***The teaching and learning of mathematics for pupils with speech, language and communication needs in mainstream classrooms in English primary schools*.**

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Declaration

I hereby declare that, except where explicit attribution is made, the work presented in this thesis is entirely my own.

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Abstract

Pupils with speech, language and communication needs (SLCN) form an ever-increasing pupil group in primary schools in England. Yet, teachers have had little training in how to best support them and find themselves conflicted with the mathematics national curriculum expectation that pupils of differing needs be taught together. This thesis investigates how pupils with a SLCN are educated in mainstream classrooms and how they learn mathematics. Its aim is to investigate connections between effective teaching in mathematics and pupils' attainment as well as to explore specific areas of mathematical difficulty for this group of pupils.

This study adopted a mixed methods concurrent complementary design. Planned as a multiple case study, participants were five teachers drawn from five different primary schools in England and 28 pupil participants. Half the pupils were selected based on having a speech, language and communication need and were compared with a group of matched, typically developing children. Teacher planning, pupil work and teacher interviews were analysed qualitatively and pupils' language scores and performance on a mathematical reasoning test and arithmetic test were analysed quantitatively. Pupils' particular difficulties and strategies used to answer questions were also analysed.

Findings showed that pupils with SLCN did significantly less well on the reasoning paper than the arithmetic paper. Their performance on the arithmetic paper was in line with TD peers. Teacher interviews illustrated teachers' general confidence in teaching mathematics aligned to the principles of the national

curriculum but the independent work of pupils with SLCN showed little differentiation and adaptation for their particular needs.

The study concluded that pupils with SLCN may not be making the progress expected in mathematics due to a complexity of factors including lack of teacher awareness of their specific mathematical needs and strategies to support them in class.

Impact statement

This research has suggested that pupils with SLCN, who form the majority of children with SEN at age 7 in mainstream classrooms, are an under-researched group in terms of how they perform in mathematics. Previous research has focused on children with particular language impairments such as Specific Language Impairment (SLI) or Developmental Language Disorder (DLD) rather than the generic term commonly used in schools and that which matches the DfE school census category. Furthermore, there is very little research that has examined pupil outcomes from an educational rather than a psychological viewpoint and none that consider mathematical error types for pupils of this age group.

Findings from this research indicate that pupils with SLCN do less well on tests of mathematical reasoning than their TD peers and lack strategies to help them to work out solutions. The research has also found that teachers have had little training on how to best support these pupils in the classroom and consequently make few, if any, adaptations to pupil independent work.

The findings from the study therefore have potential in informing classroom practice for serving teachers as well as providers of initial teacher training. Work groups and NCETM maths hub projects may also be interested in its findings. Initially, the findings will be shared with the researcher's home university and partner institutions. Wider dissemination may be possible through academy network chains and local authorities in terms of professional development for serving teachers.

The research has the potential for being written up for a journal article, both in the field of SEN and in the field of mathematics education. It therefore has potential for reaching a wider audience.

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Thank you to ex-colleagues at Mathematics Mastery, especially Dr Helen Drury who inspired me to begin this research.

Last, but not least, my lovely husband, David; your constant support and encouragement have kept me going. Thank you.

Reflective statement

This reflective statement summarises my EdD journey. It provides a personal and professional context for the research and reviews the progress from three taught modules in year one, to the Institution Focused Study (IFS) and finally the doctoral thesis.

Personal and professional background

My interest in the teaching and learning of primary mathematics is longstanding. It began with the introduction of the National Numeracy Strategy (NNS) in 1999. My personal preconceptions about the teaching and learning of mathematics were swept away as, working as a primary school headteacher at the time, we began the programme of training for schools to implement the NNS. The realisation that I enjoyed mathematics began here. The pedagogy behind teaching mathematics in the NNS aligned to my personal and professional values. The daily maths lesson had a simple structure yet encouraged mathematical reasoning and talk for learning. Pupils were taught the basics, yet in a meaningful way, using concrete resources and visual representations. Oral practice had a premium. My enthusiasm for embracing the approach led to me leaving headship and becoming a local authority numeracy consultant. In this role I was responsible for supporting schools in the implementation of the strategy. During this period, I completed my master’s degree in which I looked at the impact of setting on pupils’ attitudes to and attainment in mathematics. After other advisory work and two other headships, I worked at Mathematics Mastery as programme director. This had a profound effect on me, for which I remain very grateful. Colleagues lived and breathed mathematics.

We did ‘Monday Morning Maths’ together, those of us with a teaching background and those with an administrative background, every week, which developed my mathematical knowledge, thinking and understanding. I worked closely with talented colleagues who inspired me and taught me. My confidence grew, as I realised I was able to contribute in this environment too. I saw the effect that a mastery approach to teaching had on pupils in our partnership schools, using an evidence-based approach to teaching mathematics, and this led to my interest in pursuing doctoral study. The EdD appealed to me in that it was collegiate and sequential. As a learner, I learn best from others rather than purely self-study and I am better at breaking learning down into manageable steps rather than having a nebulous end goal.

Reflection on Year One of the EdD

Although I had an idea of what I wanted to focus my final thesis on, I was not one of those students who began their EdD by carefully plotting out the path to success from the beginning. Instead, I was led by personal and professional interests each time, although interestingly, looking back, each of the taught modules did prepare me for my final thesis. The value of the taught sessions was primarily in being able to work with others, to question others’ contributions more critically the more I read, and to learn from the feedback given by other group members and tutors. I also developed my understanding of research design and methodological paradigms during this year, which have had a bearing on my subsequent research.

My first module, Foundations of Professionalism (FoP), explored professional development in shaping the twenty-first century teacher of primary mathematics. This enabled me to explore the literature around teacher professional development and relate this to my role at the time in working for Mathematics Mastery. It had an impact on my professional work, which was to evaluate the effectiveness of the teacher training programme Mathematics Mastery offered. This brought about positive changes to the way that the teacher development programme was linked to the Teachers' Standards and led me to reflect on the most effective ways to deliver teacher education to serving teachers and how to support gaps in teacher knowledge in mathematics.

My second taught module, Methods of Enquiry 1 (MoE1), focused on how teacher attitudes towards children's mathematical ability might influence their choice of teaching methods, building on work I had carried out for my master's degree thirteen years earlier. One of the articles I read for MoE1 was Skemp's (1976) article discussing relational and instrumental understanding in mathematics. This made me reflect on my own mathematics education as a child and how this was very "instrumental", leading to me not fully understanding the operations and procedures used in mathematics. This realisation had an impact on how I delivered training for teachers, in ensuring I made meaningful links between mathematical topics. The research planned for this module was qualitative in nature and sought to collect the views of practising teachers on pupil ability and whether this impacted on what they planned and taught. Although this was a research plan and was not carried out, I developed my understanding of how to conduct robust qualitative research, including how to ensure validity and reliability, which I had not considered deeply prior to beginning the EdD.

My final taught module, Methods of Enquiry 2 (MoE2) linked to my interest in how pupils with SEND learn mathematics and how this can be supported through effective teaching methods. I carried out qualitative research in two primary schools, one using the Mathematics Mastery approach and one that did not. I used systematic observations in classrooms, using the work done by Blatchford and Webster (2013) as a basis to consider lesson structure, including how much time pupils with SEND have to carry out independent work rather than relying on a teaching assistant or teacher to support them. I realised how difficult it is to remain neutral as an observer in a classroom and how one inadvertently gets caught up in the lessons. I also realised that systematic classroom observation is one best carried out with other researchers in order to triangulate views on what one is observing. This module also developed my understanding of data analysis, and that the data generated from systematic research may be open to interpretation unless one has rigorously tested observation instruments. One of the findings from this research though, was the value of language in developing mathematical understanding, which helped inform the study focus for the IFS and the final thesis.

Institution Focused Study (IFS)

Building on the work in year one, the IFS led to me to consider Mathematics Mastery as an institutional entity. The uniqueness of the programme and the fact that two special schools for pupils with Moderate Learning Difficulties had signed up to use the curriculum materials, led me to reflect on how these schools might constitute a case study for further research. For the research, I explored how pupils with special needs were affected by a mastery approach to teaching mathematics and considered teacher attitudes and teacher professional development. Again, the research was qualitative in nature and used semi-structured teacher interviews and systematic classroom observations to gather the data. This time though, I piloted the use of an additional research instrument, participatory photography, in which participants shape and control the research. The findings from the research contributed to the aims of the final thesis research, in that I could clearly identify the importance of spoken language in developing understanding in mathematics for pupils with impaired language.

The thesis

A change of role into higher education and now working in initial teacher education (ITE) with trainee teachers at university rather than in-service teachers in schools, meant fewer opportunities to work with teachers and pupils in classrooms. Following a period of interruption to studies as Covid-19 hit the UK and the country went into lockdown, I recommenced the journey towards the thesis. The nature of the Covid lockdown and the fact that research could no longer be collected face to face meant I had to have a complete change of direction in my research. I redesigned my data collection methods and, for the first time, this research used a mixed methods design in a pragmatist paradigm. This took me out of my comfort zone. I had completed a ten-week statistics course during year two of the EdD and so had some understanding of statistical analysis but had not applied it to a real-life situation. The process of data collection for the thesis, although difficult to get willing participants, was enjoyable, especially in working with children, although I found it tough to step away from the role of a teacher into the more neutral role of a researcher. Conducting research remotely had benefits as well as difficulties. Some aspects of data collection, for example interviewing, were easier to do online than face to face, since time was not lost in travelling and closed captioning made transcription easier and quicker. However, working with young children online was intense and it was difficult to develop rapport with them. I worked closely with supervisors during the thesis period and used their feedback and advice in developing my thinking and writing and in carrying out the data analysis. I feel I have learned much about my own resilience during this period as well as in combining EdD research with a full-time job.

The future

I have always been a reflective practitioner with high standards of work output and strongly held personal beliefs. The EdD has made me consider much more critically effective teaching methods, based on research, which will shape my practice as a teacher educator. Although I felt I was well-read in the field of mathematics education before I commenced the EdD, the thesis stage in particular has taken my learning on significantly. I can now more confidently apply what I have read to my own teaching of students and draw on examples of research, rather than just on practice. I am able to think more critically and analytically. I also have more confidence in my ability to apply the principles of research to other elements of my practice and am looking forward to collaborating with colleagues in the future in carrying out other research.

Table of Contents

Declaration....................2
Abstract....................3
Impact statement....................5
Acknowledgments....................6
Reflective statement....................7
Glossary....................17
List of Figures....................18
List of Tables....................19
List of Appendices....................20
Chapter 1: Introduction....................21
1.1 Professional context....................21
1.2 Personal context....................24
1.3 Definition of key terms....................25
1.3.1 Special Educational Needs (SEN) and Typically Developing (TD) children....................25
1.3.2 Speech, Language and Communication Needs....................26
1.4 Academic context....................28
1.5 Mainstream primary schools....................29
1.6 Context of the study....................30
1.7 Scope and limitations of the study....................34
1.8 Thesis structure....................34
Chapter 2 – Theoretical Perspectives....................36
2.1 Pedagogy....................37
2.1.1 Contemporary pedagogical drivers....................41
2.1.2 Effective teaching....................46
2.2 Effective mathematics teaching- Pedagogical Content Knowledge....................51
2.2.1 Effective mathematics teaching –mastery approaches....................54
2.2.2 Effective mathematics teaching- language and mathematics....................62
2.2.3 Early learning in mathematics....................67
2.3 Strengths and difficulties for pupils with SLCN....................72
2.4 Difficulties in teaching mathematics to pupils with SLCN....................81
2.5 Research questions....................83

Chapter 3 – Methodology *87*
3.1 Ontology **87**
3.2 Epistemology **87**
3.3 Research paradigm **88**
3.4 Research design **89**
3.5 Data collection **91**
3.5.1 Piloting **94**
3.5.2 Sampling **95**
3.5.3 Teacher participants **97**
3.5.4 Pupil participants **97**
3.5.5 BPVS testing **98**
3.5.6 Age differences **100**
3.5.7 Timeline **100**
3.5.8 Ethical considerations **101**
3.5.9 Data storage **103**
3.6 Data collection methods **103**
3.6.1 Quantitative data **103**
3.6.2 Qualitative data **105**
3.7 Data analysis approach **107**
3.7.1 Quantitative data analysis **108**
3.7.2 Qualitative data analysis **109**
3.8 Reliability and validity **111**
3.9 Chapter summary **112**
Chapter 4 - Findings *114*
4.1 Quantitative results **114**
4.1.2 Comparison of SLCN pupils and TD pupils' mathematical abilities in terms of performance and reaction times **116**
4.1.3 Comparison of SLCN pupils and TD pupils' answers in terms of performance on individual items **118**
4.1.4 Error type analysis by pupil groups **120**
4.2 Qualitative data findings **121**
4.2.1 Domain-general difficulties **123**
4.2.2 Domain-specific difficulties **125**
4.3 Teacher understanding of effective mathematics teaching **127**
4.3.1 Mastery strategies **127**
4.3.2 Assessment **129**

4.4 Teacher planning **129**

4.4.1 Teaching strategies **130**

4.5 Pupil work **135**

4.6 Summary **136**

Chapter 5 – Discussion *138*

5.1 Key findings for RQ1 ..... **138**

5.1.1 Limitations to testing **139**

5.1.2 Arithmetic test **139**

5.1.3 Reasoning test **143**

5.1.4 Comparing pupils' performance on reasoning and arithmetic tasks **150**

5.2 Key Findings for RQ2 ..... **155**

5.2.1 Effective pedagogy **155**

5.2.2 Assessment for learning **156**

5.2.3 Adaptation of language **158**

5.2.4 Lesson structure **159**

5.6.4 Mastery approaches **160**

5.3 Domain-specific weaknesses **163**

5.4 Summary **168**

5.5 Bringing the research questions together **168**

5.6 Summary and recommendations for future practice **172**

5.6.1 Recommendations for teachers **172**

5.6.2 Recommendations for schools **173**

5.6.3 Recommendations for ITE providers **174**

Chapter 6 – Conclusion *175*

6.1 Research aims and design **175**

6.2 Research findings **177**

6.3 Research limitations **178**

6.4 Future research **180**

6.5 Dissemination and contribution to the field **181**

6.6 Concluding words **181**

References *182*

Appendix 1 Parent consent letter *220*

Appendix 2 Pupil consent letter *222*

Appendix 3 – Verbal consent prior to second pupil task *223*

Appendix 4 - Script for maths task *224*

Appendix 5- Teacher interview questions *225*
Appendix 6 -Interview transcript extract *228*
Appendix 7 - Emerging themes from thematic analysis *237*
Appendix 8 – Checklist to support identification of pupils with SLCN *238*
Appendix 9- Detailed thematic analysis based on five teacher interviews, transcribed. .. *237*
Appendix 10 - White Rose Spring Term Arithmetic Test *250*
Appendix 11 - White Rose Reasoning Test Year 1 .... *248*

Glossary

BPVS	British Picture Vocabulary Scale
CCF	Core Content Framework
DfE	Department for Education
EHCP	Education and Health Care Plan
GCSE	General Certificate in Secondary Education
ITE	Initial Teacher Education
NCETM	National Centre for Excellence in Teaching Mathematics
PGCE	Postgraduate Certificate in Education
SAT	Standard Assessment Test
SALT	Speech and Language Therapist
SEN	Special Educational Needs
SEND	Special Educational Needs and Disability
SLCN	Speech Language and Communication Needs
TD	Typically Developing Child

Key Stage 1 The first stage of primary education in England. Children are aged 5-7.

Key Stage 2 The second stage of primary education in England. Children are aged 7-11.

Year 1 The first year of primary school in England. Children are aged 5-6.

Year 2 The second year of primary school in England. Children are aged 6-7.

List of Figures

Figure 1: Concurrent complementary research design 90

Figure 2 - Timeline 101

Figure 3 - Example of adapted flipchart slides 132

Figure 4 -Pupil work from a lesson on money, 'Best Street' Primary 135

Figure 5 -Pupil work from a number lesson, 'Ashwood Primary' 136

Figure 6 -Arithmetic paper question 7, 'missing number' equation 142

Figure 7 - Question 1, reasoning paper 144

Figure 8 - question 2, reasoning paper 145

Figure 9 - Question 6, reasoning paper 147

Figure 10 - Questions 3.1, 3.2 and 3.3, reasoning paper 149

List of Tables

Table 1 - Data Collection Methods 93

Table 2 - School and Teacher Details, % SEN, Ofsted Grade and % FSM 96

Table 3 - Pupil Participant Characteristics for pupils with Speech, Language and Communication Needs (SLCN) and Typically Developing Pupils (TD) 100

Table 4 - Description of error types 105

Table 5 - Mean total scores (SD) and reaction times on arithmetic and reasoning papers 117

Table 6 - Item comparison of TD and SLCN pupils' correct answers on arithmetic test 118

Table 7 - Item comparison of TD and SLCN pupils' correct answers on reasoning test 119

Table 8 - Mean number of error types for Computation (C), All other errors (AOE) and Reversal (R) 120

Table 9 -Emerging themes and sub-themes arranged according to teaching strategies, pupil learning factors and external factors 122

Table 10 -Summary of key findings, interpretations and links to future practice 169

List of Appendices

1. Parent consent form
2. Pupil consent form
3. Verbal pupil consent
4. Script to introduce the mathematics tests
5. Semi-structured interview questions
6. Interview transcript extract
7. Emerging themes from thematic analysis
8. SLCN checklist
9. Detailed thematic analysis
10. White Rose Arithmetic Paper Spring Term Year 1
11. White Rose Reasoning Paper Spring Term Year 1

Chapter 1: Introduction

This thesis examined how five- and six-year-old pupils with a Speech, Language and Communication Need (SLCN) learn mathematics in English primary schools. Using a concurrent mixed method design, the study focused on how teachers planned to teach mathematics to this pupil group and the errors typically made by these pupils in arithmetic and reasoning tasks.

This chapter sets out the professional, personal and academic rationale for this focus and the structure of the thesis.

1.1 Professional context

My background in education is lengthy and varied. It includes several years as a mathematics consultant, programme director for a mathematics mastery programme and a primary school headteacher for twelve years, although latterly I have worked in university teacher education. My current role is that of programme leader for the primary (5-11 years) Post Graduate Certificate in Education (PGCE) teacher education course at a small outer London university. These roles have all involved observing teaching and learning practices in the classroom as well as noting the inequalities faced by some groups of pupils, in terms of the teaching they experience and the outcomes they achieve. I taught in areas of low socio-economic status in London, and, as a headteacher, opened an attached unit for autistic children, the majority of whom struggled with expressive and receptive language. I was struck by their failure to achieve in line with typically developing peers in mathematics. Speculating the cause of this led me to consider more deeply the link between language and mathematics. I subsequently worked for a mathematics curriculum delivery programme, Mathematics Mastery, a programme which aimed to raise mathematical attainment, particularly in closing the attainment gap between children from lower-income families and their peers (Vignoles et al., 2015). During this period, I witnessed, through observing in primary and secondary school classrooms, how the programme's emphasis on teaching explicit language skills in mathematics appeared to enhance pupils' outcomes in the subject, leading to improved reasoning and justification of their working. This was further confirmed by schools' own evaluations and responses to the introduction of the programme. This led me to conjecture whether, through careful teaching with an emphasis on language, teachers might have an impact on pupils' mathematics outcomes, particularly those whose English language skills, from whatever cause, may be low on entry to school. These experiences stimulated my interest in the link between research and practice and motivated my desire to begin doctoral research.

My Institutional Focused Study (IFS) considered the link between language use and mathematics in greater detail. This research took the form of an exploratory case study, carried out in a special school for pupils with moderate learning difficulties (MLD). This school had introduced the Mathematics Mastery teaching programme against the advice given by me as the programme director. The definition of *mastery* used by the Mathematics Mastery programme is that mastery comes after the exploration of concepts, clarification, practice and application. A child said to have achieved mastery of a concept after there is no longer a need to clarify errors and when they can apply their reasoning to a different situation (Drury, 2014; 2018). The Mathematics Mastery programme is age-specific and was drawn up to cover the national curriculum objectives for each year group. Its intended use is in mainstream schools to single age group classes. As the majority of the pupils in the special school in which the research was carried out were working at levels well below those expected of typically developing peers, it had not been recommended given the school's specific context. Nevertheless, the school had decided to buy into all aspects of the programme, including its philosophy of keeping all children together on the same content, and introduced it into several year groups. Because of this unique position, it provided an opportunity for further study. The study aimed to explore which, if any, of the key principles behind this mastery approach to teaching: conceptual understanding, language and communication and mathematical thinking (Ark Curriculum Plus, n.d.), could be appropriate in a special school setting. A small-scale case study was carried out which followed a constructivist paradigm. It used systematic classroom observations, teacher and senior leader interviews and an approach with the teacher as co-researcher, using participatory photography, a method where participants select and justify the cases they feel are relevant to the research. On conclusion of the research, key findings were that the school had adapted the Mathematics Mastery teaching programme to suit the levels of children's ability but had maintained some of the key features aligned to a mastery style of teaching. This included the introduction of key vocabulary in context, 'talk tasks,' in which pupils practised a formulaic language structure given to them by the teacher, as well as opportunities to practise this through real-life opportunities to problem-solve and use manipulatives. The findings from this case study suggested that pupils who had previously struggled to verbalise were able to explain their mathematical reasoning once a more language-rich approach had been introduced and then maintain these strategies in their independent work. However, the study's limitations were the small study size, as well as only examining children with delayed language and other speech, language and communication needs, rather than using a comparator group. Further research was therefore indicated in order to investigate more fully the links between language development and mathematics, comparing pupils with a learning need with typically developing children.

1.2 Personal context

My personal interests in pursuing this area are multiple. As an articulate and well-read child, I found mathematics more difficult. I could not see its relevance; concepts were explained in a way that made no sense to me, nor did following the methods of solving problems given by the teacher when I could find an alternative way. I therefore developed what I now know to be a ‘procedural’ understanding of mathematics, whereby there is limited understanding of the connections between different mathematical topics or what the purpose is in using different computational techniques; in other words what Skemp (1976, p.20), defined as “instrumental understanding”. As an adult, though, I grew to love mathematics and appreciate its beauty and simplicity, understand its structure and interconnectedness and was able to make links between different areas of mathematics, finally seeing the relationship between them. Working first as a numeracy consultant and later at Mathematics Mastery, solving problems with others illustrated for me the power of talk to explain reasoning, and how this can also be used to unpick where there are errors. This led me to wonder how much more difficult mathematics might be if one did not have sufficient language skills to reason and solve problems or if one has no opportunity to do so.

My own personal philosophy of mathematics teaching and learning has been formed by my experience of teaching when a school pupil, as well as through my involvement in education working with children in disadvantaged areas, many of whom did not reach national standards at the end of key stage 2 in English and mathematics. This has a bearing on my motivation for carrying out this research.

1.3 Definition of key terms

Although the acronyms used in this thesis are explained earlier (p.17), the following sections explain the terminology in greater detail and why it has been used in this context.

1.3.1 Special Educational Needs (SEN) and Typically Developing (TD) children

The definition of special educational needs (SEN) used in this research is that found in the statutory DfE Code of Practice, which exemplifies the legal requirements in the Children and Families Act 2014:

> A pupil has special educational needs where their learning difficulty or disability calls for special educational provision, namely provision different from or additional to that normally available to pupils of the same age (DfE, 2015, p.94).

Some literature refers to SEND, Special Educational Needs and Disability; the terms SEN and SEND are often used interchangeably. The terminology 'SEND' will not be used here though, as disability has a separate definition under the Equality Act 2010 as a "physical or mental impairment that has a *substantial* and *long-term* negative effect on one's ability to carry out normal day-to day activities" (Definition of disability under the Equality Act 2010, 2021). Data on pupils' disability status were not gathered for this study. The SEND Code of Practice (DfE, 2015) identifies four broad categories of special educational need, including communication and interaction, into which pupils with Speech, Language and Communication Needs (SLCN) may fall. All pupils in this study were categorised as having SEN, specifically a SLCN. By comparison, the control group were defined as being typically developing (TD), in other words those who were deemed to be making expected progress for their age.

1.3.2 Speech, Language and Communication Needs

Terminology to describe the condition of having a SLCN is used variously throughout the literature: *specific language impairment, language difficulty, language delay, language learning difficulties* and *developmental language disorder,* for example (Bishop, 1979; 2014), although there are differences in how the terms are used by professionals and in their aetiology. A ‘language disorder’ is the suggested term for pupils whose language difficulties are likely to endure “into middle childhood and beyond” (Bishop et al., 2017, p.1070), whereas the more specific term Developmental Language Disorder (DLD) is used for “language problems that are severe enough to interfere with everyday life, have a poor prognosis and are not associated with a clear biomedical aetiology” (Bishop et al., 2017, p.1078). The terminology used throughout this research, however, is *SLCN*, being an umbrella term for children with a speech, language and communication need. These children may have been identified through a formal diagnosis by a speech and language therapist or educational psychologist, or more informally through their school. SLCN matches the phrase used in schools’ annual census returns, hence is the term understood by education professionals.

