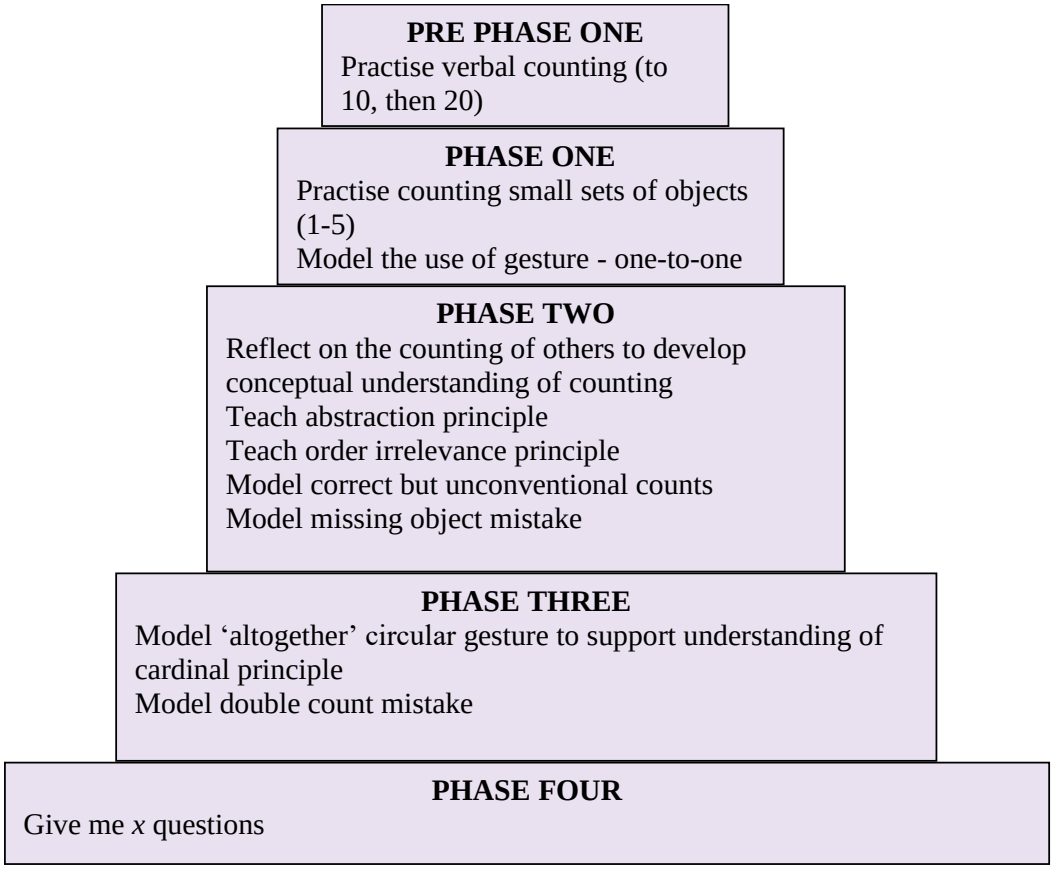
***Table 12**: Assessment tool to identify which phase of development children are showing an understanding of*

Phase	**Context and key questions (counting skill being assessed)**	**What to look for**	**Example activities**
1	'How high can you count?' (verbal counting)	Counts verbally to at least three.	Teaching a teddy how to count.
2	Place four objects (not in a linear arrangement) in front of the child and ask: 'How many objects are there?' (one-to-one and cardinal)	Able to count a set of at least four objects.	Playing a game of skittles. How many skittles are there?
2	Using a puppet explain to the child that the puppet is going to do some jumps and they need to count how many jumps the puppet does (abstraction).	Matches the count words to each jump, does not necessarily stop counting when the puppet stops jumping.	Children could count how many star jumps their friend can do.

2	'How high can you count?' (verbal counting)	Counts verbally to at least ten.	Teaching a teddy how to count.
3	Using a puppet explain to the child that they need to give the puppet four claps (abstraction).	Matches the count words to each clap, does not necessarily stop at four claps.	After watching a puppet show ask the children to give the puppets four claps.
3	Put seven objects out in a line. Adult or puppet starts counting, pointing to each object and saying the number name as they point. Count each object but skip one, neither pointing to it nor labelling it with a number word (one-to-one).	Identifies that the count is incorrect and that an object has been missed out.	Adult counts out apples for a group of children to eat, misses out an apple on purpose.
3	Put nine objects in a row. Assign number one to the middle item, then count each item to the end of the row. Then resume the count at the other end of the row until the middle item is reached (order-irrelevance).	Identifies that the count is correct but unusual.	Adult models counting 1p coins to buy something from the role-play shop. Lines up the coins then starts counting from the middle of the row.
3	Put seven objects in a row. Start counting at the end of the row, then count every alternate object, and then reverse direction when the end of the row is reached (order irrelevance).	Identifies that the count is correct but unusual.	Adult models counting how many eggs the hen has laid. Lines up the eggs then counts alternate items.
4	Using a puppet explain to the child that they need to give the puppet four claps (cardinal).	Matches the count words to each clap, stops clapping and counting at four.	After watching a puppet show ask the children to give the puppets four claps.
4	Put five objects in a row. Start counting, pointing and assigning a number to each object, *1, 2, 3, 4, 5*. Then say that there are six objects (cardinal).	Identifies that the number of objects is not six.	Adult models counting how many buttons are on a doll's dress. Counts accurately to five then says 'there are six buttons'.
4	Put six objects in a line. Count each object but double point at one object, assigning two words and two points (one-to-one).	Identifies that the count is incorrect.	Counting the bikes. How many bikes are there for children to ride? Model count but double point to one bike.

The flowchart has been developed for teachers to use once they have assessed what understanding of counting children have (figure 3). This flowchart will support teachers in planning and teaching a sequence of lessons on counting. They will be able to see what aspects of counting they need to teach the children depending on what phase they are currently working within so as to support their understanding of counting.

***Figure 3**: Teaching input at each phase of development*



This flowchart (figure 3) emphasises key teaching points that support children's progression through the phases of development. The need to practise verbal counting, first to ten and then to twenty, is emphasised, as is the need to begin counting with small sets of objects so that children have the opportunity to develop an understanding of the one-to-one and cardinal

principle on a small set of objects first. Also, because I found that the order-irrelevance and abstraction principle were not explicitly planned for in this study, I have detailed the need to teach these on the flowchart.

Alongside the assessment tool and flowchart I have made four other contributions to professional knowledge. Firstly, the differences between the understanding of counting demonstrated by children in the task-based interviews and in the nursery environment illustrates how difficult it is to establish an understanding of children's understanding of counting. The assessment of children's conceptual understanding of counting in the task-based interviews was not as evident in the nursery class assessment. However, the phases of development appear to support the interplay of both procedural and conceptual understanding (Gelman, Meck and Merkin, 1986; Hiebert and Lefevre, 1986). Generally, I found that children tended to demonstrate a procedural understanding of a principle prior to a conceptual understanding of the same principle. This contributes to professional knowledge because it appears that it is important to assess both children's procedural and conceptual understanding of counting. Muldoon, Lewis and Berridge (2007) argue that this needs to be done by reflecting on the counting of others. I would propose that it is important to include this reflection on others' counting in the assessment tool used by teachers of young children. By including this, it would encourage teachers to model both correct counts and unusual but correct counting to children, thereby improving their conceptual understanding of counting.

Secondly, my research findings indicate that gesture is a useful tool in supporting the teaching of counting to young children. Many of the children in this study used the gestures that had been modelled to them. In this study, the one-to-one principle had been the focus of the

gestures modelled by the nursery staff. Therefore, I propose that there needs to be a continued emphasis on the teaching of gesture to support counting. I also propose that this use of gesture needs to be extended to the teaching of a circular 'altogether' gesture to indicate cardinality. This would aim to support children in understanding the cardinal principle earlier than they currently do.

Another contribution to professional knowledge which has emerged from this research project is the relationship between children's age and their development in understanding of counting. The current assessment of children at the end of Reception does not take into account children's age, with summer born children expected to be working at the same level as their autumn born peers (Department for Education (DfE), 2014). I propose that age should be taken into account in this assessment, and it is only as children get older that their age is no longer considered when completing assessments.

Finally, my research indicated considerable variation in the counting experiences between the children in this study prior to starting nursery. It is good practice to find out about children's prior experiences but I propose that parents are asked specific questions about children's counting experiences so that teachers can prepare appropriate support for those children who arrive in nursery with little prior counting experience. Schools could also provide support to parents prior to children starting in the setting or once they have begun attending the setting with regards to counting activities they could do at home to support their child's development in counting. This work could focus on the elements of the first phase, such as an emphasis on the need for children to be able to verbally count with confidence.

5.5 Recommendations for future research

This study has led me to identify a number of possible areas for further research. Firstly, this study focused on a small group of children and without extending this research it is not possible to conclude that the phases of development apply to the wider population. It would be interesting to track a larger number of children's progression to see whether the phases of development are an accurate reflection of children's progression in counting. Due to the variation identified in this study between children's counting in the task-based interviews and the nursery environment, it would be useful to investigate children's progression through the phases as a researcher working within in a nursery classroom. This would allow the researcher to observe children's progression through the phases in the nursery environment and also allow the researcher to observe child-initiated counting activities. This would reduce the variation identified in this study between the task-based interview and children's counting in the nursery environment. However, this would be extremely time consuming for the researcher. It would also be useful to track children's counting progress over a longer period of time. This would enable the identification of further phases of development of counting.

Another aspect for further study which has emerged from this research is the importance of the use of gesture when teaching children to count. This research appeared to indicate the usefulness of gesture with regards to teaching the one-to-one principle and it would be interesting to explore the usefulness of a circular, 'altogether' gesture for the teaching of the cardinal principle.

It would be interesting to apply what has been found in this research to an outdoor learning context. As discussed in section 2.13.3, researchers have found that outdoor learning can have

significant benefits on children's outcomes (Fjørtoft, 2001; Borge, Nordhagen and Lie, 2003; Maynard and Waters, 2007). Outdoor learning provides children with the opportunity to develop their understanding of counting on a larger scale. In future, it would be useful to explore what benefits outdoor mathematical learning can have on children's progression through the phases of development.

It would be useful to track parental involvement throughout the preschool nursery year. This could then be used to identify any relationship between parental involvement and children's movement through the phases of development.

Finally, following extending the research into the phases of development, it would be useful to conduct research into the best teaching strategies that can be used to support children as they move through the phases of development. As discussed chapter two, there appears to be a relationship between children's early understanding of counting and their later mathematical outcomes (Aunola *et al.*, 2004; Aubrey, Godfrey and Dahl, 2006; Clements and Sarama, 2008). By supporting the development of teaching strategies in the early years, we can perhaps improve young children's understanding of counting and therefore, improve their mathematical outcomes later on.

5.6 Conclusion

Children's experiences of counting in the early years of their education can relate closely to their later understanding of mathematics (Aunola *et al.*, 2004; Aubrey, Godfrey and Dahl, 2006; Clements and Sarama, 2008; Hannula-Sormunen, Lehtinen and Rasanen, 2015).

Therefore, throughout this study I have aimed to find out more about how counting develops for the children in this study over the preschool nursery year.

My findings contribute to current theoretical knowledge through the identification of four phases of development in counting. Children at a similar point in their developmental trajectory appear to be working within a particular phase of development and demonstrate the specific counting skills detailed within that phase and the prior phases. I have then used these phases of development to contribute to professional knowledge through the development of teaching and assessment tools that can be used to support the teaching of counting. It is important to ensure children receive high quality teaching of counting in the early years as this may relate to their understanding of more complex mathematics in the future.

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Appendix 1

An example of a schedule for a task-based interview

Introduce self, explain the research again, explain ethical issues, seek permission again from interviewee.

1. How high can you count?

If child counts in Bengali ask **How high can you count in English?**

If children counts in English ask **How high can you count in Bengali?**

If the child does not recite the number string past 5 I will reduce the numbers in the following questions to 5 or below.

This is Owl Mummy. *Show the puppet.* **Mummy Owl is learning to count so she needs your help. Can you help her?**

2. **Owl Mummy has got some conkers**. Put 4 conkers on the table in a small pile.

How many conkers has Owl Mummy got?

3. **I've got some more conkers.** Put a pile of 6 conkers on the table in a pile.

Can you give Owl Mummy 3 conkers?

Standard correct count

4. **Owl Mummy is getting her nest ready for the Owl Babies so they can have somewhere comfy to sleep. Remember Owl Mummy is learning to count so she needs your help. Can you help her?**

First of all Owl Mummy collected some leaves for the nest. She needs to count out the leaves.

Line up 5 leaves. Count them correctly. Point to each leaf and say the number name as you point. Count in the same direction as the child used in questions 2 and 3.

Does this way of counting get the right answer?

Understanding of one-to-one principle

5. **Next Owl Mummy collected some twigs for the nest. She needs to count out the twigs.**

Put 7 twigs out in a line. Start counting from the same end used as the child. Point to each twig and say the number name as you point. Count each twig but skip one twig, neither pointing to it nor labelling it with a number word.

Does this way of counting get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

6. **Next Owl Mummy needs to get some food for the Owl Babies because they are very hungry. She catches some worms and needs to count them.**

Put 6 plastic worms in a line. Start counting from the same end used as the child, then count each worm but doubly point at one worm assigning two words and two points.

Does this way of counting get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Cardinal Principle

7. **Next Owl Mummy collects some conkers for the Owl Babies to play with. She needs to count out the conkers.**

Put 5 conkers in a row. Start counting at the same end as the child then count each conker, pointing and assigning a number to each conker, 1, 2, 3, 4, 5. Owl Mummy then says there are 6 conkers.

Did Mummy Owl get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Understanding of order-irrelevance principle

8. **Next Owl Mummy catches some insects for the Owl Babies to eat. She needs to count the insects.**

Put 7 plastic insects in a row. Start counting at the same end as the child, then count every alternative insect, and then reverse direction when the end of the row is reached.

Does this way of counting get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

9. **Next Owl Mummy collects some berries for the Owl Babies to eat. She needs to count out the berries.**

Put 9 berries in a row. Assign number one to the middle item, then count each item to the end of the row in the same direction as that used by the child. Then resume the count at the other end of the row until the middle item is reached.

Does this way of counting get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Abstraction Principle

10. **Owl Mummy is very excited that she has everything ready for the Owl Babies, she is so excited that she jumps up and down. Can you count how many jumps she does?**

    Owl Mummy jumps 6 times.

11. **Can you give the Owl Mummy four claps to say well done?**

Thank you for helping Owl Mummy get the nest and food ready for the Owl Babies. Here are the Owl Babies, they've come to their new nest and are very hungry. They're going to eat all of the food Owl Mummy has counted for them.

Thank you for helping Owl Mummy.

Explain what will happen with the information gathered at this interview.

END OF INTERVIEW

Appendix 2

Decisions Behind Task-Based Interview Questions

Each task-based interview began with the same introduction to the research and researcher. Then each child was asked if they were happy to continue.

Question One

As explained in the methodology, the aim of the first question was to find out how far children could say the counting words in the conventional order:

How high can you count?