Although the term SLCN is used widely in the United Kingdom, there is a lack of agreement from teachers, parents and other professionals as to exactly what this constitutes, with speech and language services and schools having divergent views as to the exact nature of the term (Dockrell et al., 2017). Acknowledging the importance of using common terminology across the field, recent attempts to achieve agreement amongst professionals (Bishop et al., 2017) suggested that the term SLCN be retained for superordinary purposes by policy makers and to bridge across professional divides.

SLCN may be a child’s primary need, or secondary to other impairments such as autism, hearing impairment, cerebral palsy, Attention Deficit, Hyperactivity Disorder (ADHD) or more general learning difficulties (Afasic, 2019; Bercow, 2008; Dockrell & Hurry, 2018). Although children with autism or those with hearing impairments may also have impaired speech (Dockrell et al., 2017), the umbrella term SLCN here refers specifically to those children whose primary difficulty is an oral language need. It is important to note that the term SLCN excludes those pupils learning English as an Additional Language (EAL), unless they have also been shown to have difficulties in any language: their English language difficulties may be attributed to lack of experience in the English language (Bishop et al., 2017).

Although some children with more severe language disorders may have been identified by their parents, health visitors or other professionals prior to entering school or nursery (Public Health England, 2020), it is likely that the majority of pupils with SLCN are identified by teachers on entry to their first educational setting. Early identification, however, is problematic and inconsistent (Dockrell et al., 2017; ICAN and RCSLT, 2018). Teachers' assessments have been seen by some as unreliable, with many categorising pupils as having a SLCN when in fact they had a more generalised learning difficulty (Dockrell & Hurry, 2018; Lindsay et al., 2010).

The term SLCN, although imprecise and, at times, controversial (Dockrell et al., 2012; Bishop, 2014), covers a wide range of expressive and receptive language difficulties. This heterogeneous group has distinct differences in children’s underlying profiles as well as in their underlying “deficits” (Archibald, 2017, p. 5). Difficulties may be related to speaking, listening and communication, with some children having one or more needs in differing combinations (Afasic, 2019). However, most children with SLCN have impaired comprehension (Bishop, 2013), with other common difficulties including delays in vocabulary development and difficulties in understanding and use of grammar (Leonard, 2014; Smith-Lock et al., 2013). Some may have communication needs, such as difficulty in understanding the subtleties of language and the varied meanings that can be derived from it (Lindsay et al., 2012).

There is no clear rationale used by schools to determine which linguistic features may be initially highlighted when first identifying a pupil with a SLCN (Dockrell et al., 2017) and this may contribute to the problems in their identification. Despite the lack of clarity on the use of the term and disparity with how pupil needs are identified, SLCN is the most prevalent reported special educational need at age seven (Dockrell & Hurry, 2018), with over 245,000 pupils recorded in the most recent school census (DfE, 2021a), around 10% of the school population. This is estimated to rise to up to 50% of pupils being identified with a SLCN in areas of high deprivation (Public Health England, 2020). Moreover, the number of children identified with SLCN is increasing, with a rise of around 3% a year. This group is therefore a particularly important one to consider, especially as the majority of these children are educated in mainstream schools (DfE, 2021a; Durkin et al., 2014).

1.4 Academic context

Pupils with special educational needs and disabilities (SEND), including the significant proportion with speech, language and communication difficulties (SLCN), underachieve significantly in mathematics at age seven compared to pupils with no

SEND (DfE, 2019a), with only 33% of pupils with SEND achieving the expected level in mathematics compared to 84% of pupils without SEND. Disaggregated data for pupils with SLCN is not in the public domain, but it would suggest that as pupils with SLCN form the largest group of pupils with SEND at age seven, and that, as children with SEND underachieve in mathematics compared to typically developing (TD) children, a large proportion of pupils with SLCN might be said to underachieve in mathematics. This is also indicated by research which finds that children with SLCN have lower educational outcomes, not only in literacy and writing, but also in numeracy (Cowan et al., 2005; Durkin et al., 2014). It is not yet clear why this might be; although there is a strong link between language impairment and mathematics attainment (Snowling et al., 2012), it is nevertheless not well understood (Alt et al., 2014). Other linguistic explanations for low performance in mathematics for this group may include difficulties with language needed for learning; poor working memory; difficulties with language-heavy tasks and interventions that focus on language input rather than mathematics (Alt et al., 2014; Cowan et al., 2015; Dockrell & Hurry, 2018; Wellington & Stackhouse, 2011). Little recent research has been carried out into effective teaching strategies for children with SLCN in the mainstream mathematics classroom, particularly at key stage 1 with the majority of the research being focused on older pupils or on pupils in early years (3-5 year-olds).

1.5 Mainstream primary schools

This research was carried out in mainstream primary schools in England. Mainstream primary schools are those without any special designation, catering for pupils from 5-11. They may further fall into categories of local authority maintained schools, foundation and voluntary schools; academies and free schools; the difference being in how they are funded rather than the make-up of the school cohort. Only local authority, foundation and voluntary schools must follow the national curriculum, although, in practice, academies and free schools also tend to do so (Types of school, 2021). All school types are obliged to abide by equalities and SEN legislation, however.

1.6 Context of the study

This study should be seen in the context of significant changes in education practice in England. Education in English primary schools has undergone, and is still undergoing, major changes over recent years, with concerns about educational standards (DfE, 2010) running alongside changes in legislation for pupils with SEN (DfE, 2015). Alongside successive UK governments' strategies to improve teaching and learning (DfEE, 1988; DfE, 2013), changing notions and definitions of inclusive education (United Nations Educational Scientific and Cultural Organisation [UNESCO], 1994) have meant that, for most mainstream primary schools, children with additional learning needs are now educated alongside typically developing peers. Indeed, there is a legally defined expectation that pupils with a diagnosed SEN should be educated in mainstream schools "…unless that is incompatible with the wishes of the child's parents or the provision of efficient education for others" (Children and Families Act, 2014, s. 33). Despite this expectation, inclusive practices in many schools are variable, with some teachers showing negative attitudes towards inclusion (de Boer et al., 2011) or feeling they cannot adequately meet the needs of pupils with SEN in their classes (Sadler, 2005; Marshall et al., 2002). Concern has also been raised regarding the over-use of teaching assistants (TAs) to support pupils with SEN, either within the classroom or in intervention groups which may take place outside the classroom (Blatchford & Webster, 2018), a strategy that has grown hugely in recent years (Webster et al., 2013) in response to the increase in pupils designated as having SEN as well as from wider school workforce reforms (Bates, 2014).

At around the same time as these changing practices in inclusive education, concerns arose from English children's lower outcomes in mathematics tests such as the Programme for International Student Assessment (PISA) and Trends in International Maths and Science Study (TIMSS) compared to other countries. The results of these have been questioned, with some writers (Leung, 2014; Murphy, 2014; Lingard & Grek, 2007; Prais, 2003) pointing out negative factors, such as selective reporting, translation issues and cultural bias, as well as the methodology behind the studies. Nevertheless, governmental reforms were heavily influenced by these statistics, leading to a revision of the national curriculum. In particular, the higher student outcomes and teacher practices espoused by high-performing jurisdictions such as Shanghai (China) and Singapore were influential on the design of a revised national curriculum for mathematics (DfE, 2013). The revised national curriculum for mathematics had a new requirement that pupils should move through the programmes of study at "broadly the same pace" without being "accelerated through new content" (DfE, 2013, p.3). Schools embraced the new curriculum requirements, leading to an increased emphasis on whole class teaching, with greater inclusion of all children in mathematics lessons, regardless of pupils' prior attainment or learning need (Boaler, 2016; Forgasz & Cheeseman, 2015; F. Leung, 2014). From my own observations of classroom practice, it is possible that teachers may have misinterpreted the national curriculum expectations and consequently have not routinely adapted work to meet the needs of pupils with SEN, leading to a frequently seen practice where all children attempt the same work, supporting neither the child with SEN nor stretching the child with higher potential. This has led me to question the effectiveness of some of the mathematics teaching I currently see in mainstream primary classrooms, both from experienced teachers as well as student teachers. It appears that this direction to keep the ‘whole class together’ may have led to more whole class and heavily controlled teaching, with little adaptation for pupils with additional needs. Some research has concurred with my observations, finding that teachers using approved mastery textbooks move through the same content at the same pace for the whole class (Boyd & Ash, 2018).

Lack of teacher confidence in teaching mathematics may also be a factor in the lack of adaptive teaching in whole class lessons, with teachers seeking to overly control content, beginning lessons with teacher demonstration, which is then followed by individual pupil practice (Stein et al., 2008). Much of the teaching I observe is strongly teacher-directed rather than a constructivist approach: in other words a triadic ‘initiation, response, feedback’ (IRF) delivery model (Cazden, 2001; Mercer, 2003) with the teacher initiating dialogue and children being given limited opportunities to express themselves at length, or to listen to others’ points of view. In line with others’ findings (Brodie, 2007; Wardman, 2013), I note that pupil feedback during lessons is often cursory, with teachers frequently asking closed questions to which pupils already know the answer. For example, checking on recall of multiplication tables, rather than attempting to elicit pupils’ understanding by asking more probing questions. Alternatively, I have seen teachers ask a question yet answer it themselves before pupils have had a chance to respond, a technique that appears to have changed little over recent years (see Brown & Wragg, 1993); teachers do not always allow ‘waiting time’. It is not clear whether a teaching style such as those based on direct instruction supports all children in having an equal chance of success in mathematics, or whether pupils with SLCN may be particularly disadvantaged by these approaches. As these pupils have a weak comprehension of language, particularly the technical aspects of mathematical language, it has been suggested that they may benefit from a discourse-rich environment in which they generalise and explore language in different contexts to cement the mathematical meaning of vocabulary (C. Leung, 2005). It is questionable, therefore, whether a direct, instructional, whole class approach may allow children sufficient opportunity to explore mathematical language in different contexts, particularly those for whom language may be impaired. Direct instruction will be explored in greater depth in Chapter 2.

The influence of, largely, East Asian teaching techniques on the national curriculum, led to more schools embracing a mastery approach to teaching mathematics, perhaps without a clear understanding of what this might look like in practice. Although some research has been carried out onto the impact of mastery teaching on English pupils in mathematics (Jerrim & Vignoles, 2016), more research is needed, particularly to identify how these strategies might support pupils with SLCN. Wide variations in how mastery teaching has been interpreted in practice (Boyd & Ash, 2018) mean this is an important issue. It is worth considering further in what ways pupils with SLCN may differ from their typically developing (TD) peers in mainstream classrooms, specifically whether any language impairment may impact on some children’s ability to understand tasks that are language heavy, such as those found in reasoning tasks.

This research, therefore, explored principles of mastery teaching, through teacher understanding of effective practice in mathematics teaching and examination of specific pupil difficulties in mathematics reasoning and arithmetic tasks, used as a tool to assess pupil understanding.

1.7 Scope and limitations of the study

Data were collected during the time of the Covid-19 pandemic at a time when schools were under great pressure, having had two recent closures (save for the children of key workers) with many children having had disrupted education. The study should be seen in this context, as the schools selected may not have been typically representative, and teacher planning, differentiation of work and pupil attainment may have been adversely impacted. Schools taking part in this research were local authority maintained mainstream schools and academies in England, detailed further in Chapter 3.

This exploratory research aimed to bring together academic study, personal interest and professional practice to add to the knowledge base that exists in considering effective teaching in mathematics, considering specific areas of mathematical difficulty for key stage 1 pupils with SLCN. It developed the work completed for the IFS in terms of exploring the link between mathematics and language, but with a focus on pupils with SLCN educated in mainstream schools following a mastery approach to teaching mathematics. It is intended to inform my current practice in teacher education, in the teaching of mathematics and in observing trainee teachers in classrooms.

1.8 Thesis structure

Chapter 1 has introduced this thesis. Chapter 2 continues with a review of theoretical perspectives. This covers themes of effective pedagogy, acknowledges the political landscape of the past 30 years in shaping classroom practice and discusses effective teaching in mathematics, including mastery techniques. An exploration of the learning needs of pupils with SLCN follows, with an emphasis on learning in mathematics, along with teacher difficulties in adapting teaching for this group of pupils. The research questions arising from the review of the theoretical perspectives are presented in Chapter 2.

Chapter 3 outlines the mixed methods research methodology used to answer the research questions. It explains how the study sample was selected, the research design and the ethical considerations. An overview of the data analysis is given.

Chapter 4 describes the findings from the data analysis, focusing on each of the research questions, including the statistical analyses undertaken.

Chapter 5 discusses the findings from the quantitative and qualitative research. It draws these together and considers the overlap between them. An interpretation of the results is offered.

Chapter 6 concludes the thesis. It offers an overview of the research, considers its limitations and suggestions for dissemination and further research.

Chapter 2 – Theoretical Perspectives

The previous chapter explained the rationale for the study and defined the context in which it is set. This chapter discusses the relevant theory which forms the conceptual framework and from which the research questions were derived. The chapter begins with clarification of the term ‘pedagogy,’ since this is often used interchangeably with teaching, yet has subtly different meanings dependent on context. A discussion of the evolution of the nature of pedagogy, teaching and learning and school improvement strategies in England follows. England is discussed specifically since the education systems in the other countries of the United Kingdom differ. The review goes on to discuss effective teaching strategies including those that support effective mathematics learning. The chapter culminates in an exploration of the specific difficulties faced by pupils with SLCN in mathematics, followed by the difficulties faced by teachers in teaching this pupil group as well as in mathematics more generally. Finally, it concludes with a summary of what this research can contribute to knowledge about pupils with SLCN in learning mathematics.

Literature searched includes that from the field of psychology, in ascertaining how children learn and the nature of SLCN, as well as that from education, through exploring effective pedagogy and the perspectives of teachers. As there are numerous uses of terms to include pupils with SLCN, literature searched included studies carried out on pupils with specific language impairment and Developmental Language Disorder.

2.1 Pedagogy

Pedagogy is defined as “The art or practice of teaching” (Oxford English Dictionary, n.d.) but it is more complex than that definition suggests. Pedagogy is distinct from notions of ‘education.’ Leach & Moon (2008, p.4) argue that “the discourse of education” is “descriptive and normative, whereas pedagogy invites us to recognise the multiple and various dynamics of scenes of teaching and learning.” Alexander (2009) suggests pedagogy comprises the act of teaching but is also wrapped up in discussions about culture, the nature of learning and the structure of knowledge. Whilst pedagogic practice is “theory-soaked” (Alexander, 2009, p.16), conversely pedagogic theory without practice is meaningless. Hence pedagogy might be seen as both the theory of learning and the practice of teaching. The concept of pedagogy, as used in this research, is that which draws together the practice of teaching and its impact on pupil learning; the ‘how’ of teaching rather than the ‘what’ of the curriculum.

Much debate has focused on effective practice in teaching, particularly since the 1960s. Its evolution has moved from the ‘traditional’ pedagogies, termed by Freire as the ‘banking model’ of education, where children are seen as empty vessels to be filled with knowledge (Freire,1970) through the so-called ‘progressive’, child-centred pedagogies of Froebel, Dewey and Montessori, and more recently to what has been termed a pseudo-scientific approach, drawing on meta-analyses and randomised controlled trials (Little, 2020). Highly influential on child-centred learning was what became known as the ‘Plowden Report’, which recommended a “combination of individual group and class work” as well as welcoming a trend towards “individual learning” (Plowden,1967, p. 294). This informed pedagogical practice in primary schools for many years. In the field of SEN, the Warnock Report

(1978) on the education of ‘handicapped children and young people’ was seminal. It proposed a paradigm shift for educational inclusion for children with learning needs, specifying for the first time that these children might be educated in “ordinary schools” rather than “being organised separately” (p.345), leading to the normalisation of this approach. During this same period, mathematics education was heavily influenced by the publication of Cockroft report (1982, p.84), which strongly promoted a holistic, practical mathematics curriculum:

> The primary mathematics curriculum should enrich children's aesthetic and linguistic experience, provide them with the means of exploring their environment and develop their powers of logical thought, in addition to equipping them with the numerical skills which will be a powerful tool for later work and study.

Teaching and learning pedagogies in England have continued to evolve, particularly over the last 20 or so years with the drive to improve both schools and the quality of teaching, much of it driven by government initiatives drawing on the work of educational researchers such as Barber (2000) and Fullan (2001). Recent work to develop teaching and learning in schools may be said to have begun with the publication of separate National Literacy and Numeracy Strategies (DfEE, 1998; DfEE, 1999), later the ‘National Strategies’. These pedagogical approaches were based on earlier smaller-scale projects using whole class teaching methods but were rolled out nationally following the election of the Labour Government in 1997 (Brown et al., 2000). The practical delivery of these strategies included increased levels of support for teachers in terms of materials, finance, and technical coaching, leading to a “transformation” (Smith, 2008, p. 16) in the way mathematics was taught and a rise in standards in mathematics at the end of key stage 2 (KS2). One of the National

Numeracy Strategy's (NNS's) key pedagogical features was a rejection of 'Plowdenesque' approaches including a reduction in differentiation (adaptation of tasks), instead encouraging whole class teaching methods with a maximum of three levels of differentiation (DfEE, 1999). 'Setting', the practice of grouping children by similar levels of attainment, had already been shown to be largely ineffective (Boaler,1997) and was further discouraged by the NNS (DfEE,1999), although government directives were sometimes contradictory; the Excellence in Schools White Paper (DfE,1997) suggested setting should be the norm. Although successful in terms of improved pupil outcomes and improved teaching practices as observed by Ofsted, the schools' inspectorate (Smith, 2008), the NNS was often viewed as highly prescriptive by the teaching profession, imposing control over teachers without addressing deeper-rooted issues of pedagogy (Brown et al., 2000); any improvements were superficial and not necessarily embedded into practice.

Alongside the NNS-promoted strategies to support pedagogy, testing took on a renewed significance with the introduction of Standard Assessment Tests (SATs) in the 1990s. Initially designed to show what pupils knew and understood at the end of key stage 1 and key stage 2, these summative tests in the core subjects of English and mathematics quickly became seen as measures by which to judge the effectiveness of a school, rather than as a reflection on teaching effectiveness and its impact on pupil learning (Whetton, 2009). Schools were set numerical targets for the percentage of children to achieve the expected level, which increased each year. They were also held to account with the publication of their test results and Ofsted reports with many teachers and headteachers becoming increasingly demotivated by this public accountability (Wyse & Torrance, 2009). Ball (2003, p.216) infamously described this performative culture as "the terrors of performativity". Additionally, there was concern that test results might have been artificially inflated because of a narrowed curriculum and teaching to the test (Hargreaves, 2009), therefore any rise in results was not necessarily linked to long-term improvements in the quality of teaching. However, despite the scepticism from some in the teaching profession that the National Strategies' approach was making a real difference to the quality of teaching, government initiatives continued with the drive to achieve ever higher results.

In its 2010 White Paper (DfE, 2010), 'The Importance of Teaching,' the incoming coalition government made clear that a highly skilled teaching workforce was needed to deliver improved standards and meet the demands of industry: the demand for unskilled manual work had declined whilst the demand for a workforce being able to offer non-routine analytic skills had increased. The White Paper's stated aspiration for a "world-leading curriculum for all" (DfE, 2010, p.20) meant schools supporting one another with improvements since this coincided with a decline in school improvement funding that had previously been held by local authorities. Instead, a greater reliance was proposed on National Leaders for Education (NLEs), experienced and outstanding headteachers, as well as Multi-Academy Trusts (MATs) leading the way in school-to-school improvement, defined as "supported autonomy" (DfE, 2010, p.10). There is little robust evaluation of the work of NLEs in improving teaching and learning but any that do focus more narrowly on pupil outcomes and Ofsted inspection results (see Hill & Matthews, 2010) rather than focusing on broader issues of developing pedagogy. Despite these various interventions, the "long tail of underachievement," especially in mathematics, as measured against international competitors through TIMSS and PISA results (DfE, 2016a, p.98) continued to plague successive governments. The various school improvement strategies implemented focused largely on improving schools, measured by an emphasis on pupil test results and successful Ofsted inspections, without fully addressing the underlying issues of pedagogy or arriving at a collective agreement of what it is. Bates (2014, p.354) described what she saw as a failure of central strategy as a “spectacular illusion.” Teachers’ collective failure to agree what was best practice, drawn from robust research evidence, meant they were “at the mercy of whichever political wind was blowing” (Lowe, 2007, p.61). The debate around effective practice is still occurring. The most recent education White Paper (DfE, 2022a), for example, refers to “brilliant lessons” (DfE, 2022a, p.28) and “excellent teachers” (DfE, 2022a, p. 20), without defining what is meant by these terms. It is possible, despite the focus on improving schools and pupil standards over the past 50 years, that this lack of agreement as to what effective teaching is, has meant that effective pedagogy has been open to interpretation by individual schools and teachers. Alongside a weak focus on classroom research, this may have contributed to variability in the overall quality of teaching.

This chapter has so far discussed the difficulties in coming to an agreed definition of effective pedagogy. It now moves on to discuss contemporary pedagogical issues and considers their general suitability as well as how they might support learning for pupils with SLCN.

2.1.1 Contemporary pedagogical drivers

Many of the current drivers of pedagogy have been influenced by what has been described as “one-dimensional pseudo-scientific approaches towards limited goals” (Little, 2020, p.127), promulgated by educational research establishments such as the Education Endowment Foundation (EEF), using what Little describes as “flawed methodology” (Little, 2020, p.129) to draw up their reports and at the behest of government ministers. Although this assertion dismisses science-based approaches to teaching and learning, their influence on recent pedagogical practices, especially on Initial Teacher Education (DfE, 2019b) is nevertheless pervasive, and therefore they will be considered in greater detail, since they are likely to influence current new entrants to the teaching profession.

This recent pedagogical theory has roots in the science of learning. This phrase, ‘science of learning,’ was popularised in a ‘Deans for Impact’ publication (Deans for Impact, 2015); a US organisation whose mission is in transforming “educator preparation and elevating the teacher profession” (Deans for Impact, p.2) and whose recommendations are said to be informed by data and influenced by cognitive science. However, limited evidence is drawn on for many of the claims made, and evidence is presented selectively. Their guidance, though, is presented as a series of easy-to-understand aphorisms including motivation, transferability of knowledge to different situations, problem-solving, learning and retention of information, and understanding of new ideas. As its format is accessible, it is likely that this might be of influence for teachers, especially since it is referenced in the Initial Teacher Training Core Content Framework (CCF) (DfE, 2019b) which content all providers of teacher education must now follow, and so is likely to be instrumental in informing trainee teachers’ practice. Of note for this review is Deans for Impact’s discussion of pupil learning, which, they suggest, can be maximised using strategies such as spacing and retrieval, explicit instruction and metacognition. These instructional principles are drawn from widely accepted and evidenced-based research (e.g. Agarwal et al., 2012; Cepeda et al., 2006; Karpicke et al. 2009) and are separate from research on cognitive load theory (Sweller et al., 2011), discussed later in this chapter.

Spacing and retrieval are instructional design techniques designed to improve long-term retention of facts; spacing being the act of referring to information over time, helping to embed facts into long term memory through the form of low stakes testing or quizzing (Karpicke, 2012; Karpicke & Roediger, 2007). Retrieval practice is the planned strategic act of recalling facts assigned to long-term memory, such as number bonds and multiplication tables. Being able to draw upon these facts easily is said to free up working memory, which is discussed in more detail later in this chapter. Some research has indicated that leaving longer spaced intervals between retrieval is beneficial (Lyle et al., 2020) since storage strength may improve over time through integration with other representations and concepts. Retrieval is said to be particularly helpful in learning, as the learner must reconstruct prior learning based on the current context and available retrieval cues; the act of retrieval means it is easier to regain in the future since learning is reshaped – the retrieval context is never identical – and it therefore becomes more meaningful than learning by rote (Karpicke, 2012; Karpicke & Roediger, 2007; Paivio,1986). There is evidence that the benefits of retrieval practice are greater for those with a weaker working memory (Agarwal et al., 2017) and so this strategy may be of particular benefit to pupils with a SLCN who have been said to have difficulties with working memory (Archibald, 2017), since they help to commit concepts to long term memory, hence reducing the demand on working memory (Agarwal et al., 2017).

Explicit (or direct) instruction is an evidence-based method referring to a “systematic approach that facilitates important instructional interactions between teachers and students” (Doabler & Fien, 2013, p. 277) where pupils have limited choice of activity. Direct instruction might take the form of teacher modelling, guided practice, the teacher checking for understanding, providing positive and timely feedback and students carrying out independent work (Doabler & Fien, 2013; Gersten et al., 2009), and has been found to be of particular use in supporting pupils with mathematical difficulties (Doabler & Fien, 2013) and those from disadvantaged backgrounds (Muijs et al., 2014), possibly, they suggest, because of its simple structure and use of routines which may benefit such pupils. However, direct instruction may be detrimental as an approach for pupils from a more affluent background, particularly when the goal of the lesson is more open-ended or complex (Muijs et al., 2014). There is also evidence to suggest, that for young children, in other words, those aged 3-8, direct instruction may be less effective than 'guided play', particularly on numeracy outcomes (Skene et al., 2022). Guided play is that where the child is an autonomous learner, where the adult guides the child's learning through modelling and use of open questions towards a specified learning goal (Skene et al., 2022). There may also be other potential difficulties in using direct instruction, as pupils may not have sufficient time to talk, listen to others and explore mathematical ideas. Instead, sociocultural strategies of learning mathematics through talk and communication have been said to strengthen connections between different areas of mathematics and lead to deeper mathematical understanding (Sfard, 2001; Bell & Pape, 2012; Webb et al., 2019). It could be argued that both direct instruction and more dialogic approaches are important as pedagogical drivers, although these should not be presented as an either/or dichotomy; instead, they should be seen as complementary, with elements of both dialogic approaches and direct instruction having their place in mathematics instruction (Munter et al., 2015).

Metacognition and self-regulated learning are the final terms commonly used and referred to in recent literature as cognitive science. These have arisen in part from the renewed focus on thinking skills, with evidence that their development can impact on attainment (Prins et al., 2006), but also because of the increased demand for thinking skills, rather than a reliance on knowledge per se (Muijs & Reynolds, 2018). Self-regulation, or self-regulated learning, relates to the ability to transform our mental abilities into academic skills, of which metacognition is the most important aspect, along with cognition and motivation (Muijs & Reynolds, 2018). Metacognition is attributed to developmental psychologist John Flavell who first defined it (Flavell, 1979). He suggested it could be broken into two aspects, metacognitive knowledge and metacognitive experiences. Metacognitive knowledge is defined as an understanding of humans as cognitive beings who have diverse cognitive actions and experiences, for example a child who comes to realise that they are better at spelling than their friends, or who recognises their own weaknesses in one area of mathematics compared to another. Metacognitive experiences are cognitive or affective experiences pertaining to academic enterprise. These might include, for example, a sudden realisation that one has not fully understood what another is saying in a social context. In a learning context, metacognitive experiences include developing an understanding one's own thought processes (Flavell, 1979). Metacognition therefore has a significant role to play in education, since learners can thus actively control their own learning (Muijs & Reynolds, 2018). Oudman et al. (2022) suggest, however, that children are often inaccurate in their own judgment of their own learning, particularly lower-performing pupils who may be overoptimistic in their judgement of success. They suggest that this might lead to pupils not seeking additional help when needed or to "stop practising too early" (Oudman et al, 2022, p.215). This has implications for pupils attaining mastery in mathematics, since this relies on a level of practice until no further errors are made (Drury, 2014) and in being able to apply their understanding to different mathematical situations (Drury, 2018).

Spacing and retrieval practices, explicit instruction and metacognition can be seen to have some credibility from the literature and hence have their place as drivers of pedagogy, alongside sociocultural strategies and guided play for younger children. There may be particular indications for the use of spacing and retrieval practices, explicit instruction and metacognition in teaching pupils with SLCN, which will be explored further later in this chapter.

This review has so far examined a wider view of pedagogy involving complexities of teacher instruction, influenced by broader societal pressures and science of learning theories. It will now examine what effective teaching might look like in primary classrooms, and how this differs from pedagogy at a macro level.

2.1.2 Effective teaching

‘Effective teaching’ as a term can be controversial, due to its association with professional competency and accountability. It can also vary depending on the age group taught, and in differing situations and contexts (Ko & Sammons, 2013). A narrow definition, including that frequently used in government publications such as White Papers, might be a teacher’s direct influence on pupil outcomes and standards achieved (Campbell et al., 2004), whereas a broader definition might include a range of other factors such as teacher behaviours and characteristics (Ko & Sammons, 2013). ‘Effective teaching strategies’ in this research draws on the more holistic definition: teacher behaviour and characteristics in the classroom and their impact on pupil learning. It is also important to note that the scope of this research is based around teacher effectiveness, rather than on school effectiveness. An effective school might be defined by an Ofsted grading of ‘good’ or ‘outstanding’, measured on a 4-point scale ranging from outstanding to inadequate (Ofsted, 2022). The effectiveness of the school is linked to characteristics of effective teaching, as Ofsted make a “rounded view on the quality of education that a school provides to all its pupils, including the most disadvantaged and those with SEN” (Ofsted, 2022, p.33), although the relationship between effective schools and effective teachers is known to be complex (Teddlie & Reynolds, 2000) and is not easily disaggregated.

In 2012, the National College for Teaching and Leadership (Husbands & Pearce, 2012, p.3) proposed nine themes to describe effective teaching ‘pedagogies’, based on what it called ‘robust evidence’. It suggested effective teaching strategies should:

- give serious consideration to pupil voice
- involve behaviour (what teachers do), knowledge and understanding (what teachers know) and beliefs (why teachers act as they do)
- involve clear thinking about longer term learning outcomes as well as short-term goals
- build on pupils’ prior learning and experience
- involve scaffolding pupil learning
- involve a range of techniques, including whole-class and structured group work, guided learning and individual activity

- focus on developing higher order thinking and metacognition, and make good use of dialogue and questioning in order to do so
- embed assessment for learning
- be inclusive and take the diverse needs of a range of learners, as well as matters of student equity, into account.

There would be little dissent from these themes by the majority of teachers, but what is perhaps striking is that many of these are quite generalised and non-specific. What, after all, does ‘good’ use of dialogue mean; ‘serious consideration’ to pupil voice;’ ‘a range of techniques?’ These would seem to be subjective rather than objective, as well as open to interpretation.

Coe et al.’s review of the research into “great teaching” strategies distilled effective teaching into six components:

- (Pedagogical) content knowledge
- Quality of instruction
- Classroom climate
- Classroom management
- Teacher beliefs
- Professional behaviours

(Coe et al., 2014, pp. 1-2).

Of these, pedagogical content knowledge and quality of instruction were found to have the strongest impact on teaching. Pedagogical content knowledge (PCK) is the knowledge that teachers have of the subjects they teach and of pupil misconceptions; quality of instruction includes questioning, use of assessment, and progressively introducing new learning through scaffolding. PCK will be explored in greater depth later in this chapter.

Coe et al.'s conclusions concur with those from a longitudinal project, the Effective Pre-School, Primary and Secondary Education (EPPSE) study (1997-2014), which followed 3000 year 5 pupils in their English and maths sessions (Siraj & Taggart, 2014). Researchers used value-added measures to categorise schools into those who showed high, medium and low effectiveness. They carried out classroom observations using standardised instruments and pupils were assessed using a standardised test. From this dataset, researchers identified eleven 'essential pedagogic strategies' and further classified these into five key ones that were consistently carried out by what they termed as 'excellent teachers.' These included:

- classroom organisation and good use of lesson time;
- classroom climate (through excellent teacher pupil relationships);
- personalised learning (rich and varied learning, high expectations, challenging and differentiated tasks);
- dialogic teaching and learning, particularly in mathematics where pupils were encouraged to discuss mathematics in depth thus demonstrating their knowledge and understanding;
- the use of a plenary, where ideas were extended and explored in depth (Siraj & Taggart, 2014, p. 17).

Dialogic teaching will be discussed in more detail later in the chapter, with links to the teaching of pupils with SLCN.

There is clearly some overlap between these different interpretations of effective teaching, especially teacher subject knowledge, questioning and assessment for learning, scaffolding new knowledge, and building a positive climate for learning. These definitions are also reflected in the Teachers' Standards, the standards by which teachers are required to practise their profession. For example, Teaching Standard 6 states: "Make accurate and productive use of assessment" (DfE, 2011a, p.12) and Teaching Standard 3 declares: "Demonstrate good subject and curriculum knowledge". The latter requires that teachers "have a secure knowledge of the relevant subject(s) and curriculum areas, foster and maintain pupils' interest in the subject, and address misunderstandings." (DfE, 2011a, p.11). However, what has been absent, until recently, is a lack of continuing professional development for teachers once qualified, including engagement with educational research. This means that many teachers may not be up to date with recent changes in pedagogy, such as adaptations for teaching for children with SEN, including those with SLCN. Recent moves to include more training for recently qualified teachers have been put in place with the move to the Early Career Teacher Framework, which: "builds on Initial Teacher Training and provides a platform for future development" (DfE, 2019c, p.5). Teachers are now offered a two-year programme after initial qualification in which they continue to build on and develop their practice, based on the "best available evidence" (DfE, 2019c, p.4). Evidence-based practice is also being developed more explicitly through establishments such as the Chartered College of Teaching. Originally established over 170 years ago, it now has a remit to rectify this lack of implementation of research into current practice. Its aim is stated as:

> We are dedicated to bridging the gap between practice and research and equipping teachers from the second they enter the classroom with the knowledge and confidence to make the best decisions for their pupils. (Chartered College of Teaching, 2022).

The current Ofsted inspection handbook details what inspectors are expecting to see as they review the quality of teaching in schools, suggesting that this is based on “research and inspection evidence” (Ofsted, 2022, p.35). Guidance includes specific reference to elements of effective teaching, including teachers having “expert knowledge”; pupils “embedding key concepts into their long-term memory’; and that teachers’ approach to teaching remains “rooted in evidence and key elements of effective teaching” (Ofsted, 2022, pp.35-36). This suggests that many of the evidence-based cognitive approaches discussed earlier such as spacing and retrieval, explicit instruction and metacognition are increasingly gaining currency and are being seen as part of the repertoire of effective teaching approaches to be used by teachers.

This section has discussed effective pedagogy as it relates to overall teaching without detailed reference to mathematics, which will be discussed further in the next section.

2.2 Effective mathematics teaching- Pedagogical Content Knowledge

Turning now to effective mathematics teaching, it is important to consider how this draws on more general pedagogical features and in what ways it differs. Early work to define features of effective mathematics teaching in England began with Askew et al.’s comprehensive study into effective teachers of numeracy that focused on 90 teachers and 2000 children (Askew et al.,1997). This study was designed on behalf of the then Teacher Training Agency which had been tasked with identifying key features used by effective teachers that could be applied more widely. The study used a range of primary schools in urban, suburban and rural environments, selected for good (although not outstanding) results. Using standardised tests, pupils in Years 2-6 were tested twice, in October and April, and teachers were grouped into those considered highly effective, effective and moderately effective, depending on the gains made by their pupils during that period. Teachers and headteachers were then interviewed and features of effective teaching were identified. Although the study focused on numeracy, defined as "...the ability to process, communicate and interpret numerical information in a variety of contexts" (Askew et al.,1997, p.10), the features of effective teaching identified from the study could also be applied to the wider field of mathematics including geometry and data. Effective classroom practice in this study was found to be based around a set of beliefs and a collection of knowledge about mathematics teaching (pedagogical content knowledge), based around Shulman's earlier work. Shulman (1987, p.8) first postulated that Pedagogical Content Knowledge (PCK) might be:

> that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding.

In other words, the 'what' of the curriculum and the 'how' of teaching combined. Askew et al. (1997) developed this further, suggesting that there was considerable interplay between teacher beliefs, practices, PCK and pupil outcomes. These features, they argued, should not be seen as a linear one-way process leading to pupil outcomes, but instead are interconnected so that changes in practice, for example, could also be seen to impact upon teacher beliefs, where teachers can see for themselves the impact that a certain teaching technique has and alter their teaching strategies accordingly. PCK in the mathematics classroom can specifically be seen as mathematics subject knowledge, knowledge of how pupils learn mathematics, and knowledge of mathematics teaching approaches (Askew et al., 1997). D.L. Ball et al. (2008) took Shulman's original definition of PCK one stage further and related this to mathematics. They described the subject content knowledge needed to be effective mathematics teachers, which they defined as 'Mathematical Knowledge for Teaching' (D.L. Ball et al., 2008, p.401). This, they suggested, goes beyond an understanding of teaching pedagogy, to the understanding that lies behind the mathematics. Teachers must be able to work out the solution to a problem themselves, but more importantly, if a student gives the wrong answer, they must know how to help the student, to unpick the errors being made and to be able to answer accurately the 'why' questions, to "think pedagogically" (D.L. Ball, 1998, p.43).

PCK is a key component of primary teacher education in England. The Initial Teacher Training Core Content Framework (ITT CCF), (DfE, 2019b) exemplifies the relevant Teachers' Standards (DfE, 2011a) and what must be covered in initial teacher education. Both the Teachers' Standards and the CCF suggest that pedagogical content knowledge is a core aspect in the process of becoming a teacher with the CCF objectives being separated into "learn that" and "learn how to" sections (DfE, 2019b, p.5). The "learn how to" element equates to pedagogy, as described above, through observing what are defined as "expert colleagues" in the classroom (DfE, 2019b, p.5.), whereas the "learn that" element equates to the knowledge that is required to teach each subject. For Teaching Standard 3 – 'Demonstrate good subject and curriculum knowledge' (DfE, 2011a), the CCF specifies some general principles, without breaking these down into subject specific areas. For example (DfE, 2019b, p. 15), trainee teachers should learn that "Secure subject knowledge helps teachers to motivate pupils and teach effectively". However, the CCF is a framework, not a curriculum, and it is down to individual university departments to determine the exact content of their mathematics curricula drawing on research and best practice. In terms of PCK, for example, this might include understanding the content of the primary national curriculum for mathematics, as well as the specific pedagogical approaches outlined here. It should be noted that university PGCE courses are constrained by time, since they are one year in duration, and therefore the subject and pedagogical knowledge that can be covered in that timescale is limited, particularly when combined with the 120 days minimum practical classroom experience that trainees must undertake (DfE, 2022b).

2.2.1 Effective mathematics teaching –mastery approaches

Oates et al. (DfE, 2011b) were charged with compiling a report on effective education practices around the globe in developing the new national curriculum, to address both complaints of curriculum crowding and the lag in educational standards compared to other economically developed countries. They stated that:

> The content of our National Curriculum should compare favourably with curricula in the highest performing jurisdictions, reflecting the best collective wisdom we have about how children learn and what they should know (DfE, 2011b, p.6).

Consequently, evidence from high performing jurisdictions was gathered, eventually leading to the introduction of a new national curriculum (DfE, 2013) for all subjects. Criticism of this approach suggested that cultural differences in Pacific Rim countries which had very different attitudes to schooling and high parental aspirations (Askew et al., 2010) might not necessarily be replicable or appropriate in England. Nevertheless, the new curriculum was introduced, despite negative feedback from some educationalists (Wrigley, 2014; Bassey et al., 2013), concerned that the curriculum was narrow, too prescriptive and relied too heavily on rote learning. Despite the dissent, schools largely embraced the new curriculum, notwithstanding its limitations.

The national curriculum framework for teaching mathematics drew on many of the effective teaching practices discussed earlier and included a detailed programme of study for each year group. To address the wide range of standards achieved in mathematics in English schools, its overarching aims were for pupils to "become fluent in the fundamentals of mathematics; reason mathematically; and to solve problems" (DfE, 2013, p.3). It suggested that "pupils should move through the programmes of study at broadly the same pace" and that:

> pupils who grasp concepts rapidly should be challenged through being offered rich and sophisticated problems before any acceleration through new content. Those who are not sufficiently fluent with earlier material should consolidate their understanding, including through additional practice, before moving on. (DfE, 2013, p.3).

Since the inception of the national curriculum, it could be argued that there has been a growing consensus in primary schools around what constitutes effective mathematics pedagogy. This has largely been driven by the NCTEM (National Centre for the Excellence in Teaching Mathematics), a government-funded organisation. Support for teachers to develop their teaching of mathematics in the new curriculum was promoted through the NCTEM via a series of ‘Maths Hubs,’ a collaborative network of schools. These led the way in the development of a series of professional development materials for teachers and curriculum resources for schools. NCETM was also responsible for introducing ‘mastery’ pedagogy, to support the national curriculum’s aims and designed to be used from the start of the national curriculum in year one, through its ‘Teaching for Mastery’ programme. Although mastery pedagogy is not explicitly referred to in the national curriculum, the aims of the curriculum given above suggest that this approach is preferred. Mastery teaching in England grew from the practice observed in high performing jurisdictions such as Shanghai and Singapore, selected due to their consistently high scores on international tests and apparently more challenging curricula (DfE, 2012). Although there were clear limitations to this research - societal factors and educational systems in the comparator countries being two such limitations - this report was nevertheless influential in shaping the direction of the new curriculum. This new pedagogy rejected much of the small group and child-centred philosophy of earlier eras, instead using whole-class and purposeful structured group work.

The definition of mastery in mathematics used by the NCETM, although differing slightly from those used in Shanghai and Singapore, is one commonly accepted and used in England. The NCETM’s definition of mastery is given as:

- pupils’ own belief in their success and in achieving their full potential in mathematics
- pupils having procedural fluency (being able to draw upon and use mathematical procedures accurately in differing contexts)

- developing conceptual understanding (having a deeper understanding of mathematics and how procedures link to one another).

  (The essence of maths teaching for mastery, 2016).

This definition of mastery does not explicitly discuss the notion of ‘variation’, however, the practice of designing small incremental changes into mathematical problems so that pupils can both practise and apply concepts and procedures and notice the underlying mathematics behind them. This teaching theory, widely practised in high-performing East Asian countries, first came to prominence in the 1980s, originating from Shanghai, China, based on earlier traditions of teaching (Gu et al., 2004). Variation takes two forms: procedural variation and conceptual variation. Conceptual variation may be defined as giving pupils multiple perspectives of mathematical concepts, combining the abstract with the concrete, allowing pupils to generalise the underlying concept. Standard figures are varied with counter-examples (Gu et al., 2004). Procedural variation, on the other hand, has small incremental changes in mathematical problems so that pupils can practise and apply knowledge, noting the subtle differences between problems. Marton (2015) claimed that variation theory is a necessary component of mathematics teaching so that pupils can notice what is being learned, drawing attention to what is the same and what is different, so helping them to fully understand and apply a new concept. Teachers, he suggested, should highlight the essential features of a concept by varying the non-essential features. Thus, using conceptual variation in teaching about a triangle, examples of different shaped triangles may be shown, along with ones that are almost but not quite triangles (perhaps vertices not joining or sides not being straight). In procedural variation, answers to a set of equations may increase by 10, for example, getting pupils to focus on the nature of the relationships between answers. The nature of procedural and conceptual variation being interrelated is fundamental to Chinese mathematics teachers' styles of teaching, being built into each lesson (Rittle-Johnson & Star, 2009; Huang et al., 2014).

Variation teaching practices contrasts with unplanned practice: sets of exercises that are arbitrarily chosen by teachers for pupils to practise a concept. Unless examples are well-chosen, pupils' learning will not proceed in a linear manner but in a 'stop-start' fashion, without engaging in the concept or making connections with prior learning or increase in fluency. Watson and Mason (2006, p.105) stated that from using methods such as this, "little can be achieved except for counting the right answers and the analysis of right answers to inform future teaching". Instead of this approach, they suggested that teachers practise 'controlled variation', in other words constructing exercises so that pupils can focus on similarities and differences through micro-modelling of examples. Variation can therefore be seen to be a carefully controlled method of practice, with small incremental steps, leading to deeper learning, a true mastery of mathematics.

In mastery teaching, procedural fluency and conceptual understanding are taught alongside one another with conceptual understanding being deepened using pictorial and concrete representations. This supports the Singaporean Concrete-Pictorial-Abstract (CPA) heuristic (Yew Hoong et al., 2015) which was developed from Bruner's (1966) work, suggesting knowledge was comprised of three stages, "enactive", "iconic" and "symbolic" (Bruner,1966, p.11), although these are not to be seen as a linear progression; first objects, then pictures, then symbols. Indeed Merttens (2012) questioned their usefulness in a British context, pointing out that concrete objects are those designed to be physically manipulated rather than pictures of objects as used in Singapore textbooks. In England, the use of concrete resources and pictorial images alongside numbers in a mastery teaching approach is designed to emphasise to pupils the structure and the connections within mathematics.

In schools that have embraced this pedagogy in England, mastery teaching is argued to have been successful (NCETM, 2016). However, its own evaluation shows that nationwide reach is still comparatively narrow. Surprisingly, considering the amounts spent on developing mastery approaches, £41 million between 2016-2020, (DfE, 2016b), there is little robust literature to support the effectiveness of mastery teaching in England. The research that does exist has evaluated the effectiveness of specific mathematics mastery programmes. Jerrim and Vignoles (2016) carried out one such study, evaluating the effectiveness of the Mathematics Mastery approach. Mathematics Mastery is a mathematics curriculum delivery framework used in primary and secondary schools developed by the Ark education chain (Ark Curriculum Plus, n.d.), which follows the principles of mastery teaching. The researchers carried out two clustered, randomised controlled trials (RCT) on approximately ten thousand pupils in total, comparing pupils in year 1 and year 7 (the first year of secondary school in England) in 90 primary and 60 secondary schools. To evaluate the effectiveness of the programme at primary level, a treatment group of 45 randomly selected schools that used the ‘Mathematics Mastery’ programme was set up and 45 schools which carried on teaching mathematics as usual were designated the control group. Schools were recruited from areas of educational disadvantage and pupils were tested at the start and end of the school year using a standardised test with high reliability (Jerrim & Vignoles, 2016). Findings showed a small positive effect at the end of the academic year in year 1 pupils who had used the mastery approach, although the results were less marked in year 7. The approach was found to be more effective in schools with higher Ofsted ratings, confirming Teddlie and Reynolds's (2000) findings that the relationship between effective schools and effective teaching is complex. Crucially, Jerrim and Vignoles found there was little difference found between the performance of higher and lower attaining pupils (Jerrim & Vignoles, 2016). A considerably smaller mixed methods RCT with year 1 pupils, using 6 control schools and 6 treatment schools was set up to evaluate the effectiveness of another mastery programme, 'Inspire Maths' (Hall et al., 2016). This found a small positive effect on pupil attainment, using standardised tests, but no difference in pupil attitudes. The researchers also found a positive effect on teachers' subject knowledge, including clearer instructions and a more effective classroom climate. Both studies indicate that mastery programmes are likely to have a small positive effect over a one-year period for pupils in year 1, particularly in more effective schools as judged by Ofsted gradings. More longitudinal research would be needed to show both whether these effects were maintained as well as the long-term effectiveness of a mastery style of teaching on pupils with SEN.

Despite the lack of robust evaluation, there is some evidence that improvements to the teaching of mathematics since the introduction of the national curriculum may have improved pupil outcomes. Findings from the most recent (2019) TIMSS (Trends in International Mathematics and Science Study), for example, report a rise in scores in mathematics for pupils tested in national curriculum year five (9–10-year-olds) (Mullis et al., 2020). The online mathematics test consisted of content domain questions with pupils being assessed on number, measures and data, and cognitive domain questions testing knowledge, application and reasoning. The TIMSS study, which has been carried out every four years since 1995, with 64 countries worldwide currently participating, is used by governments and researchers at a macro level to benchmark policy and performance (Richardson et al., 2020) as well as informing schools and classrooms at the micro level. Results in England over this period have shown a consistently upward trend in mathematics, with scores now at their highest point since the study's inception. England currently lies eighth internationally, significantly above the TIMSS centre point (Richardson et al., 2020). The relatively high performance of pupils in England on the mathematics test suggests an improvement in mathematics teaching and learning over time; the cohort assessed in 2019 in year 5 were the first cohort of pupils to have been taught from the revised national curriculum, since it came into practice when they were in year 1. However, the range of scores in this test is still greater in England than any other country in the top eight, except for Northern Ireland, and fewer pupils achieved the advanced benchmark compared to any other country in the top eight, other than Russia. This indicates that although standards are rising compared to international competitors, there is still a greater range of scores than seen in other top nations. Despite this overall increase in TIMMS scores, it is not yet clear how mastery styles of teaching may have affected pupils with SLCN, since no evaluation has yet examined the impact on this group. The national curriculum aim of keeping the whole class together also needs further examination, with a focus on lower attaining pupils: it is not clear how this principle might have affected pupils with SEN. The disparity in the TIMMS test scores between the highest and lowest performing pupils suggests that lower attaining pupil groups are worthy of further study to examine why they do not achieve more highly.