If child counts in Bengali ask **How high can you count in English?**

If children counts in English ask **How high can you count in Bengali?**

I did not stop the children when they were answering this question. If they made a mistake I let them continue counting until they chose to stop. I also did not stop the children from counting once they had reached a particular number because I wanted to find out what the highest number they could count to was. I chose to ask this question in both English and Sylheti. A bilingual teacher supported me in this part of the task. However, during the first round of interviews it became clear that none of the children knew any counting words in Sylheti. This corresponds with parental reports that families count in English at home, even when Sylheti is being spoken. I chose to use prompts to support the children with this count sequence and based the level of support on Linnell and Fluck's (2001) criteria which was developed to categorise the level of support parents gave when counting with their child. The support ranges from no support to giving the number and supplying the whole count sequence. I decided to begin by requesting the next number without referring to other numbers, 'what comes next?'. If the child was not able to give the next number I supplied the next number with the aim of this prompting the child to continue the sequence.

If the child did not recite the number string past five I reduced the numbers used in the questions during the rest of the task-based interview.

Question 2

Next children were asked to count a set of four objects. The objects used depended on the context begin used in the interview. I chose to use real objects rather than count chips pasted onto a cardboard strip, which is what I had used this in my pilot study. This is because I identified that the children had not been engaged with this type of questioning so for my main study I aimed to make the interview more purposeful, relevant and interesting to the child. I adapted the research by Briars and Siegler (1984) by setting the questions in a meaningful context. Research has shown that if a task is 'embedded' in a meaningful context it supports children in showing evidence of their number knowledge (Donaldson, 1978). I used a more meaningful context for my questions because research suggests that children can demonstrate more knowledge in meaningful contexts than in artificial contexts (Hughes, 1981). For example, in the first task-based interview conkers were used because the context chosen was the story Owl Babies. This context was selected because this was the story children were

reading in nursery at the time of the first task-based interview. Children were asked to help a puppet count in order to make the counting more meaningful:

> **This is Owl Mummy.** *Show the puppet.* **Mummy Owl is learning to count so she needs your help. Can you help her?**
>
> **I've got some conkers**. Put four conkers on the table in a small pile.
>
> **How many conkers are there?**

Four objects were chosen because the first mention of being able to count a set of objects in the developmental framework for children working in the Early Years Foundation Stage states that children should be able to count three or four objects (Early Education, 2012). I did not line the objects up but put them in a group on the table. This is because I was interested to see how the children would count the items. If the child counted the group inaccurately I then put the items in a line and asked the child to count again. This was to allow me to see any development in their counting depending on the arrangement of the objects.

Question 3

Children were asked to 'give me x' from a set of objects in this question. This was to establish children's understanding of the cardinal principle.

> **I've got some more conkers.** Put a pile of six conkers on the table in a pile.
>
> **Can you give Owl Mummy 3 conkers?**

As discussed in the previous section, I asked for three conkers because the developmental framework for children working in the Early Years Foundation Stage states that children should be able to count three or four objects (Early Education, 2012).

Question 4

At this point in the task-based interview I moved onto setting the context more for the children. For example, in the first task-based interview the tasks were based around the story 'Owl Babies':

> **This is the Owl Mummy.** *Show the toy.* **Owl Mummy is getting her nest ready for the Owl Babies so they can have somewhere comfy to sleep. Remember Owl Mummy is learning to count so she needs your help. Can you help her?**

Conceptual understanding of counting was assessed in the rest of the task-based interview by asking children to identify counting errors in another's counting. The questions asked were based on research by Briars and Siegler (1984), who assessed children's understanding of counting by asking them to judge whether a puppet had counted correctly or not. The puppet performed a range of counts, which contained errors, unusual correct counts, and correct counts. The counting errors used by Briars and Siegler (1984) indicate some of the common mistakes made by children in the early stages of conceptual understanding of counting. The counting and errors and unusual correct counts linked to Gelman and Gallistel's (1978) five principles of counting.

In this question, the puppet produced a standard correct count:

> **First of all, Owl Mummy collected some leaves for the nest. She needs to count out the leaves.**
>
> *Line up 5 leaves. Count them correctly. Point to each leaf and say the number name as you point. Count in the same direction as the child used in questions 2 and 3.*
>
> **Does this way of counting get the right answer?**

Question 5

This question was designed to assess children's understanding of the one-to-one principle. It involved the puppet missing out one item when counting.

> **Next Owl Mummy collected some twigs for the nest. She needs to count out the twigs.**
>
> *Put 7 twigs out in a line. Start counting from the same end used as the child. Point to each twig and say the number name as you point. Count each twig but skip one twig, neither pointing to it nor labelling it with a number word.*
>
> **Does this way of counting get the right answer?** *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

If children said that the puppet was correct or incorrect before I had finished the whole count I did not start the count again from the beginning. Mierkiewicz and Siegler (1981) did not restart during their study using puppets whereas Gelman and Meck (1983) did. This possibly accounts for different results for unusual correct counts

Question 6

This question also assessed children's understanding of the one-to-one principle. The puppet double counted one object.

> **Next Owl Mummy needs to get some food for the Owl Babies because they are very hungry. She catches some worms and needs to count them.**
>
> *Put 6 plastic worms in a line. Start counting from the same end used as the child, then count each worm but doubly point at one worm assigning two words and two points.*
>
> **Does this way of counting get the right answer?** *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Question 7

I then assessed children's understanding of the cardinal principle. The puppet correctly counted the objects but gave the wrong number to describe how many objects were in the set.

> **Next Owl Mummy collects some conkers for the Owl Babies to play with. She needs to count out the conkers.**

Put 5 conkers in a row. Start counting at the same end as the child then count each conker, pointing and assigning a number to each conker, 1, 2, 3, 4, 5. Owl Mummy then says there are 6 conkers.

Did Mummy Owl get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Question 8

This question assessed children's understanding of the order-irrelevance principle. The puppet produced a correct but non-standard count by counting every alternate object.

Next Owl Mummy catches some insects for the Owl Babies to eat. She needs to count the insects.

Put 7 plastic insects in a row. Start counting at the same end as the child, then count every alternative insect, and then reverse direction when the end of the row is reached.

Does this way of counting get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Question 9

This question also assessed children's understanding of the order-irrelevance principle. The puppet produced a correct but non-standard count by starting in the middle of the row of objects.

Next Owl Mummy collects some berries for the Owl Babies to eat. She needs to count out the berries.

Put 9 berries in a row. Assign number one to the middle item, then count each item to the end of the row in the same direction as that used by the child. Then resume the count at the other end of the row until the middle item is reached.

Does this way of counting get the right answer? *Wait for response. Then if they answer no then probe further* **What did Mummy Owl do wrong?**

Question 10

This question assessed children's understanding of the abstraction principle. The children were asked to count how many jumps the puppet did.

Owl Mummy is very excited that she has everything ready for the Owl Babies, she is so excited that she jumps up and down. Can you count how many jumps she does?

Owl Mummy jumps 6 times.

Question 11

This final question also assessed children's understanding of the abstraction principle. The children were asked to clap a certain number of times.

> **Can you give the Owl Mummy four claps to say well done?**

Each task-based interview concluded with the children being thanked for their help:

> **Thank you for helping Owl Mummy get the nest and food ready for the Owl Babies. Here are the Owl Babies, they've come to their new nest and are very hungry. They're going to eat all of the food Owl Mummy has counted for them.**
>
> **Thank you for helping Owl Mummy.**

I then explained to the children what would happen with the information from the interview.

Appendix 3

An example of Teacher's Mathematics Planning

Mathematics Planning

Planned activity
Concept being taught: Stable order and one – one counting skills.
Activities – Activities to take place on special rug
We are learning to recite numbers in the right order (22-36 months)
Songs 1,2,3,4,5
10 in the bed forward.
Key questions
What number comes next?
Touching one number to an object (30-50 months)
HA up to 10 and beyond
MA up to 5
Have a selection of boxes with objects in. Children to see how many objects are inside by counting them. Key counting skills – adult to model putting objects into a line and then starting from left count the objects along to the right-hand side.
Key Questions

Key Rhyme 1,2,3,4,5 once I caught a fish alive
LI We are learning to recite numbers in the correct order.
Resources: fishing rod, bowl and a fish.
Extension: Model with children using one finger for each number. Representing numbers to 10 using fingers.