2.2.2 Effective mathematics teaching- language and mathematics

This section highlights the interlinked nature of language and mathematics and how this contributes to learning for both TD pupils and those with SLCN. The mathematics national curriculum acknowledges that pupils' use of language is of prime importance, with pupils making their "thinking clear to themselves and to others" (DfE, 2013, p.4). This is based on the premise that educational and cognitive processes are enacted through interactions with others (Hennessey et al., 2016). In order that they can articulate their thinking and have success in solving problems, children will need to draw on explicit mathematical language as well as their overall language and communication abilities. Mathematical language has been described as a language in its own right, comprising a particular mathematics 'register' with its own special meaning and style of communication (Landsdell,1999; Pimm,1987; Riccomini et al., 2015; Schleppegrell, 2007). Mathematical language may be formal, with vocabulary that may have different meanings to those used in everyday life, having what Leung terms "core and non-core meanings" (C. Leung, 2005, p.5). Thus, there is a difference between the everyday usage and the technical usage of the words. Children may be familiar with the everyday usage of 'table' as a piece of furniture you sit at to eat, for example, whereas the context for the use of a 'table' in mathematics has to be specifically taught. It has been suggested that effective teaching strategies focusing on the specific language used in mathematics lessons, careful practice and repetition in context and teacher observation on how pupils with SLCN use the language of mathematics may support these children to achieve in line with their TD peers (Toll & Van Luit, 2014).

Early sociocultural theories highlighting the social and communicative nature of learning were used to explain how children developed their understanding in maths. These drew on the work from theorists such as Vygotsky (1978), who observed that young children often verbalise their thinking on being given mathematical problems. Over time, this ‘self-talk’ leads to speech becoming internalised. More recently, Sfard (2001, p.26) conceptualised mathematical thinking as a “dialogic endeavour”, in which we argue and ask questions of ourselves as we attempt to work through a problem. She later developed this into what was termed “commognition” (Sfard, 2008, p.296), where thinking and communication are seen as interlinked, each contributing to mathematical understanding. Other work has further developed the notion of pupil talk in classrooms (Dawes et al, 2000; Mercer, 2000) and teacher talk (Wragg & Brown, 2001).

More recent research has focused on ‘dialogic teaching’ (Alexander, 2017; Mercer & Sams, 2008). This is worthy of further exploration, since this is one of the features of effective teaching noted earlier in this discussion by Siraj and Taggart (2014). Mercer and Sams’s study explored a socio-cultural strategy for talk, the ‘Thinking Together’ programme, which was designed to develop pupil talk as a tool for mathematical reasoning. 14 teachers and matched control groups of 109 year 5 children in the target group and 121 year 5 children in the control group took part in this mixed methods study. The study took place over a 23-week period, the target group beginning with teacher instruction in strategies for explaining, guiding and modelling talk as well as being given 12 weeks of lesson plans to promote talk. Pupils in both groups were tested at the outset using the (then available) optional year 5 maths Standard Assessment Test (SAT) provided by the DfE. Pupils and teachers were video-recorded and their talk analysed. At the end of the project, pupils sat the same mathematics test. Although researchers studied a comparatively small sample, the target group of pupils were found to have made significantly more progress than the control group, suggesting that dialogic teaching, strategies for developing exploratory talk and encouraging mathematical reasoning could lead to greater gains in mathematics than when more traditional curricular approaches are used.

Dialogic teaching is a socio-constructivist approach, developed from a range of talk-based pedagogical skills and strategies with an emphasis on whole class discussion and extended talk time to draw out pupils' thinking. It is based on earlier traditions of research and thinking, leading to talk for learning strategies drawn from cognitive and cultural psychology (Vygotsky,1978; Bruner,1996), philosophy (Bakhtin,1984) and psycholinguistics (Halliday,1993). Dialogic teaching focuses on two aspects: one is the emphasis on who does the talking, with pupils sharing ideas and reasoning; the other is on ideas, with pupils valuing others' contributions and accepting diverse viewpoints (Hofmann & Ruthven, 2018). Alexander (2017) argued that pupils learn best by engaging in dialogue with each other and with the teacher, through teaching styles described as being "collective, reciprocal, supportive, cumulative and thoughtful" (Alexander 2017, p.28). Through these teaching styles, pupils are led to the "guided construction of knowledge" (Mercer & Sams, 2008, p.507). Dialogic talk has a cumulative quality, aiding the progressive development of pupil understanding (Mercer et al., 2009). It is important to note that dialogue is not the same as discussion. Askew (2012) suggested discussion is often about 'point-scoring', with one trying to convince the other of one's position. Dialogue, on the other hand, is created through meaning, an "exchange of views" attempting to "understand the other better" (Askew, 2012, p.149). Lefstein and Snell (2014, p.14) suggested that dialogue is an equal practice:

> Dialogue is a form of interaction which involves two or more interlocutors freely exchanging ideas, listening to one another, affording one another equal opportunities to participate, addressing one another's concerns and building upon one another's contributions.

Although there is much research suggesting dialogic approaches may be advantageous across the curriculum (Alexander, 2017*;* Mercer et al., 2009; Mercer & Sams, 2008), there is limited evidence of the benefits of this approach in mathematics, despite being cited by Siraj and Taggart (2014) as one of the approaches used by 'excellent teachers' in mathematics. It has been suggested (D.L. Ball, 2001; Stein et al., 2008) that this may be because many teachers struggle in mathematics to deal adequately with pupil responses to more cognitively challenging tasks in whole-class discussion and thus may revert to what D.L. Ball (2001, p.20) termed "show and tell" strategies. She suggested that teachers' lack of planning as to the types of answers expected led to teachers accepting pupils' explanations without real development. Instead, pupils merely show their methodology rather than explaining their mathematical reasoning. This might explain why the strategy was used effectively by the excellent teachers identified in Siraj & Taggart's study (2014), since they were found to have been more skilful at using dialogue as a teaching tool than the less effective teachers, as well as using probing questions to challenge pupils. However, dialogic teaching may not be a panacea for all pupils. Lefstein and Snell (2014) viewed dialogue as being more of a problem than a universal solution to best practice. Their research on pupils in upper key stage two, who were observed in literacy lessons three times a week for one year, suggested that dialogic teaching methods do not help pupils who find it difficult to vocalise or who are less confident. They suggested this might have been because the full participation and the level of cognitive challenge given might have been perceived as threatening by these children. Their interviews with teachers in the same study also suggested lower expectations of these children, with more cognitively demanding questions posed to children perceived as being higher achievers (Lefstein & Snell, 2014, p.147). Earlier work by Black (2004) and Myhill (2002) had also suggested that teachers' views of a child's 'ability' had an impact on the number and types of questions pupils were asked, with teachers tending to address more cognitively challenging questions to the higher attaining pupils and fewer to those seen as being academically weaker. There are implications for effective pedagogy arising from this discussion, with teachers needing to carefully plan the types of questions posed, ensuring these are targeted at all pupil groups and in setting up meaningful and purposeful classroom dialogue, rather than mere discussion.

This section has outlined strategies for effective mathematics teaching, including the importance of teaching mathematical language, and showed how these are drawn from features of effective classroom teaching in general. It has suggested that effective mathematics teachers should deploy a repertoire of approaches including whole class mastery teaching techniques, with their emphasis on teacher questioning and pupil dialogue, to achieve the aims of the mathematics national curriculum. The next section will consider the nature of mathematical learning, exploring the link between effective teaching and pupil learning in mathematics. It will focus on children aged 3-8, since this is where the foundations for learning mathematics are made and when the association between language and mathematics is the strongest (Peng et al., 2020).

2.2.3 Mathematical learning

Before considering aspects of mathematical learning, it is important to reflect on the nature of mathematics education. The English national curriculum for mathematics defined it as:

> "A high-quality mathematics education [therefore] provides a foundation for understanding the world, the ability to reason mathematically, an appreciation of the beauty and power of mathematics, and a sense of enjoyment and curiosity about the subject." (DfE, 2013, p.99).

The Organisation for Economic Co-operation and Development [OECD] used the term "mathematical literacy" (OECD, 2021, p.8) as a broad term to include the use of mathematics to solve real-world problems as well as critical thinking and reasoning, which they saw as central for young people in the 21st century. Turning to how this translates for young children, Clements and Sarama (2021, p.23) suggested that mathematics "provides a new way to see the world, the beauty of it and the way you can solve problems that arise within it." Drawing on Schoenfeld's (1992) work, they proposed that young children in particular see mathematics as a "search for patterns, structure and relationships, as a process of making and testing ideas, and, in general, making sense of quantitative and spatial solutions" (Clements & Sarama, 2021, p.278). The development of spatial skills is seen to be of prime importance to mathematics learning, particularly in supporting those early mathematical skills relating to later mathematical achievement (Young, Levine & Mix, 2018). Spatial skills are more than ‘shape and space’ activities but also include the use of representations such as number lines, which test children’s understanding of the number system and uses skills of proportional reasoning to connect numbers to their position on the number line (LeFevre et al., 2013). Connections between spatial skills and mathematical skills has been noted, such as that between visuospatial working memory and computation (Raghubar, Barnes & Hecht, 2010), especially in children younger than 8 years of age, when there is less separation of verbal and visuospatial working memory systems. Turan and De Smedt (2022), in a systematic review of the literature, discussed the importance of acquiring spatial language in the early years; words such as ‘after’, ‘above’ and ‘before’ (Turan & De Smedt, 2022, p.11). This, they suggested, may support children’s later mathematical development as quantitative and spatial terms are likely to develop earlier. Children who acquire these in early childhood may be able to use these to underpin their understanding of more complex mathematical concepts, such as in numerical understanding. Young, Levine and Mix (2018) suggested ‘spatial scaffolding’ should be provided by teachers in the form of spatial tools including gesture, spatial language and diagrams in order to develop what they termed ‘spatial memory’ and to help children learn related mathematical content.

Reasoning has been said to be the foundation of mathematics (Steen,1999) and is said to underpin mathematical cognition (Morsanyi et al., 2018). It will be discussed briefly here, including a discussion of the difference between reasoning and mathematical thinking. Reasoning is one of the stated aims of the national curriculum for mathematics. This suggests that pupils should:

> "…reason mathematically by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language" (DfE, 2013, p.3).

Mathematical reasoning in primary-aged pupils has been said to be a greater predictor of later success in mathematics than arithmetic skills (Nunes et al., 2012). It has a central role to play in the development of mathematical understanding and using mathematical ideas (Brodie, 2010). Reasoning is a broad term, covering the ability to generate an explanation from a statement or hypothesis, drawing on known facts and linking them together. An individual develops their line of thinking or argument, allowing that certain facts must be known before others can be deduced; the product of this can be spoken or written (Brodie, 2010, Steen, 1999). Mathematical reasoning can be seen as a process that assumes the linking of mathematical ideas and concepts (Watson et al., 2013). The authors suggest that although reasoning in all its many forms is crucial, teachers often leave its development to chance, without explicit teaching. However, mathematical reasoning is essential if children are to develop a deep understanding of all areas of the mathematics curriculum and if they are to begin to explain, justify and describe their results (Steen,1999) and if they are to develop crucial computational thinking skills for the 21st century (OECD, 2021). Nrich (2021) suggested that reasoning follows a five-step process: describing; explaining (the beginning of inductive reasoning); convincing; justifying; proving (deductive reasoning). They suggested that children do not move neatly from one step to another but are likely to move up and down the spectrum of reasoning fluidly, using whatever step is most appropriate at the time (Reasoning: the Journey from Novice to Expert, 2021). Inductive reasoning has been defined as

> "…the kind of thinking involved in recognizing, patterns, similarities and equivalences, and using these to predict further results and to formulate generalizations."

Deductive reasoning, however, has been described as

> "…the formulation of a valid, logical argument to explain, demonstrate or convince others that a solution to a problem must be correct…or that a particular conjecture is true or false." (Haylock, 2007, p. 42).

Mathematical thinking is involved in reasoning, but has been defined as thinking about mathematics, its patterns and relationships (Burton, 1992). The author suggested that young children were best able to think mathematically and develop their understanding of the structures of mathematics when the learning matched their own interests. Considering how mathematical thinking might be developed in the classroom by effective teachers, Polya (1945) suggested that problem-solving (through which one must reason in order to reach a solution) is no different to the learner's strategies in any other practical activity. He posited that in order to understand, one should observe, imitate and do. Heavily influenced by Polya's work, Mason and Burton (2010, p. xiv), proposed that mathematical thinking is developed through "doing and talking". They suggested that mathematical thinking should be a struggle, pupils should get stuck (and view getting stuck positively) but also possess sufficient strategies to solve problems. Mathematical reasoning can thus be linked with a socio-constructivist theory of learning. Burton (1992, p.59) suggested that "young children are thinking mathematically as a natural part of the way in which they acquire power and control over their environment" and that this is linked to their linguistic development, where speaking mathematically is essential.

It has been suggested that there may be some link between lower verbal and spatial reasoning skills and competency in arithmetic (Dowker, 2005). Early arithmetic competency is essential in the establishment of mathematical concepts, and it too has also been shown to be a predictor of later mathematical ability or difficulty (Gelman & Gallistel, 1978; Clements & Sarama, 2021). There is evidence that many typically developing pre-school children have a good understanding of numerosity, in other words, the size of a set of objects. Infants have been shown to recognise when an object is removed from or added to a set of toys, said to be as a result of an innate quantitative awareness (Butterworth, 2005; Rips et al., 2008, Clements & Sarama, 2021).Three-and-a-half-year-olds can identify a number of items in a set when the set contains between one and five items, particularly when the set consists of homogeneous objects (Gelman & Gallistel, 1978), whether by counting or 'subitising', the ability to recognise small quantities of objects without one-to-one correspondence. This early tendency to spontaneously focus on numerosity (SFON) has importance in the prediction of later number and arithmetic skills (McMullen et al., 2015) as well as being a predictor of better counting skills at age five (Hannula et al., 2007).There is some evidence, however, that children with the developmental disorder developmental dyscalculia (DD), who have problems in basic numerical skills such as counting or subitising, have a reduced SFON tendency compared to typically developing peers (Kucian et al., 2012). Thus, developing numerosity in the early stages of learning mathematics through play, exploration of regular patterns of numbers such as on dice, dominoes, and tens frames, and the use of number names in real-life contexts is crucial in building the foundations for later number work (Clements & Sarama, 2021). This will also develop mathematical thinking, since children will be thinking about and describing number patterns, through good teacher questioning.

This section has attempted to briefly show the nature of mathematics learning for young children, focusing on the importance of reasoning, including spatial reasoning, and the development of arithmetic. Given that pupils with a SLCN are usually diagnosed before the age of seven (Dockrell & Hurry, 2018), the link between early mathematics and later difficulties for pupils with SLCN is crucial for this age group, as mathematical weaknesses may already exist prior to formal schooling, due to poor mathematical language acquisition (Toll & Van Luit, 2014).

The next section discusses the specific difficulties faced by pupils with SLCN and how these might impact on their attainment in mathematics.

2.3 Strengths and difficulties for pupils with SLCN

The group of pupils with SLCN is diverse, with many potential difficulties that may impact on their educational attainment. There may be three causes of SLCN: those whose difficulty may occur in the absence of other neurodevelopmental disorders; those for whom it is secondary to other diagnosed needs and conditions such as autism; and those whose SLCN might be attributed to socio-economic disadvantage (Hart & Risley,1995; Lindsay et al., 2010). However, there is often overlap between these three areas (Lindsay et al., 2010) and therefore the cause is less relevant for schools than the need to address any potential difficulties. Problems experienced by pupils with SLCN include receptive difficulties with a comprehension deficit; pupils lack understanding of what is said or written. Secondly, pupils with SLCN may experience expressive difficulties, when their comprehension is normal but speech or written language production is impaired (Bishop,1979). Donlan (1998) suggested that there are greater numbers of pupils with SLCN with expressive language deficits than receptive deficits, with these pupils most frequently educated in mainstream schools. Expressive language deficits include difficulties with grammatical morphemes, those word endings that carry meaning such as plural ‘s’ or past tense ‘ed’. Pupils may also have problems with morphosyntax, with difficulties expressing the tense and agreement of morphemes, such as “He go to school yesterday” (Smith-Lock et al., 2013). This presents potential trouble for pupils in mathematics since they may struggle to explain their mathematical reasoning verbally or in writing (D.L. Ball,1993).

Lindsay et al., (2010) pointed out that pupils with SLCN may have difficulty with pragmatics, understanding the subtleties of the English language in differing contexts. There might be a greater struggle for these pupils towards understanding less-familiar words, those specifically found in mathematics, for example ‘tetrahedron,’ or those with a different meaning to the commonly used form in daily life. Nouns such as ‘face,’ ‘table,’ ‘degree’ may pose particular difficulty for pupils with SLCN unless used in mathematical contexts that also make their meanings clear. Many mathematical terms are used interchangeably, such as synonyms for addition: ‘plus,’ ‘add,’ and ‘and,’ for example, which may be unclear to children with a SLCN (Purpura et al., 2017). Instructional language, including words such as ‘match,’ may also be misunderstood; pupils with SLCN may be more familiar with their core (everyday) meaning (C. Leung, 2005). There may, therefore, be a need for greater emphasis on explicit teaching of new vocabulary in a mathematical context (Landsdell, 1999). Teaching should ensure, however, that terminology goes beyond superficial usage and focuses on developing deep conceptual understanding (Renne, 2004).

There is a strong correlation between language and numeracy in young children, with language skills strongly linked to numerical development (Donlan, 2007; Hornburg et al., 2018) and with mathematical vocabulary being a stronger predictor of later performance in mathematics than general language abilities (Purpura et al., 2017). Chow and Eckholm's comprehensive study of 256 5–7-year-old children, which included 47 second language learners and 19 pupils with SEN, found a strong positive correlation between pupils' syntactic ability and maths performance (Chow & Eckholm, 2019). They examined the association between receptive language, morphology and syntax with addition calculations using a range of standardised language and mathematics tests. Their findings suggested that while syntactic ability significantly affected ability in mathematics, receptive ability was less strongly linked. They also posited that syntactic ability may also be linked to solving mathematical problems involving numbers and symbols rather than just worded problems. As language and mathematics are so closely linked, pupils with a SLCN may be at a disadvantage compared to their TD peers in learning mathematics. They may be limited by functional language skills, such as those associated with numbers, money and time, and in understanding rules and social conventions. They also struggle with the language skills associated with higher cognitive demands including making connections, analysing information, and drawing conclusions. A study by Erath et al. (2018), analysing 190 lesson sequences of 10–11-year-old children in mathematics, found that more cognitively demanding discussion tended to occur with children who have higher linguistic ability. Children with weaker language skills were still able to contribute to discussion and explanation but had difficulties contextualising academic language. Children with SLCN may therefore struggle with topics with higher cognitive demands such as making connections, analysing information, and drawing conclusions since they may lack expressive language skills. Functional linguistic skills, language that is needed in everyday situations, such as explaining rules, agreeing or disagreeing, which are considered prerequisite in developing mathematical learning (Donlan,1998), may also hinder the progress of pupils with a SLCN. Riccomini et al. noted that “If students’ language development is weak or underdeveloped, their overall mathematics learning will be slowed” (2015*,* p.237).

Since the medium of instruction in mathematics is language, it suggests that pupils with a SLCN may struggle, especially those pupils with poor receptive syntactic ability who may be especially disadvantaged by verbal instruction (Chow & Eckholm, 2019). Difficulties in language and mathematics often co-occur (Purpura & Reid, 2016; Riccomini et al., 2015) as language is strongly associated with mathematics. This may be because number and language processing have been said to share common neural pathways as they activate similar areas of the brain (Purpura & Reid, 2016). Purpura et al. (2011) carried out a study on 91 3-5-year-olds in pre-school and followed up with 69 matched pupils one year later to determine how skills in one domain influenced skills in another. Pupils were assessed on both literacy development (vocabulary, phonological awareness and print knowledge) and numeracy development (numerical relations and arithmetic reasoning). They found that vocabulary and print knowledge were uniquely predictive of later numeracy performance whereas phonological awareness (the ability to detect and manipulate language, blending, matching and deleting word parts) were not. They suggested that this might be because the understanding of specific language terms, such as ‘fewer,’ is necessary for the completion of basic mathematical tasks. This has implications for the mathematics learning of pupils with SLCN.

Rather than their difficulties being limited to language, pupils with SLCN may also have a problem with counting and knowing number names. Alt et al. (2014) suggested that just as children with SLCN struggle to attach linguistic symbols to words, the same difficulty may also apply to their attachment of number names to number symbols. Donlan and Gourlay (1999) reported that this may not only be because of difficulties in attaching spoken numerals to their written form, but also because verbal skills are a precursor to understanding the number system. Young children learn to chant number rhymes without assigning particular numerals to them, which impacts those with SLCN, who may struggle to learn and say any kind of rhyme by rote (Fazio, 1994). Number comparison may also present difficulties for pupils with SLCN, suggesting there may be a mathematical symbolic deficit in pupils with SLCN, crossing both linguistic and numerical domains (Donlan & Gourlay, 1999). The researchers compared 13 clinically diagnosed, speech and language impaired (SLI) 7-8-year-olds with two matched groups; one matched for age and non-verbal ability, and one younger group, matched for language comprehension. Pupils had to match spoken numerals 0-9 to their written form and select which number was greater using a series of double-digit numbers. All were secure in matching single digit numerals to the spoken form. In the place value test, findings showed that there was no difference in the speed at which answers were chosen, but both the younger children and the SLI group were more prone to making errors.

This, the researchers suggested, indicated both limited exposure to the teaching of double-digit numbers and lack of understanding of the place value system. Both children with SLI and the matched control group were able to say more easily which number was larger in what the researchers termed ‘transparent’ cases, where the tens digit was obviously greater than the ones digit (for example 70 versus 50). However, what SLI pupils struggled with the most was both where there was a place value reversal (e.g. 13 versus 31), and where the pairs of numbers were close together (18 versus 21) and the digits of the smaller number summed to more than the larger number’s total. This suggested that the pupils’ responses did not take place at the digit level, but at a holistic level whereby the digits are processed into a magnitude of both digits (Donlan & Gourlay, 1999, p.15). This, they argued, was evidence to explain that non-verbal symbolic processes underlie place value and offered support to a theory of global symbolic deficit in SLI children.

Pupils with SLCN may also have greater difficulty in developing mathematical reasoning than their TD peers. Because children need to be able to use language to justify and explain their reasoning (Riccomini et al., 2015), pupils with SLCN may find it harder to develop an argument or justify knowledge when working on their own and with others (Erath et al., 2018). It may also be that successful mathematical learners are more likely to be reflective and to engage in metacognitive activity during the reasoning process (Steen,1999). Metacognitive practices, as previously discussed, may be more difficult to develop in lower-attaining pupils (Oudman et al., 2022) and therefore this may also hamper pupils with SLCN in their engagement with reasoning tasks.

Pupils with SLCN may struggle to work through mathematical problems, with many arithmetic reasoning tasks presented in language through ‘story problems’

(Purpura et al., 2011). This is not only because an understanding of specific language terms is necessary (‘fewer’, ‘more than’, ‘altogether’), but also because pupils with SLCN have been found to have difficulties with comprehension as well as in understanding instructions (Bishop, 1979*,* Donlan, 1998). Difficulties in mathematical comprehension for pupils with SLCN may be not only because of weak reading ability, but also because of their capacity to draw meaning from verbally presented word problems, due to the language demands these might make. Working memory is implicated in solving word problems too, particularly those that have more than one step (Swanson et al., 2013). Swanson et al. studied 100 7–9-year-old children with mathematical difficulties and 92 without. Children were randomly assigned to one of four treatment conditions, verbal only, verbal and visual, visual only or an untreated control group. Researchers worked with children over 20 sessions, where children were given practice and feedback in the assigned strategy. A battery of tests assessed reading comprehension, word recognition, story problems and arithmetic as well as three tests for working memory. At the end of the research period, researchers found that children with a higher working memory, whether they had mathematical difficulties or not, were more accurate in completion of arithmetic problem-solving tasks. Pupils with limited working memory were less accurate. Pupils who had had visual training made more progress in solving problems than any other group, suggesting that visual-spatial strategies, such as bar modelling, may support problem-solving for pupils with mathematical difficulties. Although this research was carried out on pupils with mathematics difficulties rather than those with SLCN, the findings also have implications for the teaching of pupils with SLCN due to the limitations of working memory for these pupils, which will now be discussed.

One explanation for problems with counting and number names for pupils with SLCN is the link with poor working memory, defined as the ability to hold different items in the short-term memory at a given time, such as random collections of numbers, letters or digits (Baddeley, 2007). Working memory is a domain-general resource which can be influenced by three factors including the novelty of the task, its simplicity and the context in which it is being completed (Archibald, 2017). Working memory facilitates a range of cognitive activities such as reasoning, learning and comprehension. It is commonly held to have three components, the central executive (the control system), and two storage systems, the visuo-spatial sketchpad and the phonological loop (Baddeley & Hitch, 1975). The visuo-spatial sketchpad is argued to be particularly important in mathematics, through holding information mentally when problem-solving; retaining and using number facts; and in accessing the language of story problems and remembering patterns (Alt et al., 2014; Cowan et al., 2005). Pupils with SLCN have been found to have difficulty with visuo-spatial working memory in particular (Alt et al., 2014). Working memory is generally accepted to be around seven items for adults (Anderson & Lyxell, 2007; Baddeley, 2007), with young children having a lower capacity than this, usually around four. This is further diminished when two or three different items are processed together, such as carrying out formal addition or multiplications calculations (Ding et al., 2017). Linked to working memory is what has been termed Cognitive Load Theory (CLT) (Sweller et al., 2011). They proposed that working memory was influenced not by the intrinsic structure of information, but the way in which it is presented, or through activities with which the learner must engage. Hence, learning by rote to attain automaticity has strong negative connotations, whereas learning with understanding has strong positive connotations, as it increases the number of interacting elements in working memory (Sweller at al., 2011) and learners make connections between different areas of mathematics to solve new types of problems (Clements & Sarama, 2021).

Another important issue when considering memory for pupils with SLCN is that of procedural memory, sometimes referred to as unconscious or implicit memory. Procedural memory, knowing how to do something, such as in learning to ride a bicycle or in touch typing, is where the brain controls new learning and draws on well-established learning; skills and concepts are applied automatically, the learner is not able to control them (Ullman & Pierpoint, 2005). The structures of the brain that support procedural memory are linked to grammar, lexical retrieval and working memory and hence this is of importance for children with a SLCN. A procedural deficit hypothesis (Ullman & Pierpoint, 2005, p.405) suggests that there are procedural brain abnormalities for those with SLI resulting in grammatical retrieval deficits. Declarative, or explicit memory, ('knowing that') on the other hand, relies on facts and events that can be consciously recalled and has been found to be unimpaired in youngsters with SLI (Ullman & Pierpoint, 2005; Lum et al., 2012).This memory system has been implicated in the learning of facts such as 'London is the capital of the United Kingdom' and suggests that pupils with SLCN may be able to learn number facts by rote, for example, but do not embed these into their long-term memory. Their potential difficulties in understanding grammar may also impact on their ability to understand the language of mathematical problems.

However, despite their apparent difficulties, pupils with SLCN can also be said to have some relative strengths, where their attainment is little different to their TD peers. Durkin et al. (2014) found from their analysis of 176 pupils' performance on the then end of primary school (KS2) tests (SATs), that pupils with SLCN did less well than their TD peers in English, but that performance in maths was broadly comparable, with science outcomes the least affected. They suggested that children with SLCN were able to draw on “other capacities” (p.237) such as relative strengths in declarative memory to achieve these outcomes, particularly when mathematical tasks involved working with number and abstract symbols. Donlan et al. (2007) in their study of 48 8-year-old speech and language impaired children (SLI), found that despite deficits in the count-word sequence, cumulative calculations and place value, confirming earlier findings by Fazio (1994, 1996 and 1999), children’s performance in arithmetic was nevertheless similar to non-SLI control groups. They suggest that this may be because arithmetic principles may be linked to non-verbal mental models.

There is also some evidence to suggest that some children with a deficit in the verbal domain acquire conceptual understanding at a similar rate to TD children, particularly when the linguistic load or instruction is reduced (Cross et al., 2019; Donlan et al., 2007). Cross et al. carried out a review on 20 articles that discussed pupils with developmental language disorder (DLD) compared to matched peers on numerical cognition tasks in verbal and non-verbal domains. Studies discussed pupils between the ages of 4 and 14. Their findings suggested a relationship between DLD and mathematics; pupils were likely, they suggested, to “struggle in any mathematical tasks that place demands in the verbal domain including number transcoding, counting and arithmetic” (p.162).

2.4 Difficulties in teaching mathematics to pupils with SLCN

There is much literature suggesting that, for many primary teachers, mathematics is a subject in which they lack confidence to teach, not having the prerequisite knowledge to anticipate the mistakes that pupils often make, nor the strategies used to correct these (Ofsted, 2012). Primary teachers are generalists, rather than specialists, since most are required to teach all subjects to their classes and few primary teachers have a mathematical background. The minimum entry requirement for teaching is a grade ‘C’ (or level 4) at GCSE, which is thought to be the modal grade attained by primary teachers (Burghes et al., 2009), although this data has not been made available. An earlier recommendation was for the entry requirement to be raised to a grade ‘B’, although this was never implemented (Williams, 2008), to take account of the need for primary teachers to have a greater security in mathematical understanding in order to successfully teach the subject. Another difficulty may be an unconscious bias towards primary teachers’ lack of mathematical subject knowledge from teacher educators. D.L Ball (1988) argued that trainee teachers already know a great deal about the teaching and learning of mathematics from when they were learners at primary school. Rather than assuming that trainee teachers do not have sufficient subject knowledge, it is necessary instead to undo some of the misconceptions they might have from their own education. There is, therefore, a need to develop in trainees an up-to-date understanding of mathematical content and subject pedagogy, what she called “unlearning to teach mathematics” (D.L. Ball, 1988, p.40). It is also possible that many teachers have negative perceptions of being a maths learner themselves and may convey their own anxieties and predispositions to teaching mathematics to their pupils (Beilock et al., 2010), which in turn can lead to pupil anxiety in learning maths (Beilock et al., 2010; Boaler, 2009; Brown et al., 2012).

In addition to their difficulties of teaching of mathematics in general, the limited research available indicates that teachers may find pupils with SLCN particularly hard to teach, since their needs may be less obvious, and teachers may lack the skills needed to address any difficulties (Dockrell & Lindsay, 2001). Dockrell and Lindsay interviewed 69 teachers of children with specific speech and language difficulties and tested children on their language, educational and behavioural development. They found a lack of confidence in teachers' perceived ability to meet pupils' needs, despite their understanding of pupil needs being accurate. Other research by Marshall et al. (2002) came to similar conclusions. Here, researchers used questionnaires to ascertain the views of 154 trainee teachers enrolled on a PGCE course and found that just over 10% felt competent in meeting the needs of pupils with SLCN. Some also held negative stereotypes of these pupils, with 4.4% suggesting they would come from a deprived background, and 3.4% suggesting they would be disruptive. These figures are concerning but likely to be indicative of current practice, although more up to date figures are not available. Most initial teacher education courses touch only upon generic inclusive pedagogies rather than specific strategies to meet individual special educational needs (Lawson et al., 2013), and so unless teachers attend post-qualification specific training, they are unlikely to have had input into effective strategies specifically for pupils with SLCN. Over 50% of teachers in a study by Dockrell et al. (2017) had had no training in teaching pupils with SLCN, for example. Consequently, any of these pupils' difficulties in mathematics may be compounded by a lack of teacher understanding of this group's needs or of specific strategies to support them effectively (Dockrell & Lindsay, 2001).

2.5 Research questions

This review of the literature has discussed and identified several emerging themes that lead into the research questions. These themes can be categorised into two broad areas: those affecting teaching (input) and those affecting learning (outcomes). The review has emphasised the heterogeneity of pupils with SLCN and the difficulties teachers face in meeting their needs, especially in mathematics. This may be compounded by teachers' potential lack of confidence in teaching mathematics and in having sufficient pedagogical content knowledge to address pupil misconceptions. This review has also highlighted the debate around what effective pedagogy is and how strategies that have found to be effective, such as mathematical talk in small groups, may be perceived to be at odds with the national curriculum directive to keep classes together and from learning theories such as direct instruction. Previous research has highlighted specific mathematical difficulties for pupils with SLCN, although drawn from more specific research into pupils having DLD and SLI. These indicated that pupils with SLCN struggle with mathematics in the verbal domain, although the types of errors made has not been well researched. There has been very limited research into the efficacy of whole class mastery approaches to teaching in the national curriculum and none that consider their effectiveness for pupils with SLCN, particularly those in key stage 1, who are more likely to have a language impairment: the prevalence of pupils with language impairments diminishes as an identified special educational need as children get older. Furthermore, there is very little current evidence around teacher preparedness to teach pupils with SLCN, especially in mathematics. This research therefore aimed to investigate, through focusing on key stage 1 classrooms that used a mastery approach to teaching mathematics, what specific difficulties pupils with SLCN experienced compared to their TD peers. It particularly sought to investigate how pupils with SLCN approached mathematics that was couched in language, such as worded problems, compared to that which was presented in purely numerical format. To identify specific strategies to support pupils with SLCN in their mathematics learning, error types and strategies used on answering questions involving language, and arithmetic questions using numbers only, were investigated and compared to TD pupils. The research also sought to investigate teacher understanding of current mathematics pedagogy and how the needs of pupils with SLCN were met in the classroom.

The following questions were identified from the review of the literature:

RQ1: How do children with SLCN perform on a mathematics task with high language demands compared to one with lower language demands and how does their performance differ compared to TD pupils in terms of error type, overall score and reaction time?

This research question seeks to explore the particular difficulties experienced by pupils with SLCN compared to their TD peers, by comparing their answers, reaction times and errors on a mathematics task with a high language demand (a reasoning test) with those with a lower language demand (an arithmetic test).

RQ2: How does teacher understanding of effective mathematical pedagogy influence the planning of mathematics lessons to meet SLCN pupils' needs?

This question seeks to elicit teachers' views to explore more fully some of the issues experienced by teachers in adapting their planning to take account of pupil needs with SLCN in mathematics. It also seeks to draw out and compare teachers' understanding of effective mathematical pedagogy.

This chapter has highlighted how pedagogy can be broken down into inputs (teaching) and outputs (learning) wrapped up in the framework of the mathematics national curriculum and how this has been influenced by external factors such as the need for all pupils to attain higher outcomes in mathematics. It has noted teachers' difficulties in teaching mathematics, especially for pupils identified with a SLCN, and discussed some of the reasons behind why learning for this group might be impaired. Chapter 3 will go on to consider the research methodology most suited to answering the research questions.

Chapter 3 – Methodology

This chapter outlines the general methodology and approach to research used in the study. It also discusses the ethical issues involved in the research and how these were addressed. It explains how a mixed method concurrent design using a case study approach addresses the research questions. The methods of data analysis are described.

3.1 Ontology

Ontology may be defined as the 'study of being' (Crotty, 1998, p.10) or the nature of reality. Taking the position that reality is constantly debated and interpreted leads the researcher to the viewpoint that there are multiple realities rather than one objective reality, a constructionist view. This research seeks to uncover the views of teachers and analyse the performance of different pupil groups in mathematics, hence there will be multiple ontological explanations.

3.2 Epistemology

Epistemology is defined as the study and theory of knowledge. The epistemological approach used in this research, in other words how reality is understood, is that all knowledge is provisional, it can change over time and is never "absolute or perfect" (Denscombe, 2010, p. 129). The research is driven by the research questions rather than particular philosophical convictions (Tashakkori and Teddlie,1998; Biesta, 2010). This may be described as pragmatism in that all observation is fallible; the truth can only be approximated (Onwuegbuzie et al., 2009). Pragmatism has been defined as a "philosophical movement that considers beliefs and theory as being linked to our practical engagement in the world rather than to the world as it truly is” (Guyon et al., 2018, p.155).

3.3 Research paradigm

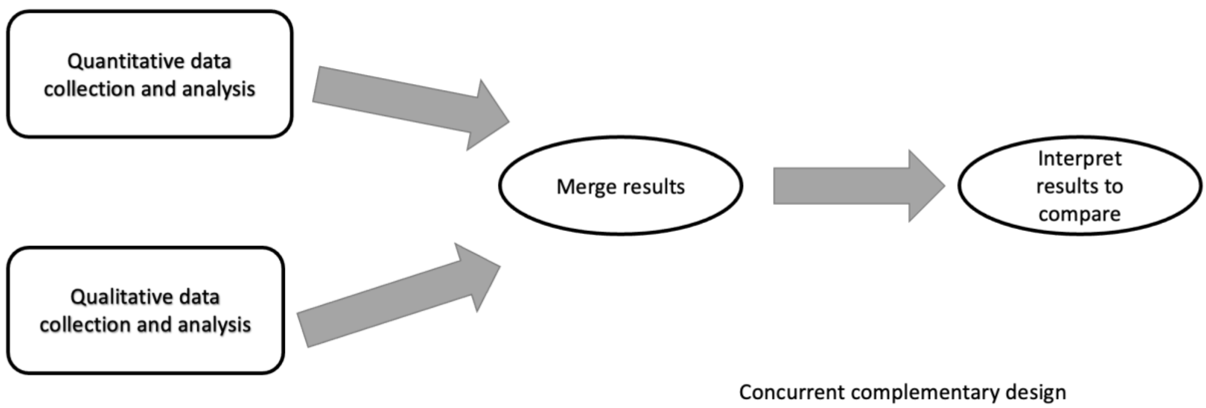
The research paradigm or ‘worldview’ (Cresswell & Cresswell, 2018), is underpinned by the researcher’s ontological and epistemological assumptions. Paradigms, according to Greene and Carcelli (1997, p.8), are best viewed as “descriptors of, not prescriptions for” research practice. Johnson & Onwuegbuzie (2004) argued that researchers should be free to select the most appropriate methods to answer the research questions in each enquiry, without being limited by philosophical assumptions. Paradigms should not be seen as what is right and wrong, but rather what is most appropriate for any particular purpose (Morgan, 2007). The paradigm here is of mixed methods which have increasingly been seen as a paradigm in their own right, rejecting the pure qualitative or quantitative approaches of the past (Tashakkori and Teddlie, 1998). Whilst there has been criticism of multi-strategy or mixed methods designs (e.g. Mason, 2006; Robson & McCartan, 2016), due to a perceived lack of focus and disjointedness or even incompatibility, the differing nature of the two research questions in this case suggested a mixed methods approach was preferable. A mixed methods approach could be said to reject the traditional conflict between qualitative and quantitative methods, adding additional value to research, and is often useful, particularly in educational research, in terms of understanding the perspectives of teachers and the impact of teaching practices on pupil outcomes (Sammons, 2015). Many terms have been used for this approach in the past including ‘mixed research’ and ‘mixed methodology’, but recent researchers have preferred the term ‘mixed methods’ (Cresswell & Cresswell, 2018).

3.4 Research design

This research developed that used in the IFS, which was a qualitative case study design. The strength of the design of the IFS was that it built up a rich picture of pupil attainment and teacher understanding of mathematics strategies using a variety of data collection sources, including participant research. However, partly to strengthen the thesis research design, but also because the research questions seek to discuss the holistic nature of pedagogy, with attempts to understand the connection between teacher input and pupil outcomes, qualitative and quantitative methods in a concurrent (one-phase) design were indicated, with each being used separately and independently of each other (Cresswell & Cresswell, 2018; Robson & McCartan, 2016). There are a number of potential problems to the researcher in a mixed methods design, not only being time-intensive, but requiring an understanding of both qualitative and quantitative procedures (Robson & McCartan, 2016; Cresswell & Cresswell, 2018). Each method in this study was designed to complement the other and sought to make connections across the data (Greene et al., 2004), allowing for elaboration and enhancement. This strategy was designed to capitalise on the strengths of each approach, counteracting biases, rather than attempting a full blending or integration of data. As the sample size is small, the purpose of the qualitative data collection is to add detail to the quantitative data and to add richness through an exploration of teacher perspectives. The data is therefore both exploratory and confirmatory (Onwuegbuzie & Teddlie, 2003). The qualitative and quantitative data were integrated to provide in-depth evidence (Cresswell & Plano-Clarke, 2018) as the study's purpose was not to provide conclusive solutions to a problem, but to explore and describe educational practice within mathematics education for pupils with SLCN in a group of schools, forming a small case study of practice. Case studies are generally accepted as being more pertinent to answering ‘how’ and ‘why’ questions (Yin, 2014) and may include single or multiple sites. Stake (2005, p.461) describes this as a ‘collective case study approach’. Owing to the ongoing Covid-19 pandemic in 2021, the research was designed to take account of the fact that face-to-face contact with teachers and children was not possible, and so research was planned to be carried out remotely. This had an added advantage as the case study schools could be geographically disparate, so research collection time would be better used since travel time would not be lost.

The research strategy was of a concurrent, complementary design, where the qualitative and quantitative data are collected simultaneously and complement and enhance each other. Figure 1 shows the research design.

Figure 1: Concurrent complementary research design



The research questions arising from the literature review were designed to explore both teacher pedagogy and pupil understanding of mathematics through the analysis of error types typically made by pupils on arithmetic and reasoning tasks and comparison of reasoning task and arithmetic task answers. It is argued that quantitative and qualitative research questions are most aligned when they are both open-ended and descriptive, hence both questions researched are ‘how’ questions, lending themselves well to the exploratory nature of this research (Onwuegbuzie & Leech, 2006).

3.5 Data collection

This section provides an overview of the data collection methods, including the research timeline and a consideration of ethics.

Although practical, classroom-based research would have been more appropriate for pupils at key stage 1 and would have built on that carried out for the IFS, this was not possible due to the limitations imposed by the pandemic and the timescale for the research. Instead, mathematics tests were selected as a tool to compare answers for pupils with SLCN and those that were TD as well as comparisons of pupil strategies. Mathematical tests are commonly used in primary schools, both summatively and formatively, and pupils were therefore likely to be familiar with this style of assessment. A list of selection criteria that allowed for RQ1 to be answered were drawn up: 1) the facility to carry out question-level analysis; 2) the test being in a style that pupils were familiar with; 3) the test being available as a paper test rather than an online version; 4) the test including both arithmetic and reasoning questions; 5) being readily available to the researcher during the Covid lockdown period. Paper tests were preferred since these allowed the researcher to analyse the methods used to answer questions after the tests had taken place. Standardised tests were not held to be necessary as the focus was on the strategies used by children to answer the questions rather than producing a standardised score. Similarly, screening tests such as the Test for Early Mathematical Ability (Ginsburg & Baroody, 2003) were not considered necessary since diagnosis of particular mathematical weaknesses was not the aim of the research. The tests selected matched the five selection criteria and were at the time produced free of charge by a leading maths curriculum and training provider in the UK, aligned to the national curriculum and designed to be used each term (White Rose, 2021). From experience, these tests are widely used in primary schools. The tests comprised a reasoning paper (Appendix 10) and an arithmetic paper (Appendix 11). Both tests were based on the mathematics national curriculum requirements for the focus year group. The ‘reasoning’ test questions contained more language than the ‘arithmetic’ test, which involved the solving of basic number problems without extraneous language. Arguably, formal testing should not be carried out on young pupils, with assessment carried out through play that is “meaningful and worthwhile” (Dunphy, 2008, p.4). However, testing pupils at key stage 1 is common, with schools being increasingly accountable and data driven (Bradbury & Roberts-Holmes, 2017) and therefore these tests were likely to be accepted by both teachers and pupils in the study. Teacher interviews revealed that similar tests were already used in four out of the five schools.

In order to screen pupils for their language ability, a standardised assessment of receptive language ability, the British Picture Vocabulary Scale Third Edition (BPVS-3) (Dunn et al., 2009) was selected. Although a test that measures expressive language as well as receptive language would have given a clearer insight into the language needs of the children with SLCN, the BPVS test was chosen as it is simple to administer and, from experience, is one commonly used by teachers in school settings. In addition, the BPVS has been used in research as an indicator of language needs (e.g. Camilleri and Law, 2014) and is often used in the UK by speech and language professionals as a check for receptive language ability (Jackson et al., 2022). To mitigate against its limitations and to check that teacher identification of pupils with SLCN had been accurate, a simple, freely available checklist from The Communication Trust (Pearson, 2011) (Appendix 8) was also used. This was used to confirm that pupil participants did indeed have a SLCN, rather than an undiagnosed general learning difficulty, since correct identification of pupils with SLCN is a known weakness for teachers (Dockrell & Hurry, 2018).

To answer RQ2 and to explore teacher understanding of mathematical pedagogy and the understanding of the needs of pupils with SLCN, it was decided to use a range of qualitative methods. Interviews, one week's worth of teacher planning and corresponding pupil work for the planned week were sufficient to yield sufficient data.

Table 1 shows how the data collection methods were designed to answer the research questions. RQ1 is a comparative question, designed to compare two groups on an outcome variable (mathematical reasoning task outcomes compared to arithmetic task outcomes). RQ2 is more open-ended and designed to explore insights into teacher understanding of mathematical pedagogy and how it might relate to pupils with SLCN.

Table 1 - Data Collection Methods

	Research question	Data collection method
RQ1	How do children with SLCN perform on a mathematics task with high language demands compared to one with lower language demands and how does their performance differ compared to TD pupils in terms of error type, overall score and reaction time?	• Completion of arithmetic and reasoning test papers.
RQ2	How does teacher understanding of effective	• Teacher interviews • Scrutiny of teacher planning

	mathematical pedagogy influence the planning of mathematics lessons to meet SLCN pupils’ needs?	• Pupil work

3.5.1 Piloting

Several stages were involved prior to carrying out the final research. The thesis proposal was firstly presented at a doctoral school online poster conference and feedback was given, leading to a redesign of the research questions and data collection methods. For RQ1, online testing using the BPVS vocabulary test and the White Rose mathematics test was carried out using a typically developing child in year two whose parent had given permission. This was to establish any difficulties with carrying out the British Picture Vocabulary Scale assessment and White Rose mathematics tests online. Following this, a modification in the process was proposed for the pupils in the research schools, with the BPVS test being carried out on one day and the mathematics test on another. The piloting had suggested that online concentration waned, which could have led to underperformance in the maths test scores had the two tests been carried out consecutively within a single session. The piloting also led to the physical layout of the mathematics tests being altered, with the need to avoid having multiple questions on each page. The fact that the original format had more than one question on each page had caused a lack of clarity as to when one question was completed and another begun when viewed online, and so, for the research, the tests were cut up and re-photocopied to ensure there was one question on each page in order to make timing more precise.

For RQ2, using a convenience sample from a school known to the researcher, teacher planning from three different year groups was collected. This planning was scrutinised for emerging themes which included:

- Percentage of time teaching the whole class, small groups, pairs and individuals
- Key word vocabulary analysis
- Differentiation for SLCN pupils

These themes were then used to design the questions for the semi-structured interviews for use with the teachers in the research schools.

3.5.2 Sampling

Purposive and convenience sampling was used to help in generating data for the research. With purposive sampling, the samples are not randomly selected, but deliberately chosen (Robson & McCartan, 2016). This approach has its drawbacks, namely a lack of objectivity and possibility of embedding bias. However, during the time of the Covid-19 pandemic, with schools understandably feeling overwhelmed with work and the ever-changing nature of the restrictions that were imposed on them, schools, academies and organisations known to the researcher in a professional capacity were initially contacted, as a prior relationship was seen as advantageous in enabling research access. Most of these organisations were in areas of low socio-economic status, so more likely to have the target group of pupils, those diagnosed with a SLCN, than those serving more affluent areas (Dockrell et al., 2012). However, insufficient schools were recruited and so the pool of potential schools was widened. As gatekeepers, the headteachers, principals and maths hub leads in fifty-five schools, academy chains and maths hubs were approached by email, explaining the purpose and nature of the research. This was followed up by phone call or a video call to further explain the research and answer any questions. Five schools were ultimately recruited to take part in the research. Although smaller in number than had originally been planned for, this was hoped to have been sufficient to answer the research questions, although the small sample size has its limitations.

Participant schools were based in Greater London and South Yorkshire and, at the outset of the research, had the full range of Ofsted (the Office for Standards in Education, responsible for monitoring school effectiveness) grades available, ranging from grades 1 to 4, with a grade of 1 being outstanding; 2, good; 3, requiring improvement; 4, inadequate. A summary of the school details using the latest available government figures (DfE, 2021) is given below in Table 2, including the percentage of pupils with SEND, both those at school support (SENS) and those with an Educational Health and Care Plan (EHCP) compared to the national average. The percentage of pupils eligible for free school meals (a measure of disadvantage known as 'Ever 6 FSM') is also given as an indicator of the schools' relative deprivation. Four out of five schools used in this research were much more deprived than nationally, using this indicator.

Table 2 - School and Teacher Details, % SEN, Ofsted Grade and % FSM

School name[1]	**Teacher name[1]**	**School most recent Ofsted grade**	**% SEND [National average- 12.2% SENS (3.7% EHC plan)]**	**Ever 6 FSM [National average 23%]**
Ashwood	Amy	3	16.9 (1.1)	38.4%
Best Street	Bella	4 (2) [2]	15.9 (3.8)	34.5%
Church Street	Claire	1	9.4 (6.1)	9.1%
Dunwood	Daisy	4	14 (0.6)	52.4%

Eastern Grove	Ellie	2	23.6 (1.1)	40.8%

[1]All school and teacher names are pseudonymised and none are names of real schools in England.