Cooking activity: Make muffin pizzas
Have a recipe for children to use with the amount of different ingredients for their pizzas.
1 spoon of tomato sauce
2 spoonsful of sweet corn
6 slices of pepper

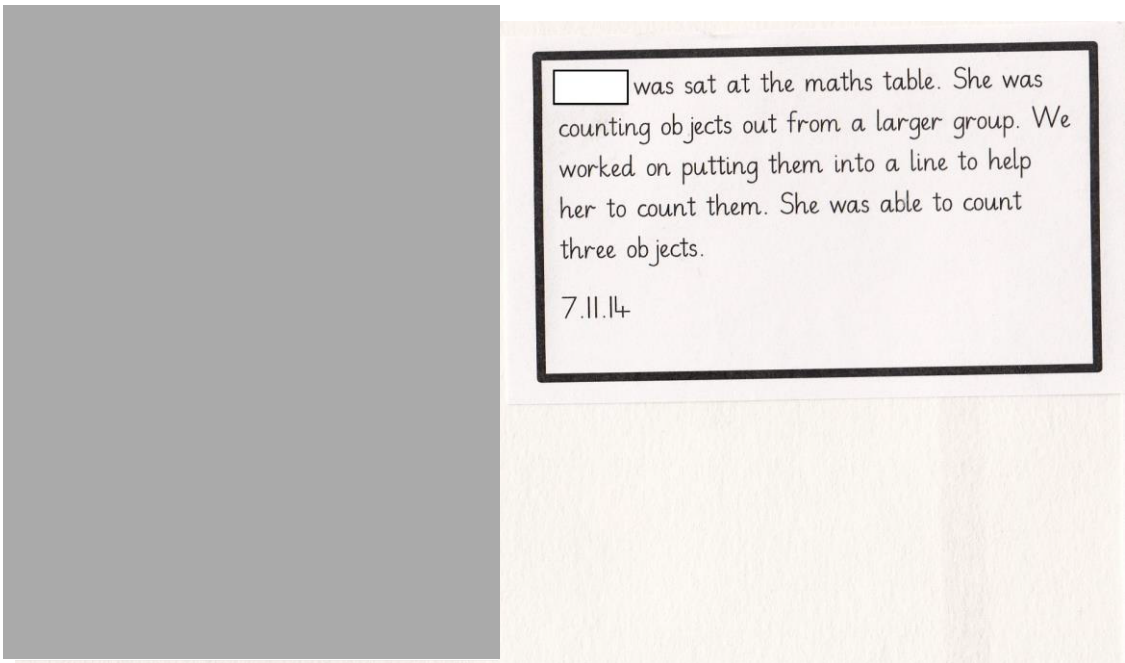
Everyday Mathematical learning
Snack time – every day count the children to see how many children there are for snack time. Then count out the snacks with the children as you give one to each child.

Recording and assessment

Links to continuous provision
Mark making outside – chalk alongside big handwritten numbers on wall (next to construction)
Sand: Inside –
Sand: Outside
Water: Inside – cups and different sized spoons – how many spoonful's fills up the cup?
Water: Outside- 1,2,3,4,5 water – fish, coloured water, nets.
Malleable: Inside – corn flour and unifix.
Malleable: Outside – mud kitchen with recipes – can you make a mud pie?
Construction: Inside – Tower blocks. How tall can you build your tower? Use both hollow and solid blocks. How can we find out how tall your tower is? Have clipboards available for children to draw their towers and how tall they are.
Outside-
Maths table – unifix printing. Make towers or individually print. Adult to make sure that the children are touching one object for each number name.

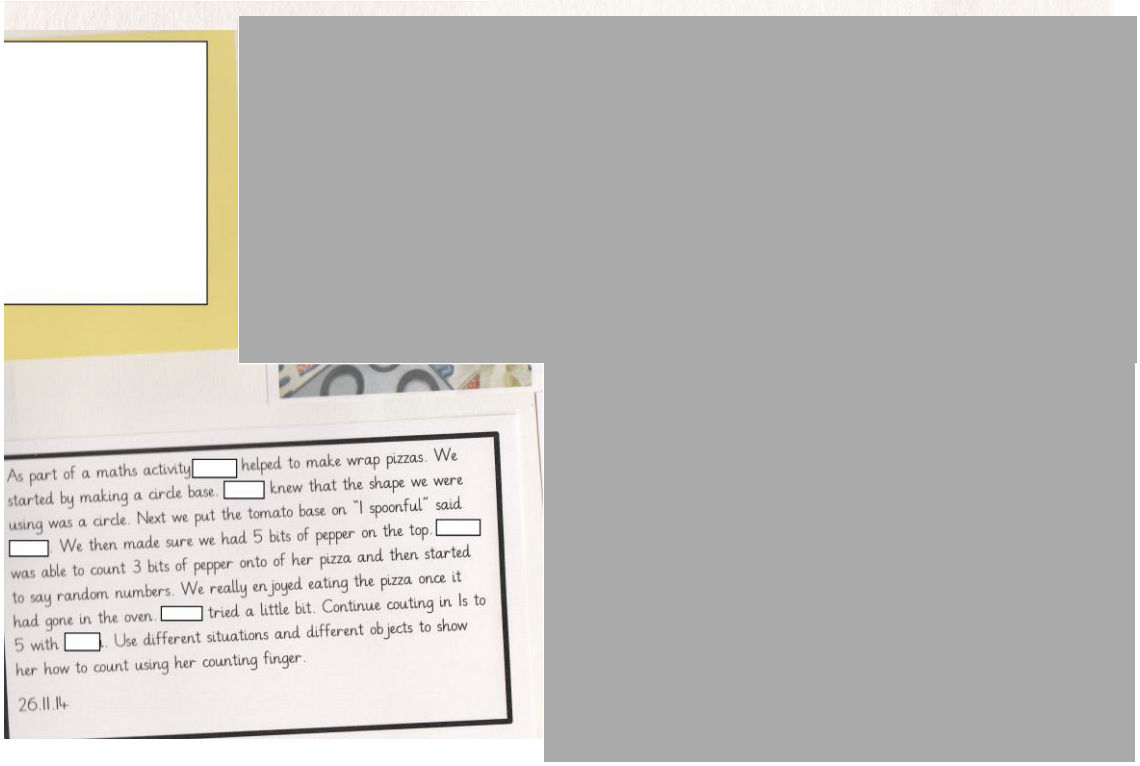
Appendix 4

Examples of Observations made by Nursery Staff - Maryam



[redacted] was sat at the maths table. She was counting objects out from a larger group. We worked on putting them into a line to help her to count them. She was able to count three objects.

7.11.14



As part of a maths activity [redacted] helped to make wrap pizzas. We started by making a circle base. [redacted] knew that the shape we were using was a circle. Next we put the tomato base on "I spoonful" said [redacted]. We then made sure we had 5 bits of pepper on the top. [redacted] was able to count 3 bits of pepper onto of her pizza and then started to say random numbers. We really enjoyed eating the pizza once it had gone in the oven. [redacted] tried a little bit. Continue couting in 1s to 5 with [redacted]. Use different situations and different objects to show her how to count using her counting finger.

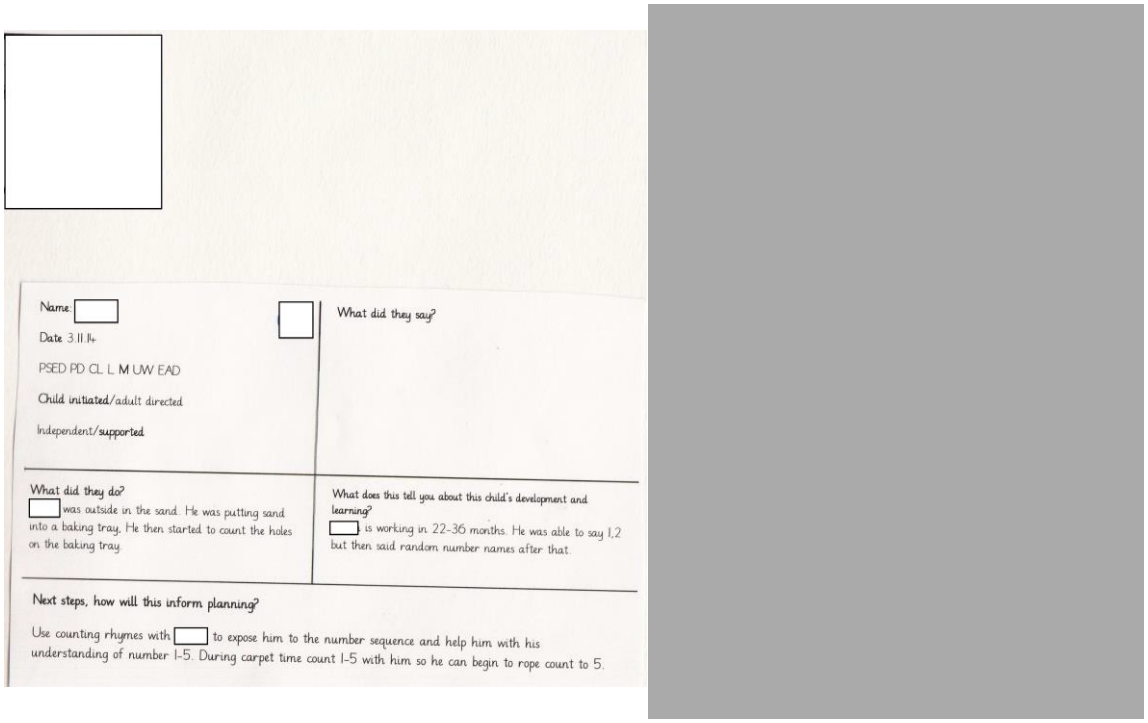
26.11.14

16.12.14

Counting secure to 3. When 4 objects are there she misses the 4th one.

Appendix 5

Examples of Observations made by Nursery Staff - Safwaan



Name:

Date 3.11.14

PSED PD CL L M UW EAD

Child initiated/adult directed

Independent/supported

What did they say?

What did they do?

was outside in the sand. He was putting sand into a baking tray. He then started to count the holes on the baking tray.

What does this tell you about this child's development and learning?

is working in 22-36 months. He was able to say 1,2 but then said random number names after that.

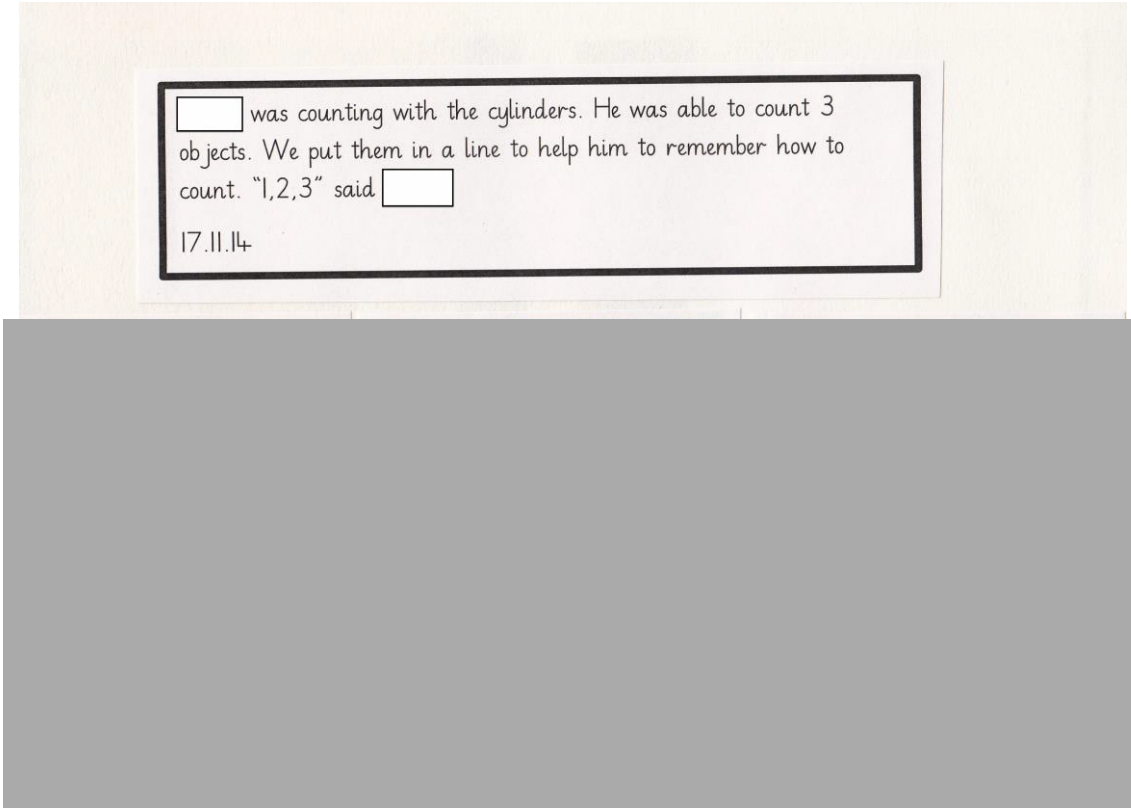
Next steps, how will this inform planning?

Use counting rhymes with to expose him to the number sequence and help him with his understanding of number 1-5. During carpet time count 1-5 with him so he can begin to rope count to 5.

17.11.14

M

[redacted] was counting object - pointed 1:1 for 3 objects. He then started saying random numbers. "I need more" and he put more on his line.


[ ] was counting with the cylinders. He was able to count 3 objects. We put them in a line to help him to remember how to count. "1,2,3" said [ ]
17.11.14

Appendix 6

Schedule for Interview with Parents

Introduce self, explain the research again, explain ethical issues, seek permission again from interviewee.

Overview questions:

1. How has *child's name* settled in to nursery?

2. Do they have any brothers/sisters? *Follow on with questions to establish age of siblings, position of participating child in the family*

3. What language(s) are used at home?

Questions about counting:

4. Do you or anyone else in the household do any counting at home with *child's name*?

If they answer no ask - Have you ever done any counting with *child's name* at home?

5. What language do you count in?

6. Do you play any counting games at home or when you are out with your child?

If they answer yes ask - what games do you play?
and - What language is used when these games are played?

PROMPT if respondent is unsure about the meaning of this question – for example, counting as you go up the stairs, looking at bus numbers, playing board games, playing with dice

7. Do you sing any nursery rhymes/traditional songs at home that involve counting?

If they answer yes ask - What language are these sung in?

8. Have you done any counting activities at home to prepare your child for nursery?

Probing questions – to use if necessary

Could you say something more about that?
Do you have further examples of this?

Thank you and goodbye – explain what will happen with the information gathered at this interview.

Appendix 7

Decisions Behind the Parental Interview Questions

At the beginning of each interview I introduced myself and explained the research again to each parent. I also explained the ethical issues and sought permission from the interviewee to carry out and record the interview. Below I explain the purpose of each question asked in the interview.

Question 1
The first question asked was an open question.