[2]This school was inspected during the research period and its grading changed from 4 to 2.

To answer the research questions, the study involved teacher and pupil participants in each school, described below.

3.5.3 Teacher participants

All schools had one form of entry and hence one teacher in the target year group, with five teachers taking part in total. Teachers were all female, with the length of time they had been teaching varying from one to eleven years, the median being five years. All five teachers had only worked at their current school and all were currently involved in projects associated with NCETM maths hubs or through their academy chain; several had had significant input from mathematics specialists. Teachers gave voluntary and ongoing consent to take part in the research. Their involvement was crucial in that they selected the pupils, gave of their time to be interviewed, submitted their maths teaching plans and pupil work and obtained parental consent for pupils to be approached.

3.5.4 Pupil participants

It had initially been intended to focus on pupils in year two (6–7-year-olds) for the research, since this year group already takes part in national testing and were therefore more likely to be mature enough to cope with the test conditions imposed. No school approached, however, wished to take part in research with this year group. Reasons given were the pandemic and the two periods of lockdown. Schools were focusing heavily on catching up year two pupils to age-related expectations. They were, however, especially interested in testing year one (5-6-year-old) pupils to uncover gaps in learning from which to build the following academic year, both in their language and mathematics, and so consent was gained more readily for this age group. From the five schools, 30 pupils in national curriculum year one were therefore selected to take part in this research. Year one is the year group by which children with SLCN will generally have been identified (Bishop, 2014) and this was the case for this sample. For each school there were six pupils selected; three with an identified SLCN and three gender-matched typically developing (TD) children. Pupils with SLCN were chosen by class teachers as those having a specific language need and all were on the school's SEN register. Some, but not all, were receiving speech and language therapy, although this was being carried out remotely due to the pandemic. All children were categorised as receiving SEN support; none had an Education and Health Care Plan (EHCP), and none had comorbid diagnoses of SEN, such as being on the autism spectrum. Teachers were asked to complete the checklist (Appendix 8), described earlier, to help categorise the specific area of difficulty with SLCN. Pupils at early stages of learning English as an Additional Language (EAL) were excluded from the sample, as having EAL may be a confounding factor in language development (Hasson et al., 2012). Out of the 30 pupils initially selected by their teachers, 28 pupils eventually took part in the research as for two children no parental consent was obtained.

3.5.5 BPVS testing

Prior to carrying out the mathematics tests, it was necessary to establish the receptive language level of each child, both those with SLCN and those who were TD, and so the BPVS standardised assessment was used. The BPVS assessment consists of 12 items at each level, starting with the level closest to the child's chronological age. This assessment took place one-to-one online with the researcher screen-sharing the BPVS pictures following the instructions given in the BPVS manual. The tester showed a series of four pictures and stated a word: a noun, verb, or adjective. The child indicated which picture matched the word used by saying the number under the picture and the tester recorded the pupil response. Testing continued until eight errors had been made within a set of items, the 'ceiling set'. Each pupil's assessment took around 10-15 minutes and was scored following the completion of the test following the instructions in the BPVS manual. Unlike the subsequent maths tests, these sessions were not recorded as the record sheet was scored live. There were no perceived disadvantages to carrying out these assessments online, either for the researcher or the child, confirming work by other researchers that online testing can show the same profile as face-to-face testing (Ashworth et al., 2021). Standardised scores were then calculated using the pupils' raw scores and age on date of testing using look-up tables. Standardised scores were used since pupils were of differing ages, although all were within the year one age group (5-6 years old).

An independent samples t-test was carried out to compare pupils' standardised scores on BPVS. The receptive language scores for pupils described by their teachers as having SLCN were not found to be statistically different from the control group (TD pupils), $t(26) = {}^{-}1.713$, $p = .099$. However, as can be seen from Table 3, those with SCLN had a wider range and some had BPVS age standardised scores that show delayed comprehension vocabulary scores (below 80). Table 3 shows the participant (pupil) characteristics.

Table 3 - Pupil Participant Characteristics for pupils with Speech, Language and Communication Needs (SLCN) and Typically Developing Pupils (TD)

	SLCN **N= 13**	**TD** **N= 15**
Male/female	6/7 (46%/54%)	7/8 (47%/53%)
Mean (SD) age in years	5.75 (0.43)	5.92 (0.32)
BPVS mean (SD) age standardised scores	88.62 (9.59)	94.40 (8.29)
BPVS scores - range	75-100	84-107

3.5.6 Age differences

An independent samples t-test was conducted to compare age differences between the group of pupils with SLCN with the TD pupil group. Although the SLCN group had a slightly lower average age (M= 5.75, SD= .43) compared to the control group (M= 5.92, SD= .32), there was no significant difference between the two groups for chronological age, $t(21.77) = -1.066$, $p = .298$. This means that any differences between the groups cannot be explained by age.

3.5.7 Timeline

As the research was of a complementary concurrent design, data were collected simultaneously. Some data fed into subsequent elements, such as the teacher planning and pupil work into the teacher interviews (see Figure 2).

Figure 2 - Timeline

3.5.8 Ethical considerations

Ethical approval was granted in March 2021 from UCL's doctoral ethics committee. There were numerous ethical considerations to be addressed in line with the British Educational Research Association [BERA] (2018) guidelines for research and data protection (GDPR) regulations. All teacher participants were made aware of the reason for the data collection - the purpose of a doctoral thesis - and were told that they would be sent a report following the research. Schools, teachers and pupils were guaranteed anonymity in the writing up of this research and all school names, teacher names and pupil names used here are pseudonyms and school names do not reflect those of real schools in England. School, teacher, parent and pupil consent forms were received in advance of carrying out the research and these were carefully checked to ensure all parents had given informed consent for the researcher to work one-to-one with their child. An example is given in Appendix 1. Ongoing pupil consent was given prior to individual pupil work taking place. Pupils completed a simple consent form suitable for the age of the child (Appendix 2) as well as giving verbal consent prior to each test being carried out (Appendix 3). All pupils were assigned a unique pupil code which was written on their work and on all assessments to ensure they could not be identified. Due to Covid-19 restrictions, with face-to-face research not possible, all assessments and interviews were instead carried out remotely using Zoom©, 2020 https://zoom.us or Microsoft Teams®

https://www.microsoft.com/en-gb/ videoconferencing platforms for both teachers and pupils. Teacher interviews were recorded and transcribed with teachers having the option not to be video recorded but use audio only. All pupil assessment took place during school hours and at the child's school. As the researcher was unknown to pupils, a familiar adult such as a teacher or teaching assistant remained with the pupils during all assessments and pupil consent was obtained before recording any online work. In each school, the laptop camera used was angled on the pupils' work rather than their faces, to help protect their anonymity as well as to gain an insight into strategies used to work out answers.

Because of the researcher's position, especially the power balance and how each situation was controlled, developing empathy and trust with both teachers and pupils was crucial. Empathy is defined by Patton (2002, p.51) as combining "cognitive understanding with affection connection" to fully appreciate the position of others. This presented additional challenges when working with teachers and pupils remotely as it was more difficult to build rapport. To address this, both teacher work and pupil work included some element of relationship-building offline, which was not recorded, in the form of ice-breaker questions. For pupils, this included statements and questions such as: "Today we're going to do some maths together. Do you like maths? What do you like doing best?" The warm-up questions at the start of the teacher interview served a dual purpose. Getting teachers to talk about the length of time they had been teaching and the length of time they had been at the school enabled a rapport to be established as well as finding out background information such as length of time teaching given in Section 3.5.3. This section of the interview was not transcribed and coded.

3.5.9 Data storage

All data was anonymised using codes, including teacher interviews, teacher planning, pupil work and pupil testing videos. Electronic data was stored securely using the password protected UCL OneDrive platform. Paper copies of pupil maths tests were anonymised using codes and stored in a locked filing cabinet.

3.6 Data collection methods

This section shows how the different methods of data collection were used to answer each research question. These methods were replicated in each of the five case study schools.

3.6.1 Quantitative data

To answer RQ1, the two maths assessments were carried out. As this cohort of pupils had missed time in school in both 2020 and 2021 due to Covid-19, the White Rose spring term test papers for arithmetic and reasoning for year one were selected rather than the summer term tests, which would have been more usual, given that testing took place in July at the end of the academic year. This meant that children were more likely to be familiar with the content and allowed for the examination of the strategies used rather than just a comparison of raw scores.

Schools were sent copies of the arithmetic and reasoning test papers for each pupil and a stamped addressed envelope to return the scripts to the researcher. Envelopes containing the test papers were opened in front of the researcher online and pupils worked through the arithmetic test first, followed by the reasoning paper. This work was video recorded to later analyse the strategies used in answering the questions, which could be clearly seen from the camera angle. A standard script (Appendix 4) introduced the task to the children to ensure equity, and a set of prompts was drawn up to ask the children if they became stuck on a question. Children were already familiar with the researcher, as the BPVS vocabulary assessment had already been carried out. Mathematics testing was completed in between 10 and 20 minutes in total per child for both tests.

Each question was read by the researcher to ensure fairness for all children and to avoid being penalised because of weak reading skills. Questions were timed, using both a timer and the time facility on the videoconferencing software to check for accuracy. Timing began when the question was read by the researcher and ended when the child completed the answer. Children were encouraged to tell the researcher when they had completed the question so that the timer could be stopped. Sometimes this was done instead by the adult sitting with the child, who could more clearly see when the question had been completed. The researcher also noted strategies used by the child such as the use of jottings, pictures and fingers as well as whether any adult help was needed.

There was a need to be empathetic to the children during the testing process; this meant that on analysis of each video following testing, some questions had to be discounted as the children had been given too much help from the researcher to answer some questions, in order that they did not become distressed. On occasion the teacher or teaching assistant sitting with the child also inadvertently intervened, meaning a lack of fidelity to the test, so these too had to be discarded from the dataset. Eight questions in total on three pupils’ work was discarded in this way. However, although there were some gaps, sufficient raw score data was available for analysis.

On completion of the maths testing in each school, the completed test papers were sent back to the researcher where further analysis was undertaken, marking each script and noting error types. A description of these is given in Table 4.

Table 4 - Description of error types

Error type	**Description**	**Example**
Reversal	Reversals affecting place value	04 for 40
All other errors	Addition for subtraction 'Wild guessing'[1]	4+2 not 4-2 10+2= 31
Computational	Where answer has been carried out using correct operation and associated strategies and answer is within 2 of correct one.	2+8=11

1 'Wild guessing' is the term used in this research when a child appeared to have no strategies to solve a problem and seemed to pluck a number out of the air, rather than leave a question unanswered.

Teachers were emailed certificates to print off to give to the children to thank them for their cooperation. As a recognition of the teachers' time and commitment, a zip file was also emailed containing a selection of useful resources to support them in supporting children with a SLCN.

3.6.2 Qualitative data

To answer RQ2, teachers were asked to send one week's planning for a number topic in whatever format they chose, to minimise the demands on their time. Number was selected as a topic as there is some evidence that ability in number is not dependent on language abilities (Gelman & Butterworth, 2005; Papagno et al., 2013). It was hoped that this would enable pupils with SLCN and those who were TD an equal chance of success and eliminate any potential bias towards TD pupils. All five teachers sent whiteboard slides as planning; two were commercially produced using a commonly used mathematics curriculum package and three had been made by the teachers themselves, drawing on commercially produced materials. Teachers were also asked to send pupil work from the target children in their class (three SLCN and three TD) that corresponded to the week's planning in question. Both these elements enriched the discussion during the teacher interviews and are discussed in Chapter 4.

Semi-structured teacher interviews were conducted outside of school hours and recorded using Zoom© or Microsoft Teams® software with a transcription function. Teachers were given a choice as to which software package they preferred for the interviews and were able to opt for audio only. Semi-structured interviews were selected as a method of data collection, as they give a detailed picture of a respondent's beliefs or perceptions of a topic (Smith, 1996). These also allow the researcher more latitude than a structured interview or survey since they are more adaptable and flexible. Most interviews took place after the pupil testing period had been completed, but variability was allowed, since the interviews were autonomous and not dependent on the results of pupil testing.

Using the themes derived from the pilot study, interviews were designed to explore teachers' experiences in teaching mathematics to pupils with a SLCN. These themes included: 1) understanding of effective teaching strategies in mathematics; 2) knowledge of specific difficulties experienced in mathematics for pupils with a SLCN; 3) specific strategies used to support pupil learning. Dummy tables were drawn up in advance of the interviews with anticipated answers to guide the questioning in order that all questions remained relevant and focused (Foddy,1993). The structure consisted of open-ended questions with follow-up prompts (Appendix 5). Questions were kept neutral rather than being value-laden (Smith, 1995) for example, "*How* *typical is the planning you sent me? How do you adapt the teaching to suit the needs of individual pupils?"* In conducting the interviews, Kvale and Brinkman's (2015) advice was followed in that the stage was set for the interview. Clear ground rules were given at the start, with the researcher listening attentively, making comparatively few notes, and then summing up at the end by asking participants if they had anything further to add. The mean length of the interviews was 28 minutes, (SD=9.86). An unforeseen issue from carrying out interviews after school hours was the number of interruptions, from other colleagues and cleaners entering the classroom, to children attending after school clubs returning to collect their belongings. This meant that some interviews were fragmented and did not allow for an uninhibited flow of conversation. Nevertheless, they yielded rich data, sufficient to be analysed for this research.

The use of videoconferencing software allowed for full and largely accurate transcriptions to take place following the interviews, whether they had been video recorded or audio recorded. Both software packages used have a transcription facility in which speech-to-text transcription using artificial intelligence (AI) and machine learning takes place in real time. It was a simple matter to play this back and correct any errors the AI software had made, ensuring accuracy. The resulting transcripts were also time-stamped, which made searching for key words and phrases relatively simple (see Appendix 6 for an example).

3.7 Data analysis approach

The qualitative and quantitative datasets to answer each research question were independent of one another and were analysed as such. In a complementary mixed methods design, the main themes emerging from each may be integrated using a side-by-side comparison (Cresswell & Cresswell, 2018). Themes from each are discussed in Chapter 4 and the comparison of the two approaches is discussed in Chapter 5.

3.7.1 Quantitative data analysis

To answer RQ1: *How do children with SLCN perform on a mathematics task with high language demands compared to one with lower language demands and how does their performance differ compared to TD pupils in terms of error type, overall score and reaction time?* a dataset was produced in SPSS. This dataset consisted of, for each pupil:

- scores on the arithmetic test
- scores on the reasoning test
- time taken to answer each question on the arithmetic and reasoning tests
- types of errors made on each paper
- any adult help given
- strategies used in answering questions.

A detailed analysis was undertaken of the two groups' (pupils with SLCN and those who were TD) performance on the arithmetic and reasoning papers. The performance of those with a SLCN and those who were TD were compared, in terms of average number of questions correct and incorrect, the average time taken for each item on the arithmetic and reasoning papers and the error types made.

The hypotheses tested and the methods of data analysis were:

1) *Pupils with SLCN would do less well than their typically developing peers on the reasoning but not the arithmetic test.* To analyse this, a 2*2 ANOVA was used, comparing TD and SLCN pupil groups' mean scores between arithmetic and reasoning papers.

2) *Pupils with SLCN would be slower than TD pupils on the reasoning but not the arithmetic test for both their correct and incorrect answers.* To analyse this, a 2*2 ANOVA was used, comparing TD and SLCN pupil groups' mean times for each question on arithmetic and reasoning papers.
3) *Pupils with SLCN would make more computational, all other errors and reversal errors.* To analyse this, chi-square analyses for each type of error were used, comparing the pupils with SLCN to the TD group.
4) *Pupils with SLCN would do less well than their TD peers on questions with high language demands on both papers*. As not all questions on the reasoning tasks contained similar amounts of language, some items were expected to be more demanding from a language point of view than others and thus performance on individual items were explored. To analyse this, a question level analysis showing the difference in correct answers by the two pupil groups was initially used to compare results within the reasoning and arithmetic tests. Percentages were used, since the two pupil groups were of unequal sizes. This was followed up by a chi-squared analysis to look for significant difference in correct answers. Finally, qualitative analysis followed, focusing on individual questions where there was a significant difference in performance in the two pupil groups.

3.7.2 Qualitative data analysis

To answer RQ2: *How does teacher understanding of effective mathematical pedagogy influence the planning of mathematics lessons to meet SLCN pupils' needs?* data analysis took a general inductive approach, common in qualitative data analysis. Miles and Huberman (1984) describe three main methods: data reduction, data display and verification. Although this has been described as less rigorous than some other analytic strategies such as grounded theory (Thomas, 2006), it nevertheless allows research findings to emerge from the data free from the restraints imposed by more structured methodologies. The first stage is for the researcher to familiarise themselves with the data (Braun & Clarke, 2008). It had originally been planned to use NVivo, a qualitative data analysis software package, but because only five teacher interviews were carried out, and hence the dataset was relatively small, it was not considered necessary, and the researcher would become more familiar with the data if analysis were done manually. Interviews were transcribed using the videoconferencing transcription software described above. Having transcribed all five interviews, each was read and re-read to search for emerging themes relevant to the research question. These themes were then refined and classified. Text segments were labelled and coded to create categories. Qualitative coding differs from quantitative coding in that some text segments can be coded into more than one category and some text may not be categorised at all if it does not fit the research question (Thomas, 2006). Categories relevant to the research question were identified and grouped into a framework, based on recurring themes from more than one interview (Appendix 7).

Although it had initially been planned to analyse teacher planning and pupil work in depth, there was insufficient detail given in planning to yield meaningful data, and pupil work for TD and SLCN children was very similar, with little adaptation seen. Instead, both pupil work samples and teacher planning led into specific interview questions and hence has enhanced the teacher interviews.

3.8 Reliability and validity

Reliability in this research took the form of ensuring consistency in all interviews and pupil testing. Several measures were implemented to ensure reliability. There were potential issues of participant error, participant bias, observer error and observer bias in this study. To help reduce any gender bias, TD and SLCN pupils were matched by gender in each school. To eliminate teacher participant error, with teachers incorrectly selecting pupils with SLCN, all teachers were asked to complete a checklist produced by The Communication Trust (Pearson, 2011) (Appendix 8) on both TD pupils and those with SLCN. These ensured teachers had thought carefully about the selection of pupils to take part and that they did indeed have a SLCN. BPVS testing was carried out to standard conditions using the test manual. All pupils had an adult present during the BPVS testing. To minimise pupil participant errors on the mathematics test, each test was carried out under the same standardised conditions, with the researcher reading a standard script and with the same possible interventions given if the pupil got stuck on the mathematics tests. (*What is the question asking? What maths do you need to do? What could help you to work this out?)* Adults who knew the children well were present during the testing and were primed to intervene if the child became distressed in any way during testing, although none did.

To minimise observer error, video recordings of the maths tests were checked and re-checked twice at the conclusion of the research to ensure errors, codes and times were accurate for each question. Where the time on the stopwatch and video differed by more than two seconds, the time-stamped time on the video recording was used in preference. To reduce observer bias, two pupil videos were also coded by two independent researchers. Coding was done for strategies used, error type and adult help given. This showed high inter-rater reliability, with 100% agreement on strategies used, 96% on error type and 84% for adult help given.

Teacher interviews were semi-structured and followed the same loose script. They were recorded and transcribed using the auto generated transcripts from the video conferencing software which were checked against the video recording for accuracy. Because of the quality of recordings and their matching time-stamped transcripts, these are accurate representations of each interview, with few inaudible words.

Validity as a term is rejected by some mixed methods researchers, since its use is often associated with quantitative research (Onwuegbuzie & Johnson, 2006). They propose *legitimation* instead. However, others have argued that the term should continue to be used, since validity is used by both quantitative and qualitative researchers (Cresswell & Plano-Clark, 2007). O'Caithan (2010) prefers the term *quality* since this suggests overall design quality from planning, undertaking the research and interpretation and this is the preferred term in this research. This research design has attempted to use both qualitative and quantitative data in a complementary concurrent design. Complementarity seeks to elaborate and enhance the results from one method of data collection with the results from the other (Greene et al.,1989). Each analysis was attempted independently and common themes led into the research findings. Attempts to eliminate bias and error were considered and adequate sampling commensurate with the size of an EdD thesis carried out.

3.9 Chapter summary

This chapter has outlined the research approach used, a mixed methods model, and the methods used to collect and analyse the resulting data. Quantitative data from carrying out language and mathematics tests on year one pupils and qualitative data from teacher interviews, planning and pupil work analysis in five schools were analysed in order to answer both research questions. Findings arising from the data analysis are discussed in Chapter 4.

Chapter 4 - Findings

This chapter examines the findings for research questions 1 and 2. It begins with the quantitative results before moving onto the qualitative findings and summarises the key themes emerging, which will be further discussed in Chapter 5.

4.1 Quantitative results

This section describes the results obtained from the quantitative data collection to answer RQ1: *How do children with SLCN perform on a mathematics task with high language demands compared to low language demands and how does their performance differ compared to TD pupils in terms of error type, overall score and reaction time?*

Prior to carrying out the analyses of the mathematics tasks, analysis of the age of the two pupil groups and BPVS standardised scores was carried out to investigate whether there was a difference by age for the two groups and whether the pupil group defined as having SLCN by their teachers did indeed have language difficulties. It was predicted that pupils with SLCN would have lower BPVS scores than the TD group. This is reported in section 3.5.6.

For the maths test scores it was predicted that pupils with SLCN would do less well than their typically developing peers on the reasoning but not the arithmetic test. Two groups (TD and SLCN) and two conditions (a task with high language demand – reasoning paper, and a task with low language demand – arithmetic paper) would produce variable scores so a 2*2 ANOVA was used.

For the reaction time, it was predicted that pupils with SLCN would be slower than TD pupils on the reasoning but not the arithmetic test for correct answers. Again, two groups (TD and SLCN) and two conditions (task with high demand and task with low demand), would give variable outcomes in terms of reaction times on each task so a 2*2 ANOVA was used.

The same analysis was repeated for incorrect answers. For the reaction time, it was predicted that pupils with SLCN would be slower than TD pupils on the reasoning but not the arithmetic test for incorrect answers. Again, two groups (TD and SLCN) and two conditions (task with high demand and task with low demand), would give variable outcomes in terms of reaction times on each task so a 2*2 ANOVA was used.

Considering the error types, it was explored whether the SLCN group would make a greater number of computational errors, more ‘all other errors’ and reversal errors by using chi-square analyses for each type of error compared to the TD group.

It was predicted that on the arithmetic paper, pupils with SLCN would make more computation errors as they may have had difficulties with working memory and struggled to learn number facts to automaticity. For the reasoning paper, it was predicted that they would make more ‘all other errors’ because they might be more likely to make ‘wild guesses,’ as their language difficulties might have impeded their understanding of worded questions, including the operation type used. It was also predicted that on each paper SLCN pupils might not have had secure understanding of place value and therefore may have made reversal errors. The two pupil groups (TD and SLCN) were analysed for the total number of type of errors on each paper as several pupils made no errors that could be categorised in this way and overall totals were small, making individual analysis meaningless. Chi-square analyses were used. As the SLCN group was highly heterogeneous and as the tasks on each paper assessed several mathematical concepts, further differences in terms of performance on each item were explored using an item-by-item analysis for the arithmetic and reasoning paper using Chi-square analyses. Comparison of each group's performance on individual questions was explored through a question level analysis.

4.1.2 Comparison of SLCN pupils and TD pupils' mathematical abilities in terms of performance and reaction times

A 2 group (TD versus SLCN) by 2 condition (arithmetic versus reasoning) ANOVA for the overall mean raw scores showed that there was no difference in variance between the two groups using Box's Test for Equivalence of Covariance Matrices, $F(3,484765.792) = .556$, $p = .644$).There was a significant effect for type of task, $F(1,26) = 103.751$, $p < .001$, $\eta_p^2 = .80$ with both groups performing better on the reasoning task compared to arithmetic task. There was also an effect for group, $F(1,26) = 10.173$, $p < .004$, $\eta_p^2 = .281$ with the TD children (Mean = 7.90) outperforming the SLCN group (Mean= 5.46). Finally, there was an interaction between type and group, $F(1,26) = 5.624$, $p = .025$, $\eta_p^2 = .178$. Post-hoc independent *t*-tests showed a significant effect for group for the reasoning test, $t(26) = -3.605$, $p = .001$, but not the arithmetic test, $t(26) = -1.647$), $p =. 112$. Results are reported in Table 5.