> **How has *child's name* settled in to nursery?**

The purpose of this question was to build up rapport and co-operation with the respondent from the beginning of the interview.

Question 2
The purpose of this question was to obtain factual information about the child's background and demographic. I needed to know this in order to find out if there was any relationship between children's counting and the age of any siblings they have.

> **Do they have any brothers/sisters?** *Follow on with questions to establish age of siblings, position of participating child in the family*

Due to the purpose of this question it was more highly structured than other questions and required closed responses (Robson, 2002). This information helped me to locate each respondent in relation to the others (Patton, 2002). This data is relatively easy to gather from respondents although can contain errors due to lapses in memory or if respondents deliberately do not give accurate responses (Robson, 2002).

Question 3
As with the previous question, this purpose of question three was to obtain factual information.

> **What language(s) are used at home?**

I needed to know what language experience the child had because this may have related to their understanding of counting.

Question 4
I then began asking questions specifically about counting. The purpose of this question was to begin to find out about the child's experience of counting in the home environment.

> **Do you or anyone else in the household do any counting at home with *child's name*?**

I left the question open with regards to who did the counting activity with the child because I did not want to limit this to just the parents. I prepared a follow-on question to ask if the

respondent answered no to the first part of the question. I prepared this in-case parents had done counting activities with the child in the past but did not do them now.

> If they answer no ask - **Have you ever done any counting with *child's name* at home?**

Question 5
The purpose of this question was to obtain factual information about the language used for counting. I needed to know what language parents used to count in as this would be the model children would have heard at home.

> **What language do you count in?**

During the interviews, I found that I needed to use a probe for this question. Probes are a technique for encouraging respondents to expand on an answer they have given when the interviewer thinks that they have more information to give (Robson, 2002). I had prepared a probe for this question in advance but did find that I needed to ask:

> **Do you ever count in *name their first language?***

All parents responded that they counted in English so I was interested to find out if they did ever count in their first language. In response to this further probe all but one parent revealed they did sometimes count in their home language. I probed further to find out the child's preferred counting language and all parents responded with English.

Question 6
The purpose of this question was to find out if any counting games were played with the child in their home life.

> **Do you play any counting games at home or when you are out with your child?**

For this question, I had prepared a probe to ask respondents. This probe was designed to ask for more details or for an example (Denscombe, 2010).

> If they answer yes ask - **what games do you play?**
> and - **What language is used when these games are played?**

I also prepared a prompt for this question because I thought this question might need further clarification about what a counting game is. Prompts are used when the respondent seems unsure about how to answer the question by suggesting a range of possible answers the interviewer expects to the question (Robson, 2002). I decided that providing an example was the best way to prompt the respondents (Denscombe, 2010). However, in the interviews this prompt was not required.

> PROMPT if respondent is unsure about the meaning of this question – for example, counting as you go up the stairs, looking at bus numbers, playing board games, playing with dice

Question 7

The purpose of this question was to find out about the child's experiences of counting songs at home.

Do you sing any nursery rhymes/traditional songs at home that involve counting?

If they answer yes ask - **What language are these sung in?**

Question 8

This question was included to find out if anything specific had been done to prepare the child for nursery with regards to counting.

Have you done any counting activities at home to prepare your child for nursery?

I also prepared probing questions – to use if necessary

Could you say something more about that?
Do you have further examples of this?

At the end of the interview I thanked the parents and explained what would happen with the information gathered at the interview.

Appendix 8

Example of Transcript of an Interview with a Parent

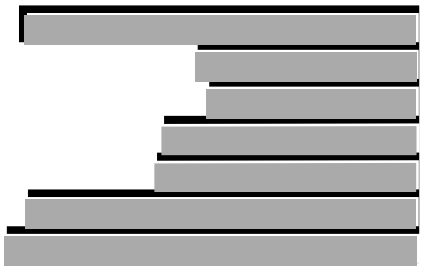
Name of child: [redacted]
Parent: [redacted] (Mum)
Date: 10/10/14

1. How has [redacted] settled in to nursery?
He's done really well, he settled in the first week and then the second week he stayed on his own. I was really concerned about him but he's done really well. Did he go to any playgroups before? *He did but he didn't really like them, he was around me and sort of attached so it was really strange to see him going straight away. The first couple of days he cried but after that he was fine.*
2. Do they have any brothers/sisters? *Follow on with questions to establish age of siblings, position of participating child in the family*
Two sisters and one brother. His sisters are 9 and 8 and his brother is 3 weeks old.
3. What language(s) are used at home?
Bengali but he speaks more English than he does Bengali.
4. Do you or anyone else in the household do any counting at home with [redacted]?
His dad does a lot of counting with him when he's going up the stairs and down the stairs especially and the rest he's learnt off watching Mickey Mouse and TV programmes. How about his sisters. Do they do any counting with him? *(Laughs) No, he don't settle with them, he's more play fighting around them.*
5. What language do you count in?
English Do you do any counting in Bengali at all? *No, because we are so used to English, it's probably our second language but we use it a lot more than Bengali. And Bengali counting we don't use it day to day.*
6. Do you play any counting games at home or when you are out with your child?
No, not really, no board games or stuff like that, just computer games.
7. Do you sing any nursery rhymes/traditional songs at home that involve counting?
No
8. Have you done any counting activities at home to prepare your child for nursery?
No, because I know he's very smart and he learns very quickly, and just by watching the TV and the programmes they have on now is a lot to do associated with children, counting, colours, stuff like that and he picks it up really quickly so I was ok, I knew he could count, like from 1 to 10, sometimes he gets it wrong, but I knew

he was ok and ready for that stage.
9. Is there anything else you wanted to tell me about [redacted] counting?
No, I'm happy I'm fine, he's a quick learner and if you show him one thing, the second time around he can do it himself.

Appendix 9

Letter Inviting Parents to Information Session



29th September 2014

Dear

Counting research project for Nursery children – Information session on Tuesday 7th October at 9am in the Nursery.

I would like to invite you to take part in an exciting counting project with your nursery child. The aim of this project is to develop understanding into how children's counting language and skills develop during Nursery.

The project will involve your child's counting language and skills being assessed and video recorded every month by Leanne Gray. They will also be observed in class participating in counting lessons with their class teacher by Leanne Gray. At the beginning of the project you will also need to be interviewed to find out about any counting you do at home.

There is an information session on Tuesday 7th October at 9am in the Nursery for those who are interested in participating in the project. It is very important that you attend this session to find out more about the project if you would like to take part. Participation in the project is voluntary and your child does not have to take part in the project unless you wish them to do so.

Please could you complete the slip below and return it to your child's class teacher. If you have any questions please do not hesitate to contact me.

Yours faithfully

Leanne Gray

Counting research project for Nursery children – please return to Leanne Gray or your child's class teacher

I will be attending the information session on Tuesday 7th October at 9am.

Child's Name: _____

Parent's Name: _____

Appendix 10

Project Information Sheet

UNIVERSITY OF BIRMINGHAM

Project Information sheet

The aim of the project

- To develop understanding into how children's counting language and skills develop during nursery.

What will be required of the participants:

- Parents/carers
    - Attend the information session;
    - Be interviewed by Leanne Gray before the first counting activity. This interview will be audio recorded.
- Children
    - Take part in counting activities with Leanne Gray every month during nursery.
    - For these counting activities to be video recorded.
    - To be observed during counting lessons on six occasions during the school year by Leanne Gray.

Confidentiality and security of information:

- All information obtained and recordings made during the research will only be seen by Leanne Gray and her university supervisors.
- All information will be kept securely.
- In the final report all children and parents will be anonymised.

Participation in this project is completely voluntary. You are free to withdraw your child before July 2015. Whether or not you choose to participate will not affect your child's usual nursery provision and what they are taught in school. The lessons will carry on as usual whether or not children participate.