Table 5 - Mean total scores (SD) and reaction times on arithmetic and reasoning papers

Group	Mean total arithmetic score [1] (SD)	Mean arithmetic time per item– correct items (SD)	Mean arithmetic time per item- incorrect items (SD)	Mean total reasoning score [2] (SD)	Mean reasoning time per item- correct items (SD)	Mean reasoning time per item– incorrect items (SD)
SLCN	3.61 (2.10)	35.53 (28.67)	50.33 (24.03)	7.31 (2.50)	21.10 (12.77)	27.22 (11.40)
TD	4.93 (2.12)	25.36 (16.72)	36.76 (19.94)	10.87 (2.70)	22.85 (9.47)	29.24 (13.25)

1 Out of a total of 10 marks; 2 Out of a total of 14 marks

To test whether the covariance between the reaction time for the correct answers were equal, Box's Test for Equivalence of Covariance Matrices was carried out. This showed that these were not significant: $F(3,132508.071) = 1.19$, $p = .314$. There was a significant effect for type of task, $F(1,25) = 5.85$, $p = .023$, $\eta_p^2 = .190$, with participants in both SLCN and TD groups responding faster for correct answers on the reasoning task (M= 22.04, SD= 10.75) than on the arithmetic task (M= 29.88, SD= 22.45). However, there was no significant effect for group, $F(1,25) = .52$, $p = .479$, $\eta_p^2 = .020$. There was also no significant interaction with group and type, $F(1,25) = 2.86$, $p = .103$, $\eta_p^2 = .103$. The standard deviation, however, shows there was more variance within the SLCN group than the TD group (See Table 6).

To test whether the covariance between the reaction time for the incorrect answers were equal, Box's Test for Equivalence of Covariance Matrices was carried out. This again showed no significance, $F(3,103680) = .30$, $p = .829$). There was a significant effect for type of task, $F(1,24) = 19.795$, $p < .001$, $\eta_p^2 = .452$, with both groups taking longer to respond on the arithmetic task (M= 43.55, SD= 22.62) than the reasoning (M=30.89, SD=18.16). There was no significance for group, $F(1,24)= .86$, $p = .362$, $\eta_p^2 = .035$. However, there was a significant interaction for group and type, $F(1,24)= 5.13$, $p = .033$, $\eta_p^2 = .176$, with the SLCN group taking much longer than the TD group for the arithmetic answers. There was no significant difference for the incorrect items on the reasoning task.

Although the difference in performance is larger for the reasoning task, the pupils with SLCN take longer than TD pupils on both correct and incorrect items on arithmetic and they make more errors.

4.1.3 Comparison of SLCN pupils and TD pupils' answers in terms of performance on individual items

An item analysis was carried out to explore the differences between the two groups' correct answers to individual questions on each paper. A chi-square test, weighting each case, was then used to examine whether the differences in performance by pupil group on each item was significant, carried out for arithmetic and reasoning tests. Chi square analyses could not be performed on item 7 or item 9 as one group scored 0. Overall, the chi-square analyses showed no significant difference in the performance of SLCN pupils on any of the arithmetic items compared to TD pupils. The results are shown in Tables 6 and 7.

Table 6 - Item comparison of TD and SLCN pupils' correct answers on arithmetic test

Item no.	SLCN (n=13)	SLCN (%)	TD (n=15)	TD (%)	χ^2 (df)
1	11	84.61	14	93.33	$\chi^2(1) = .360$, $p= .549$
2	10	76.92	14	93.33	$\chi^2(1) = .667$, $p=.414$
3	1	7.69	2	15.38	$\chi^2(1) = .333$, $p= .564$
4	5	38.46	6	40.00	$\chi^2(1) = .091$, $p=.763$
5	6	46.15	6	40.00	$\chi^2(1) =0.00$, $p= 1.00$
6	4	30.77	7	46.67	$\chi^2(1) =.818$, $p= .366$
7	0	0.00	4	26.67	-
8	4	30.77	10	66.67	$\chi^2(1)= 2.571$, $p=.109$

9	0	0.00	1	7.67	-
10	3	23.07	8	53.33	$\chi^2(1) = 2.273$, p=.132

Table 7 - Item comparison of TD and SLCN pupils' correct answers on reasoning test

Item no	**SLCN (n=13)**	**SLCN (%)**	**TD (n=15)**	**TD (%)**	**χ^2 (df)**
1	6	46.15	12	80.00	$\chi^2(1) = 2.000$, p= .157
2.1	12	92.30	14	93.34	$\chi^2(1) = .154$, p= .695
2.2	12	92.30	15	100.00	$\chi^2(1) =.333$, p=.564
2.3	12	92.30	14	93.34	$\chi^2(1) = .333$, p= .564
3.1	2	15.38	11	73.34	$\chi^2(1) = 6.231$, p= .013*
3.2	5	38.46	12	80.00	$\chi^2 (1) = 2.882$, p= .090
3.3	5	38.46	11	73.34	$\chi^2 (1) = 2.250$, p=.134
4	5	38.46	10	66.67	$\chi^2(1) =1.667$, p= .197
5	6	46.15	6	40.00	$\chi^2(1) =0.000$, p= 1.00
6	2	15.38	10	66.67	$\chi^2 (1) = 5.333$, p= .021*
7.1	6	46.15	8	53.34	-
7.2	3	23.08	6	40.00	-
8	12	92.30	15	100.00	$\chi^2 (1) = .333$, p= .564
9.1	2	15.38	8	53.34	$\chi^2(1) = 3.600$, p= .058
9.2	0	0.00	0	0.00	-
10	11	84.62	15	100.00	$\chi^2 (1) = .615$, p= .433

Items 3.1 and 6 were statistically significant with *p* values less than 0.05. Items 7.1 and 7.2 had equal weighted values meaning chi square could not be performed. Chi square could also not be performed on item 9.2 since no child from either group got this question correct. Items 3.1 and 6 are discussed in detail in Chapter 5.

Comparison of the scores between the two groups on the arithmetic paper showed there were relatively few differences between the two, both in numbers of items correct on each paper, and no significance in terms of the time taken for all correct answers and incorrect answers. There were, however, some emerging differences in the two groups' performance on the reasoning paper.

4.1.4 Error type analysis by pupil groups

In order to explore whether a particular error type was more prevalent in SLCN pupils than TD, an analysis was undertaken to explore the mean number of errors made by error type on each paper. The null hypothesis was that there would be no difference in the type of errors made by TD or SLCN children.

A chi-squared analysis was carried out to compare each pupil group with the mean number of error types made by each group on reasoning and arithmetic papers. A one-tailed t-test, using unstandardised residuals was carried out on each error type. For the error type R (reversal) no analysis could be calculated due to one group scoring 0 for this type of error. The analysis of error types is shown in Table 8.

Table 8 - Mean number of error types and standard deviations for Computation (C), All other errors (AOE) and Reversal (R)

Paper type	**Error Type**	**SLCN Mean (SD)**	**TD Mean (SD)**
Arithmetic	Computation	2.08 (1.69)	2.67 (1.66)
	All other errors	2.92 (2.37)	1.00 (1.10)
	Reversal	0.00	0.00
Reasoning	Computation	1.46 (1.22)	0.80 (0.99)
	All other errors	5.77 (2.49)	3.67 (2.44)
	Reversal	0.00	0.20 (0.54)

Chi-square analyses showed that there was no significant group difference on the arithmetic task: $\chi^2(1)$ =2.522, p= .112, nor on the reasoning task, $\chi^2(1)$ =1.581, p= .209. Pupils with SLCN therefore do not make significantly more computational errors than their TD peers.

Separate analyses for the tasks showed that there was a significant difference between the SLCN and TD groups using an error classed as ‘all other errors’ for the arithmetic paper; $\chi^2(1)$ =9.981, p= .002 and a near significant effect for the reasoning paper; $\chi^2(1)$ =3.077, p= .079.

In summary then, both groups made more errors on the arithmetic paper than the reasoning paper. In terms of types of error, it is not computational errors the pupils with SLCN tend to struggle with, but the use of other errors to complete them with, either significantly (as in the arithmetic paper) or to a borderline extent (as on the reasoning paper).

4.2 Qualitative data findings

Moving on to consider the qualitative data, the findings to answer RQ2, focusing on teacher understanding of effective pedagogy, are presented here.

How does teacher understanding of effective mathematical pedagogy influence the planning of mathematics lessons to meet SLCN pupils’ needs?

As described in Chapter 3, thematic analysis was carried out on the five transcribed teacher interviews carried out in the case study schools, which included discussion of the teacher planning and pupil work previously sent to the researcher. During analysis, a number of themes emerged across the data requiring a degree of interpretation. Emerging themes centred around aspects of pupil learning and specific teaching strategies to address these, along with some external factors, both positive and negative (Appendix 7). These are presented in detail below, with participant quotes to illustrate each of them: these are presented verbatim and so may contain grammatical errors. The value of the participant quotes in this research is to add richness to the data collected and provide an alternative perspective to the quantitative data. Braun and Clarke (2006) discourage researchers from presenting numerical frequency in research analysis: frequency does not necessarily confirm value and so themes presented here (Table 11) are valuable in themselves, representing the views of all the teachers interviewed, the themes emerging from teacher planning and the pupil work. Themes were grouped into three areas. The first two themes centred around aspects that related to teaching and aspects that related to pupil learning for pupils with SLCN. 'External factors' was used to describe other factors that impacted on both teaching and learning.

Table 9 -Emerging themes and sub-themes arranged according to teaching strategies, pupil learning factors and external factors

Teaching strategies	Pupil learning – SLCN pupils	External factors
-Mastery approaches -Adapted lesson structure -Assessment -Seating plan -Use of resources -Vocabulary/language input -Repetition -High level of adult support	-Having SLCN does not always have a negative impact on maths ability -Organisational problems -Working memory -Low attainment -Difficulties with verbal expression -Mathematical language difficulties -Difficulties with subitising -Difficulties with place value -Difficulties in learning number bonds	-Specific training for maths mastery -Lack of training for SLCN -Covid disruption

Further analysis led to pupil learning difficulties being grouped into domain-specific and domain-general areas; in other words, difficulties that are mathematical in nature (domain-specific) and those that are more generalised (domain-general), to draw out the precise nature of mathematical difficulties faced by pupils with SLCN. This was to explore any links with the findings from the quantitative data analysis (Appendix 7). Domain general and domain specific difficulties will now be explored in greater detail.

4.2.1 Domain-general difficulties

Most, but not all, teachers suggested that pupils with SLCN had specific learning needs that were additional to those of the TD children. The difficulties they described as experienced by children having a SLCN varied, with some disagreement among the teachers as to whether these pupils had mathematical needs greater than TD children in the class, or than those with other types of SEND.

> He is actually really strong at maths, so I don’t think his speech impacts him (Amy).

Another teacher, Daisy, commented that:

> I wouldn’t say that their abilities are massively different either…there are some children who don’t have a speech and language (*sic*) that are probably less able than the others.

However, most teachers gave specific examples of difficulties faced by the pupils with SLCN, not just in their mathematical ability, but also more generally in terms of overall difficulties that impacted on mathematics and other aspects of learning. Three out of five teachers cited personal organisational difficulties, such as:

> Lucy often needs me to go over and give her instructions herself, and then Stephen *really* struggles. He'll often do the totally wrong thing

> I’ve asked him to do, even if I’ve spoken to him and given him a task planner and everything like that. (Amy)

> You need one thing at a time. “Open your page” and then you have to check, have they got the page open, get your pencil. “Right, we're going to look at this one question” and we might go through them on the board as a class as an example and we'll do one as an example together, and then they go off and do the rest of them. Sometimes they'll have forgotten which question they're doing, even though it's right in front of them. (Daisy)

The children’s lack of organisational ability influenced some of the adaptations made by the teachers to support pupil learning and affected their planning for these children. This included strategies such as small group work, adapted slides and additional resources, which will be discussed in full in section 4.3.

Poor working memory for those with SLCN, to a greater extent than TD children, was also a theme suggested and again influenced lesson planning and choice of strategies used:

> That working memory’s working so hard, if they've got that visual representation of the colours of the Numicon it's taking that strain away from them to be able to process what they need to do to get there (Bella).

One teacher showed an understanding of the link between long term and working memory:

> Their working memory is stretched all the time because I don't think they easily put things into long term memory (Bella).

Teachers also expressed concern that pupils with SLCN suffered from an inability to understand instructions in mathematics as well as in other areas of the curriculum. Some showed some precision in their understanding of complex language needs:

> It is a lot to do with that language barrier that they don't always understand what's being asked of them during the lesson (Daisy)

> Understanding more complex sentences, I think, longer instructions, communicating with peers effectively; misuse of smaller words, determiners and suffixes (Claire).

Fewer domain-general difficulties than domain-specific difficulties were cited by teachers.

4.2.2 Domain-specific difficulties

Those teachers who felt that SLCN pupils achieved less well in mathematics than their TD peers gave many examples of domain-specific mathematical difficulties which they argued were frequently attributable to children’s language problems. These included difficulties in acquiring new vocabulary, especially terms used in a mathematical situation that have different meanings to those used in everyday contexts:

> I spend a lot of time explaining what those words mean because some of them won’t have come across them before or used them in the way, in the maths term. They might have heard [them] in a different subject area (Bella).

A lack of mathematical language was also attributed to pupils being unable to express their mathematical reasoning clearly:

> But as soon as the maths develops and they have more than one part to the maths or they've got to explain how they got there, they become a little bit unstuck. And because they can't sometimes put into words how they've got there (Daisy).

Teachers also commented that their own vocabulary had to be kept simple as pupils struggled to understand more complex sentences and instructions. Teachers were particularly mindful of pupils' perceived lack of language, and this was demonstrated in the adaptations to their teaching, discussed in section 4.4.1.

In terms of domain-specific mathematical difficulties, teachers felt that these lay with number work, rather than in geometry or measures, although the precise nature of children's difficulties again varied. Place value, number bonds (and a lack of fluency with these) were mentioned and affected how teachers planned for these pupils:

> …place value and things like that are quite a struggle for them (Claire).

> So do you know the basic number bonds and getting those fundamentals? They're not as fluent as some of the other children (Daisy).

There was, perhaps, a lack of understanding about progression in early number, with the importance of counting and one-to-one correspondence and a lack of understanding about subitising:

> It's like showing them the counters, say eight counters, and not having to count them individually, to just know that there's eight. They do seem to struggle a little bit more with that (Daisy).

Some mentioned that pupils struggled to use manipulatives to represent their working, perhaps because of a lack of understanding of the mathematical processes behind them:

> Either they can't use the manipulatives in the right way, or you know, they kind of don't understand the process (Claire).

4.3 Teacher understanding of effective mathematics teaching

This section considers how the difficulties presented by pupils with SLCN impacted upon teachers' understanding of effective practice, their subsequent planning, classroom organisation and use of resources.

4.3.1 Mastery strategies

Most teachers appeared to have a strong grasp of the mathematics national curriculum. They shared a common expectation that the whole class be kept together through teaching all pupils the same content, with any differentiation given by additional support or adaptation. This was true both for pupils with SLCN or other types of SEND.

Teachers spoke confidently of mastery teaching, including the need to have high expectations of all children. Some gave very clear and well-informed answers when asked to define effective mathematics teaching:

> Making sure that they're all at the same point and keeping them together, and we don't want any children falling behind, but then extending knowledge for children that are able to access that but making sure that they all progress at the same speed (Amy).

> You don't need to cap what they get to learn; they can learn the same thing (Ellie).

These high expectations of all children and the notion of ensuring no child falls behind matched that expected in the national curriculum for mathematics (DfE, 2013). This was also evident from the planning and in the pupil work that was sent, which typically did not differ in terms of expectations for pupils with SLCN but were adapted to best meet their needs. This will be discussed more fully in section 4.4.

Teachers mentioned, and this was also seen through their planning and on the annotated pupil work, evidence that concrete manipulatives and pictorial representations were well used by all children throughout lessons, both to support those with SLCN and to give TD children a chance to explore mathematics in greater depth. Concrete resources included bead strings, hundred squares, number lines, base-10 apparatus, cubes and Numicon ®, a concrete resource representing numbers 1-10, which teachers felt particularly reinforced the concrete-pictorial-abstract approach. Pictorial representations included part-whole models and tens frames. Some children were clearly more familiar when working on the maths assessments with representations of ten than others and this helped them to be more efficient and be more accurate in their answers. This will be discussed more fully in Chapter 5.

> All the children, they have always access to a range of manipulatives, so bead strings, counters, cubes (Claire).

> We tend to use sort of like number lines and hundred squares for all the children, that wouldn't be a different thing (Ellie).

4.3.2 Assessment

All the teachers assessed formatively during the lesson rather than summatively. They referred to assessing children during whole class times as well as during their independent work, helping them to target children for additional support or interventions:

> We know which children we'll need to check in with and we tend to mark, both my TA and I, will mark in the lesson (Claire).

Questioning appeared to be used as an assessment strategy to challenge and check understanding:

> I'll try and ask questions as I'm going along with maths…"What do you think it is? Talk to your partner" (Bella).

Use of questioning was also evidenced in the teacher planning scrutiny, which showed use of planned questions at all points during the lessons.

4.4 Teacher planning

All five teachers planned lessons using flipchart slides as a basis to keep the whole class together and provide the same input. Timings varied, but mindful of children's attention span, most teachers kept whole class listening time to a minimum and interspersed this with whiteboard work:

> At the beginning five minutes, they normally come in from break, they have a starter activity at their tables, then they come to the carpet for 2-5 minutes for an on-carpet talk task with their partner, there'll be like a reasoning problem or an error on the board, and they have to discuss with their partner what that is, just to settle them into the lesson. And then the input is between five to 10 minutes long before

> the talk tasks so that's all I would say, high demand listening time is between five and 10 minutes (Claire).

Whole class time was also used to assess the children’s progress and make decisions about whether pupils were ready to go onto independent work or whether they needed additional adult input.

> If they're not getting it, then I would have said “right, let's go to the tables and let's do it practically with some resources” (Ellie).

Whilst the same lesson structure applied to both TD and children with SLCN, teachers further differentiated the lessons for pupils with SLCN through adaptations such as paired work, adult support, additional manipulatives, visual images and careful attention to language usage, including frequent repetition and specific vocabulary teaching.

4.4.1 Teaching strategies

Most teachers used mixed attainment pairs and described the advantages of paired talk for SLCN pupils with a child whose language was better developed. Some described how, because of Covid and the need to seat children in twos rather than small groups as they had done previously, children had been seated next to a more confident speaker.

> I do think it's important if you've got children with speech and language difficulties, if you have a good role model next to them, and in terms of them hearing new sentences modelled correctly and that rich vocab coming from the teacher as well (Bella).

One teacher, Ellie, did not use paired talk as an approach, feeling that it did not benefit her class which comprised many EAL learners:

> Because paired talk and group talk is a skill that some of them really struggle with and if it's not the learning intention, I don't know how helpful that would be in terms of their maths because in this school 80% are EAL and, as I said, that's a skill that we're still sort of working on in year one.

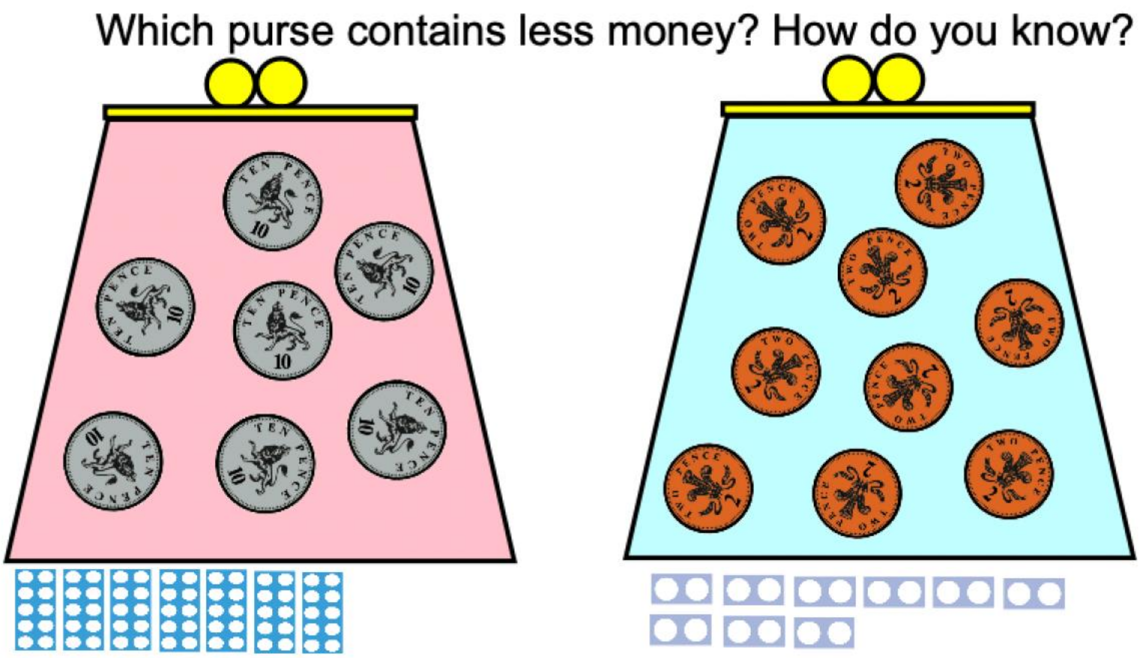
Teachers cited both the use of manipulatives and visual representations as additional interventions to support pupils with SLCN. Although teachers made good use of manipulatives as an effective teaching aid for all children, some indicated that pupils with a SLCN were sometimes directed to use a particular resource, or a greater variety of resources:

> So definitely with them, I use a lot, a lot more resources, so this particular child works well with the unifix cubes, I might also use Numicon because they use them a lot in early years and they are familiar with the Numicon so they're able to recognize ‘oh that one's five’ without counting it, which I think is quite helpful and yeah I would say, those are the sort of the main ones that we use for them and not for other groups, we, I mean we tend to use sort of like number lines and hundred squares for all the children, that wouldn't be a different thing (Ellie).

Numicon® was cited by three teachers, who referred to its use as a familiar object from early years but also in supporting children with subitising, a skill identified through the thematic analysis as being difficult for pupils with SLCN to acquire. Numicon might be seen as both a manipulative and visual representation, with its regular visual patterns supporting children’s subitising skills. The image of ten is also very similar to the use of a tens frame representation. One teacher, Bella, added

Numicon images to her commercially produced flipchart slides to help children in being able to count and identify numbers and to correspond to other visual images used such as coins or bead strings, shown in Figure 3.

Figure 3 - Example of adapted flipchart slides



Differentiation by language input, through simplification or repetition, was mentioned by all teachers and was also apparent in some planning, although not seen in pupil work scrutinised. Most teachers adapted the language used on flipchart slides when following those from a prescribed scheme, including reducing the amount of language to keep the slides clearer.

> Sometimes, if the text isn't needed, I'll take it out or might add another slide in just so it's not too much or too busy for them (Bella).

Worksheets and discussion (talk) tasks were also adapted to suit children with SLCN better:

> I do tend to make adaptations mainly to like the written tasks. I tend to adapt those and I will adapt the talk tasks if I feel that they need to

> be adapted and I do slight alterations to the formatting of the 'Actives' [whiteboard slides] (Claire).

Teachers were also very aware of keeping language simple for children to understand, especially instructions, which they believed pupils with SLCN often struggled to comprehend:

> One of the changes I made in the planning is I will change how I deliver the instructions (Claire).

Teachers spoke about how children with a SLCN needed a great deal of vocabulary development, including specifically teaching new words for each lesson or topic and repetition of these, more than TD children:

> [Discussing text on slides] It's to highlight that this is the language that I want to use, because this is the vocabulary that applies to this part of the maths that I want them to take away from it, so the 'equal' and 'unequal' was really important and so it is repeated many times over (Ellie).

Four out of the five teachers had a teaching assistant (TA) assigned to them and it appeared that the two adults worked well together in these cases to offer a variety of interventions such as pre- and post- lesson interventions, in-class support and taking out small groups for additional support. Additional interventions often took the form of going back over the tasks using more practical equipment:

> So they have their pre-learning in the morning and then we'll kind of reassess as we're marking in the lesson and any children we feel still need support and we'll kind of do and sort of a 15 minute session, either with myself or the TA re-covering… so, for example, it tends to be more the practical things (Claire).

> They might have me or the teaching assistant and they might, maybe in the afternoons if they’ve not quite got something in the morning, they'll go off and have a little bit of an intervention with that. We might get them something else or they might do a more practical activity (Daisy).

One teacher used her TA to take the group of children out of the class, to have a quieter, more focused support session, either from herself as the teacher or by the TA.

> So they would probably also go out with me or my TA, there's just five of them in that group, so that it's quiet. They can have the support that they need with the fewest distractions as possible and I would have the rest of the class in here (Ellie).