The proposed benefit of participating in the study is that you will help to support understanding of the development of counting language and skills of nursery age children.

Contact details: Leanne Gray, [redacted]

University Supervisor: Dr Kirsty Wilson & Dr Dave Hewitt, School of Education, The University of Birmingham, Edgbaston, Birmingham, B15 2TT, Telephone: 0121 415 8225

Should you wish to make a complaint please contact Leanne Gray, Dr Kirsty Wilson or Dr Dave Hewitt at the addresses above.

Appendix 11

Research Participant Consent Form

UNIVERSITY OF BIRMINGHAM

Title of project: A case study of the development of children's counting during nursery in a primary school in Tower Hamlets.
Research Establishment: The University of Birmingham
Name of researcher: Leanne Gray
Name of supervisors: Dr Kirsty Wilson & Dr Dave Hewitt, School of Education, The University of Birmingham, Edgbaston, Birmingham, B15 2TT
Telephone: 0121 415 8225

	Yes	**No**
I confirm that I have read and understood the information sheet for the above study and what **my child's** contribution will be.		
I confirm that I have read and understood the information sheet for the above study and what **my** contribution will be.		
I have been given the opportunity to ask questions.		
I agree to my child taking part and understand that this will involve them being video recorded whilst taking part in counting activities.		
I agree to take part in the interview.		
I agree to the interview being recorded.		
I understand that my child's participation is voluntary and that they can withdraw from the research at any point before July 2015.		
I understand that my participation is voluntary and that I can withdraw from the research at any point before July 2015		
I agree for my child to take part in the above study.		
I agree to take part in the above study.		

Name of child:		Name of parent:	
Signature:		Date:	

Appendix 12

Codes used for Children's Responses in Task-Based Interviews

g = gesture
o = one-to-one principle
v = verbal counting
c = cardinal principle
a = abstraction principle
or = order-irrelevance principle
vr = interesting verbal response
↑ = improvement in response compared to previous task-based interview
→ = same response compared to previous task-based interview
↓ = decline in response compared to previous task-based interview

Question 2 – how many?
As with question one, I recorded whether children made progress compared to the previous task-based interview. I coded the mistakes made by the children with regards to the one-to-one principle using the mistakes noted by Fuson (1991):

- Skim error – moves finger along a row of objects saying counting words without really pointing at objects
- Flurry error – produces a flurry of words and points directed generally but not specifically at the objects
- Points to an object without saying a word
- Says multiple counting words whilst only pointing at one object
- Skips an object without counting it
- Counts an object multiple times
- Points at two or more objects whilst only one number is said

I also coded any gestures the children made when responding to this question.
Question 3 - 'give me x'
These responses were coded according to the actions taken by the child. I used findings by researchers that children usually grab objects when asked this question to frame the matrices (Wynn, 1990, 1992; Bruce and Threlfall, 2004). I used six different descriptions of the actions the children could have taken to code their responses:

- Grabs the objects with no counting
- Gives the objects one at a time with no counting
- Gives the objects one at a time. Counts aloud but the count words do not match the movement of the objects
- Gives the objects one at a time. Counts, with the number word matching the movement. Number string said incorrectly.
- Gives the objects one at a time. Counts, with the number word matching the movement. Counts accurately but does not stop counting when the final object is given. Does not stop at x
- Accurately gives the correct number.

I also used arrows to indicate whether children had made progress when compared to the previous task-based interview.

Appendix 13

An example of a Matrix and Coding (Stable-order principle)

Ridwan		October	November	December	January	February	March	April	May	June	July
How high	↑→↓		↑	→	↓	↑	↑	↓	↑	↓	↑
	What number the stopped at	4	5	4	3	6	20	10	13	7	13
	Prompted?		4			5		6,11	8	8	8, 12
	Any numbers missed out?										
	Other info	Presses finger down as he says each number	Required a lot of encouragement to count				'Teen' not always clear			Instead of 8 says, 18,19,20	Says 18, 19
Count objects	↑→↓		→	→	→	↑	↓	↑	↓	↑	↓
	Number of objects	4	4	4	4	4	8	4	8	4	8
	Numbers said	1,2,3,4,5,6,7	1,2,5	1, 2, 3	1,2,3,4,5	1, 2, 3, 4	1,2,3,4,5	1,2,3,4	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4	1,2,3,4,5,6,7,8,9,10,11

Safwaan		October	November	December	January	February	March	April	May	June	July
How high	↑→↓		↑	↑	↑	↓		→	↑	↓	→
	What number the stopped at	0	3	4	6	5		5	11	10	10
	Prompted?		1, 2	2	2	5		4	8	11	
	Any numbers missed out?										
	Other info	FIVE	1,2,3,1,2	What comes after 4? 9	Holding up fingers - inaccurately			Holding up fingers - inaccurately	Says random number sounding words after 11, e.g. eleventeen	Says random number sounding words after 11	Says 'y'
Count objects	↑→↓		↑	→	→	↑	Absent	→	↓	→	→
	Number of objects	4	4	4	4	4		4	8	8	8
	Numbers said	5	1,2,3	1,2,3,4,5	6,5,10,11,14	1,2,3,4		1,2,3,4	1-10	1,2,3,4,5,6,7	1,2,3,4,5,6,7,8,9,10,11,12

Abdul		October	November	December	January	February	March	April	May	June	July
How high	↑→↓		→	↑	↑	→	↑	→	↓	→	↑
	What number the stopped at	5	5	12	30	30	39	39	29	29	39
	Prompted?	5		5, 11, 21	6, 11	6, 11, 21	11, 21, 31	5,11, 21,31	6,11,21,	6,11,21	11,21,31
	Any numbers missed out?			13							
	Other info	Holds up fingers as he counts		Counted to 30	13 not articulated correctly	30 not articulated correctly	39..100	39..100, hundred one, hundred two to hundred nine	29..40	29, 100	39,100, what comes after 100, '2,10'
Count objects	↑→↓		→	↑	→	→	↓	↑	↑	→	↑
	Number of objects	4	4	4	4	4	8	7	8	8	9
	Numbers said	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4,5,6,7,8, 9,10	1,2,3,4,5,6,7	1,2,3,4,5,6,7,8	1,2,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9

Musa		October	November	December	January	February	March	April	May	June	July
How high	↑→↓		↑	↑	↓	↑	↑	→	→	→	→
	What number the stopped at	10	20	29	13	20	29	29	29	29	29
	Prompted?	1,2	11	11, 21	11	11	11, 21	11, 21		11,21	11
	Any numbers missed out?		14 – not said correctly		14, 16						
	Other info	Using fingers but not accurately		29…100	Counted to 20		29…100	29…100	29…100	29…100	29…100
Count objects	↑→↓		→	→	→	→	↓	→	↑	→	↑
	Number of objects	4	4	4	4	4	8	8	8	8	9
	Numbers said	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1-20	1-10	1-8	1-8	1-9

Maryam		October	November	December	January	February	March	April	May	June	July
How high	↑→↓		↓	→	→	→	↑	↑	↓	↓	↑
	What number the stopped at	5	3	8	8	8	10	19	18	17	24
	Prompted?	2		9	9	9	11	20	11,17	18	
	Any numbers missed out?		1,2,3,5,4								
	Other info		Pressing fingers down on table		Patting hands on table as she counts						24, 29, 26
Count objects	↑→↓		↑	→	→	↓	↑	↓	↑	→	↑
	Number of objects	4	4	4	4	4	8	8	8	8	10
	Numbers said	1,2,3,4,5,6,7, 6,4,5,6	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4,5	1,2,3,4,5,6,7,8	1,2,3,4,5,6	1,2,3,4,5,6,7,8	1,2,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9,1 0

Sadia		October	November	December	January	February	March	April	May	June	July
How high	↑→↓		↑	→	→		↑	↑	→	→	→
	What number the stopped at	4	12	12	12		14	29	29	29	29
	Prompted?	1	1, 11	1, 2, 10, 11	1, 3, 6, 11	Absent	1, 11		21	11,21	
	Any numbers missed out?		16	13, 16, 17, 30, 32	13, 15, 17, 19		15	16			
	Other info		Counts to 29	counts to 36	Counts to 28		Counts to 25	29, 'twenty-ten'	29, 'twenty-ten'	29, 'twenty ten'	29, twenty ten, thirty 12
Count objects	↑→↓		↑	↓	↓		↑	↓	↑	→	↑
	Number of objects	4	4	4	4		8	8	8	8	10
	Numbers said	5, 2, 3, 4	1, 2, 3, 4	1-20	1, 2, 3, 4, 5		1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4, 5, 6, 7, 8	1, 2, 3, 4, 5, 6, 7, 8	1,2,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9,1 0

Ayesha		October	November	December	January	February	March	April	May	June	July
How high	↑→↓		↑	↓	↑	↓	↑	↑	→	↓	↑
	What number the stopped at	2	6	5	10	6	8	10	10	4	13
	Prompted?		3		6		5				
	Any numbers missed out?										
	Other info	Points to objects as she counts	Holding up fingers as she counts – not accurately	Holds up fingers one at a time accurately, then counts back 5,4,3,2,1	Says some undistinguishable number names after 10		Holding up fingers as she counts – not accurately 8..20	What comes after 10? Points to the sky.	Holding up fingers as she counts – not accurately	Saying random numbers, 24,35,26,27,29,twenty-ten	13, 16-25, 24, 21, 26, 25
Count objects	↑→↓		→	→	↓	→	↑	↓	→	→	↑
	Number of objects	4	4	4	4	4	4	8	8	8	9
	Numbers said	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4,5,6,7,8	1,2,3,4,5	1,2,3,4	1,2,7,4,1,6,8	1,2,3,4,5	1-12, then says some random number names	

Appendix 14

Map of Ayesha's Progression

Gelman and Gallistel's Principle	Question	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July
Verbal counting	How high can you count?	✓									
One-to-one principle	How many objects are there?	✓									
	Puppet misses out an object										✓
	Puppet double counts an object			✓							
Cardinal	How many objects are there?	✓									
	Can you give the puppet *x* claps?							✓			
	Puppet gives the wrong number for total items in the set										
Abstraction	Can you count how many jumps the puppet does?						✓				
	Can you give the puppet *x* claps?				✓						
Order Irrelevance	Puppet starts counting in the middle			✓							
	Puppet counts alternatives				✓						

Appendix 15

Observations made by Nursery Staff

Observations	October	November	December	January	February	March	April	May	June	July
Ridwan	Uses number names 'two' and 'three' in play (but not accurately. Catches fish in a net 'I've got two', 'I've got three'.	Threading pasta onto string 'I need one more'.		Experiments with the sequence of numerals 1-10 (1, 2, 3, 6, 10, 8, 9, 7). Knows to start on the left-hand side.	Holding some cups. Another child asks him for one. Child A gives him one. The other child asks for two. Child A said 'no, not two'. Sings 'Five Little Monkeys'	Counts 15 children during snack time. Touches each child's head as he counts. Cut out three objects to match the numeral 3.	Counts 5 objects by counting one-to-one.		Recognises the numerals 0, 1, 4, 5	
	22-36 emerging		22-36 emerging				22-36 developing		22-36 secure	
Safwaan	Uses number names spontaneously when counting pictures of Spiderman. Able to give one from a larger group.	Counts three cylinders by counting one-to-one. He then started saying random numbers. 'I need more'. He put more in the line to count.		Says random number names as he is drawing around number stencils. Puts magnetic numbers on the board. Experiments with the sequence of numerals 1-10 (1, 5, 9, 1, 1, 7). Knows to start on the left-hand side. When asked 'what comes after 1' he replies '2'. Counts aloud to 5.			Counting 5 objects. Moves from left to right, touching each object. Counts slowly but accurately. He later sees a picture of this activity. He says 'counting'. Counts aloud to 10. Drawing a picture of his teacher 'it needs two eyes'.			
	16-26 secure		22-36 emerging				22-36 developing		30-50 developing	

Abdul		Counts 10 objects. Able to say how many there were when 1 more was added without counting (up to 10) Using fingers when counting		Correctly ordered numerals 1-10					Hopped between numbers on the counting mat and said the numbers as he landed on them 1-10	
	22-36 secure		22-36 secure				22-36 secure		30-50 secure	
Musa	Asked what the next number to 9 is. Says 'ten'.	Counted the 'cakes' he had made in the sand. Counted to 12, matching one-to-one. Remembered how many he had when asked 'how many?'. Securely counts 7 objects. Played with the numicon and paint.		Orders the numerals 1-10 correctly, starting at the left.	Counted his sandcastles correctly 1-7. When asked 'how many?, replied '7'.	Counts aloud to 15.				
	22-36 secure		22-36 secure				22-36 secure		30-50 secure	
Maryam		Counted 3 pieces of pepper when making pizza, matching one-to-one. Then said random numbers. Counts aloud to 5. Counts three objects from a larger group. Puts them in a line to count.	Counts 3 objects securely. When there are 4 objects she misses the 4th item.	Accurately counts 12 building blocks when they are in a tower she has built. Starts from the bottom and counts up. Accurately counts 15 pine cones that she has lined up.		Holding 2 toy monkeys. Starts singing '2 little monkeys jumping on the bed'. When it fell off she put it behind her back. 'I've 1 left'.				
	22-36 developing		22-36 secure				30-50 developing		30-50 developing	

Sadia		Counting the fish in the tank. Says '1, 2, 3, 4, 5'. She moved her finger along the tank as she said each number. Counted 6 pieces of pepper to put on her pizza.	Accurately counted 9 objects, matching one-to-one. When asked 'how many?' she uses her fingers to show 9.	Accurately counted 7 spoonsful of jelly as she put them in a bowl. Matches one-to-one.						
	22-36 emerging		22-36 developing				22-36 secure		30-50 developing	
Ayesha	Accurately counted 4 items of clothing. Matched one-to-one. Counts aloud to 10 whilst playing with the numeral stencils. Finds a numeral 4 in the classroom. Picks it up 'I got number 4'. Whilst playing with toy sea life creatures says 'I've got three' (accurate).	Counted 5 pieces of pepper to put on her pizza.				Plays with the number fan. Gets a magnifying glass. 'number is getting bigger', 'it is getting smaller'. Accurately counts 5 objects, matching one-to-one.				
	22-36 developing		22-36 developing				30-50 emerging		30-50 developing	

Appendix 16

Development Matters Compared to Phases of Development

Phase	Counting skills	Procedural or conceptual?	Context	Development Matters 30-50 Months	Development Matters 40-60 months
1	Verbal counting	Procedural	How high can you count?	Recites numbers in order to 10.	Children count reliably with numbers from one to 20
2	One-to-one principle Abstraction principle	Procedural	How many? How many jumps?	Model counting of objects in a random layout, showing the result is always the same as long as each object is only counted once.	Counts objects to 10, and beginning to count beyond 10. Counts an irregular arrangement of up to ten objects.
3	Abstraction principle One-to-one principle Order irrelevance principle Order irrelevance principle	 Conceptual Conceptual Conceptual	Claps (give me) Missing objects Starting in the middle Counting alternatives	Realises not only objects, but anything can be counted, including steps, claps or jumps.	Counts actions or objects which cannot be moved.
4	Cardinal principle Cardinal principle One-to-one principle	Procedural Conceptual Conceptual	Abstract Puppet's count Double count	Knows that numbers identify how many objects are in a set.	Counts out up to six objects from a larger group.