The teacher who was without a teaching assistant used a similar format, but got children to do additional work in her lunch break, working with the children to do their corrections (green pen work):

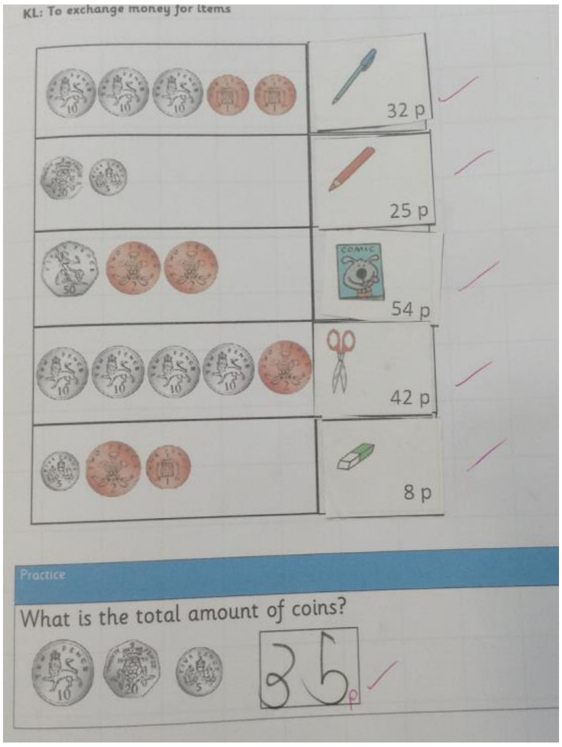
> They do get a lot of support, but I’ve not got a classroom TA, so it is, it is me doing one intervention. I sometimes collect them at dinner times and just if they've got any wrong answers I’ll go through and we do green pen work (Bella).

4.5 Pupil work

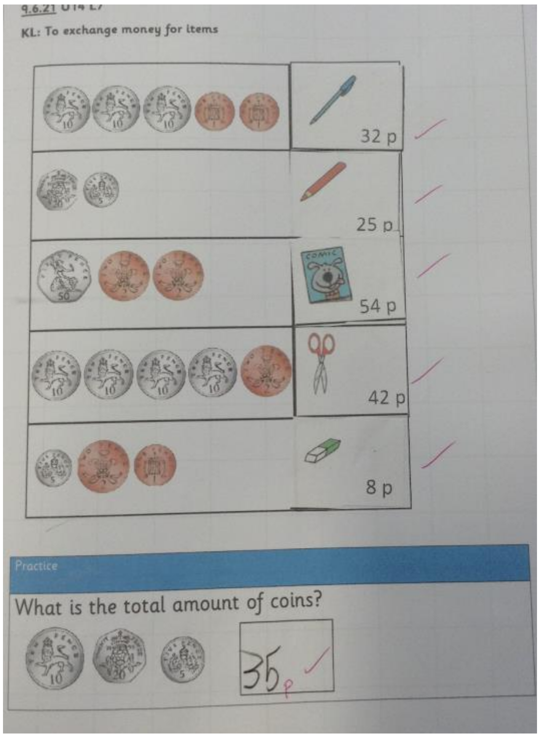
Although there was adaptation to the mathematics lesson delivery, in terms of pre-teaching, simplification of language and adaptations to slides, when it came to pupil work, there was often no differentiation and pupils with SLCN and those who were TD were usually asked to do the same tasks. Figure 4 shows an example.

Figure 4 -Pupil work from a lesson on money, 'Best Street' Primary

1) SLCN child

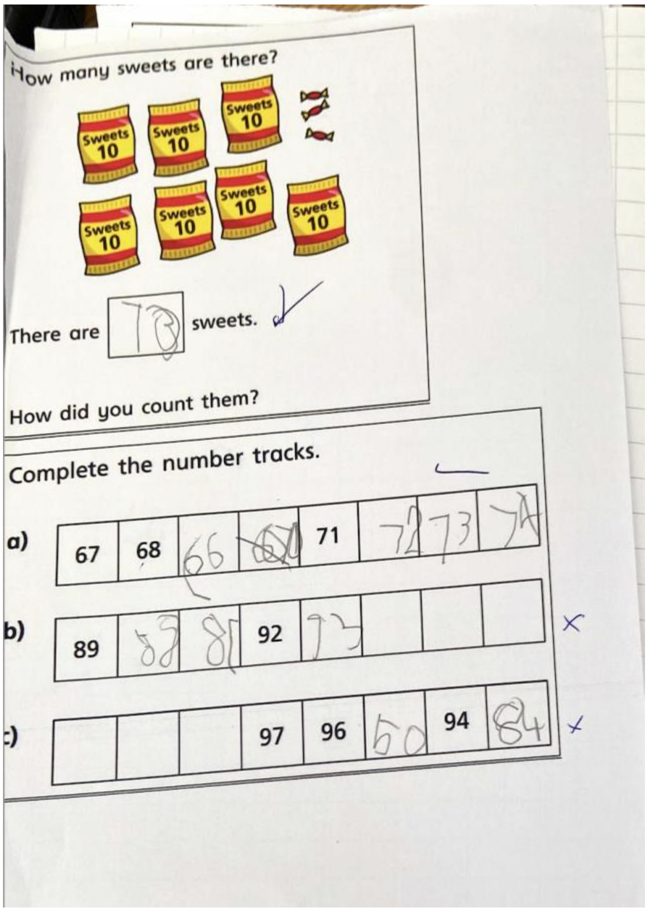
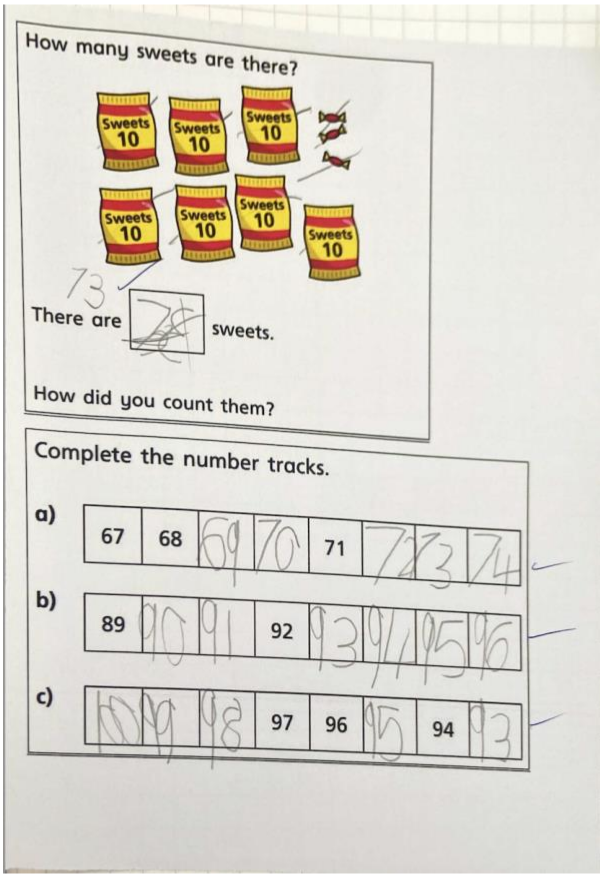


2) TD child, same lesson



Sometimes there was an expectation that fewer questions were answered or that a TA would work with the children; this was usually annotated on pupils' work where this was the case. In some instances, pupils completed work independently without adult support and this resulted in incorrect answers, in those cases where pupils lacked strategies to complete tasks. An example is given in Figure 5.

Figure 5 -Pupil work from a number lesson, 'Ashwood Primary'

1) Child with SLCN	2) TD child, same lesson
	

4.6 Summary

It was clear from the interviews and teacher planning that the children with SLCN needed additional support in order to maintain the mathematics national curriculum expectation of keeping the whole class together. It was also apparent, however, that teachers had not had additional training to support them to address these specific learning needs of pupils with SLCN in their teaching. Scrutiny of pupil work showed that there was little differentiation in terms of the work pupils with SLCN were asked to do compared to their TD peers. Teachers were, however, confident teachers of mathematics, and all were or had been involved in projects with their local maths hubs or with other mastery projects. Discussion of these findings will follow in Chapter 5.

Chapter 5 – Discussion

The overall aim of the research was to explore effective teaching in mathematics, considering specific areas of mathematical difficulty for KS1 pupils with SLCN in schools that used a mastery approach to teaching mathematics. Limited evaluations of mastery approaches to teaching have previously been carried out, and none have considered their impact on pupils with a SLCN. This concurrent mixed-method design sought to compare pupils with SLCN with gender-matched TD peers on a reasoning and an arithmetic test and to explore teacher views of effective teaching strategies and particular difficulties faced by those with a SLCN, enriched through discussion of their planning and pupil work.

This chapter first discusses the findings from the quantitative and qualitative research and interprets these in line with evidence from previous studies. The findings are drawn together and a summary of the common themes will be given. The chapter concludes with recommendations and a link to practice.

5.1 Key findings for RQ1

How do children with SLCN perform on a mathematics task with high language demands compared to one with lower language demands and how does their performance differ compared to TD pupils in terms of error type, overall score and reaction time?

This research question sought to explore the difficulties experienced by pupils with SLCN and their TD peers, by comparing their answers, reaction times and errors on a mathematics task with a high language demand (a reasoning test) with those of a low language demand (an arithmetic test). Questions were analysed quantitatively with qualitative discussion of six questions where there were large differences in the percentage of questions answered correctly by the two pupil groups.

5.1.1 Limitations to testing

Before discussing the findings, it is important to note that there were some limitations to the tests used and the way they were presented online. The tests were used as a tool to examine pupil strategies and difficulties in mathematics tasks that were language based (the reasoning test) compared to one that was numerical only (the arithmetic test). They were used during a time of Covid-19 lockdown, when face to face visits to schools were not allowed and therefore do not seek to replicate usual classroom practice. In addition, the tests used in this research represent those typically used in schools by teachers, rather than being specifically designed for psychological testing, hence the results from one test are not directly comparable to the other. The reasoning paper questions do not directly mirror those used in the arithmetic test, for example, since individual questions did not test the same mathematical concept across papers. The tests were originally designed to be used in schools at the end of the spring term in year 1, as a summative test at the end of a prescribed programme of study, comprising some of the year 1 national curriculum objectives for mathematics. It is acknowledged that they were used in a different context in this research and hence have limitations.

5.1.2 Arithmetic test

The arithmetic paper consisted of ten items (Appendix 10). Worded questions were read aloud to the children, to ensure none were penalised for weaker reading ability. Overall, despite the difficulties on some questions on the arithmetic paper, the performance of pupils with SLCN was not significantly different to those who were TD. This would appear to back up findings from Donlan (2007) and Fazio (1994, 1996, 1999) that arithmetic principles are not necessarily impaired in pupils with SLCN, as they may be linked to intact mental models of number. The difference in the performance of the two groups at a question level will now be discussed.

There were some difficulties noted in reading the questions aloud. Question 4, for example, 'Add together twelve and six', a question matching the year 1 national curriculum objective "count, read and write numbers to 20 in numerals and words," (DfE, p.6), did not assess this objective when read aloud. Instead, it merely assessed pupils' addition skills within 20. Since the aim of testing was to investigate children's strategies and to compare outcomes between TD pupils and those with SLCN, this was not thought to invalidate the research outcomes. However, neither pupil group performed well on this question, with 38.46% of pupils with SLCN getting the question correct, against 40% of TD pupils (Table 6). It could be that neither group were used to seeing arithmetic questions presented in this way, being more used to seeing a written equation. The national curriculum non-statutory guidance for key stage 1 suggests that pupils should

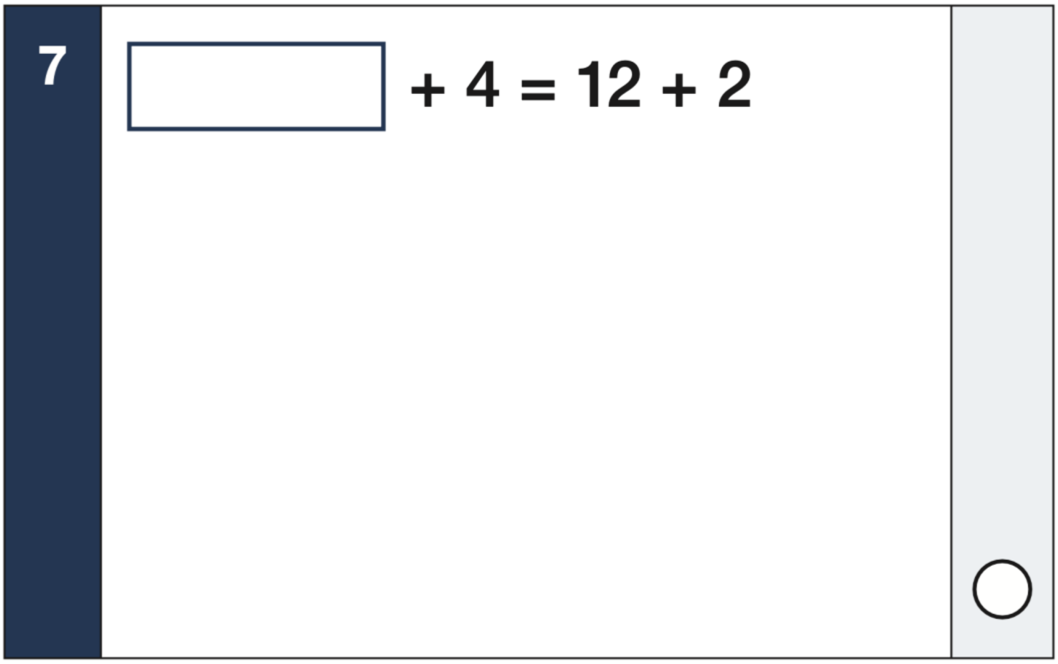
> "…discuss and solve problems in familiar practical contexts, including using quantities. Problems should include the terms: put together, add, altogether, total, take away, distance between, difference between, more than and less than…" (DfE, 2013, p.103).

For this group of pupils, who had had a disrupted education due to Covid, it is possible that this language was not yet familiar.

However, question 8 on the arithmetic test, ‘12 is one more than $\boxed{}$ ', designed to test the year 1 national curriculum objective “Given a number, identify one more and one less” (DfE, p.6), is more than a purely numerical arithmetic question as it included additional quantitative language, ‘more than’. It is noteworthy that only four of the 13 pupils with SLCN (31%) got this answer correct, compared to 10 of the 15 TD pupils (67%) (Table 6). Given that overall pupils’ scores on the arithmetic paper showed no group difference between pupils with SLCN and those who were TD, the larger difference in the correct answers between the two pupil groups on this question may have been due to the quantitative mathematical language contained in the question, given that this is highly correlated with mathematics ability (Kung et al., 2019).

In line with the year 1 national curriculum objectives, the arithmetic test assessed pupils’ number skills to 20 using a variety of simple addition and subtraction questions, but also included some missing number type equations, with which pupils may have been unfamiliar or not developmentally ready for. This may have particularly been the case for this group of pupils, who had missed significant schooling due to two Covid lockdowns and who therefore had gaps in learning. An example, question 7, is shown below as Figure 6. Unfamiliarity with the style of question layout may explain why both groups had fewer correct answers on the arithmetic test than the reasoning test. No child with SLCN got the correct answer to question 7, and only four out of the 15 TD children (see Table 6).

Figure 6 -Arithmetic paper question 7, 'missing number' equation



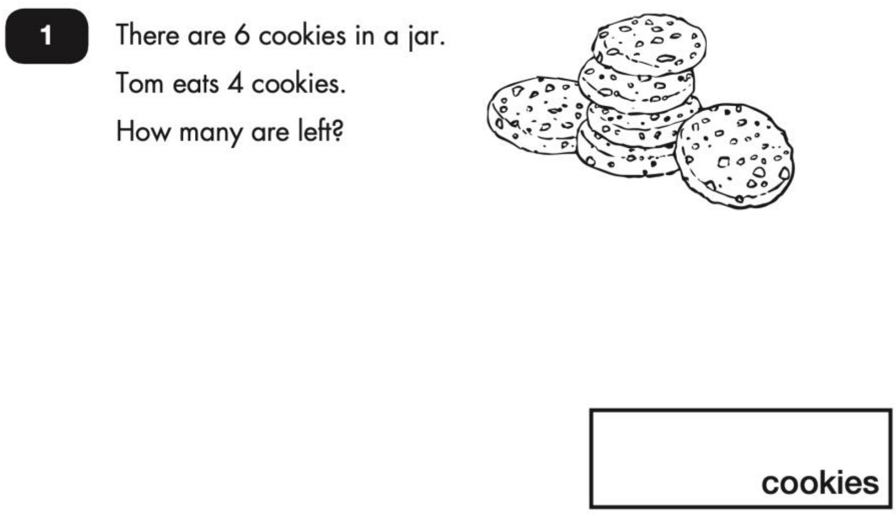
Considering the response times in answering questions, both participant groups were significantly slower in their answers per question on the arithmetic test than the reasoning, for both their correct and incorrect answers. This could be because neither group had yet learned number bonds to automaticity, and so had to resort to inefficient methods of working out, taking more time to answer each question. This would appear to be comparable to findings by Swanson et al. (2013), who found that pupils with high working memory, whether they had mathematical difficulties or not, performed better on arithmetic tasks than those with a lower working memory. This has implications for teaching both pupil groups, since learning number bonds to automaticity would reduce the load on working memory and lead to more accuracy in solving problems, since calculations do not have to be worked out afresh each time. It would also appear to support Ding et al.’s findings (2017), which noted the links between low working memory and tasks involving low automaticity and pupil response times, in which pupils were slower and showed less accuracy than on tasks in which they could retrieve schemas (a framework for solving problems) with a high degree of automaticity.

Turning now to error types, both groups made more computational errors on the arithmetic paper (where the response was within 2 of the correct answer and the correct operation was used to solve it) than using another error type. The use of computation error was not significant, either for TD pupils or those with SLCN. This suggests that pupils understand the correct operation to use, but because number facts are not learnt to automaticity, errors are made in the working out. However, pupils with SLCN made significantly more errors coded as ‘all other errors’ on the arithmetic paper than TD pupils. ‘All other errors’ is used as a term in this research to describe a strategy that includes ‘wild guessing’, where answers bear no relation to known facts or use familiar or logical strategies to work out the answers, as well as wrong answers where addition strategies were used to solve a subtraction equation, or vice versa. This suggests that, since pupils with SLCN may have not learned number facts to automaticity, they cannot draw on mental schemas to support them and so may resort to wild guessing, drawing a number ‘out of the air’ to fill in an answer.

5.1.3 Reasoning test

Moving on now to discuss performance on the reasoning test: this test comprised 14 items, as some questions were split into multiple parts (Appendix 11). The questions were not of the kind normally associated with reasoning, defined as “following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language” (DfE, 2013, p. 3). Testing pupils’ reasoning skills was not part of this research design, however. For the purposes of this research, the questions instead provided a useful comparator for the two pupil groups with some questions being language heavy with others being capable of being worked out using known facts. The item comparison between the two pupil groups indicates that where language demands were greater, fewer pupils with SLCN got correct answers than their TD peers. For example, question 1, shown below as Figure 6, was an example of a typical word problem involving subtraction.

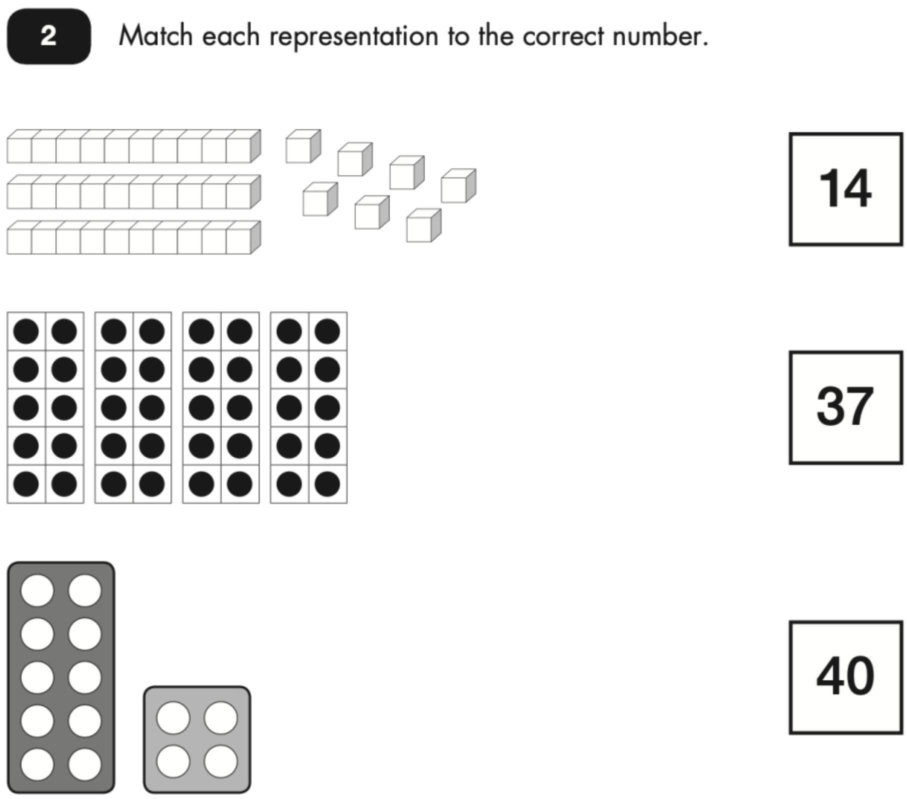
Figure 7 - Question 1, reasoning paper



This question was answered correctly by 6 out of 13 pupils with SLCN, 46%. However, 12 out of 15 TD pupils answered the question correctly, 80%. This suggests that, although the picture of 6 cookies could have been used to solve the subtraction equation, the language demands of the question perhaps meant that children with a SLCN were less able to access it, or to know it was a subtraction problem. It will be recalled that worded problems were read aloud by the researcher and hence children with SLCN may have been impeded by the questions being presented verbally, in line with findings from Cross et al. (2019, p.160), who concluded from their review of the research of pupils with Developmental Language Disorder that having the condition negatively impacted pupils' performance on "verbally mediated mathematical tasks".

Question 1 serves as an interesting comparison to the three parts to question 2, shown below as Figure 8. This question was designed to test responses to the objective "Identify and represent numbers using objects and pictorial representations" (DfE, p.6). The instructions were read to the pupils, but the familiar visual images here supported pupils' understanding of the question. Review of the video footage showed all pupils approached this question with confidence and completion times were not significant for the two pupil groups (Table 5).

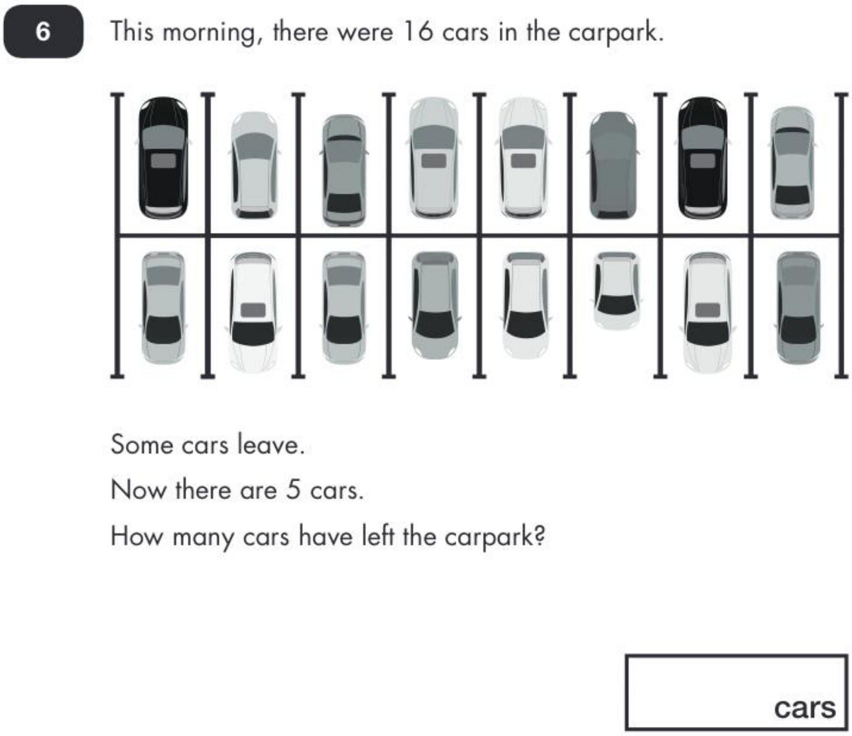
Figure 8 - question 2, reasoning paper



The images of Numicon, Dienes apparatus and tens frame representations of these numbers were obviously familiar to the children since 12 out of 13 (93%) pupils with SLCN and 14 out of 15 (93%) TD pupils answered the first part correctly (matching the answer 14), for example, with similar responses for the other two question parts. This suggests that, in the absence of concrete apparatus and where familiar pictorial images are used to support children, the language demands of the question do not cause difficulty. This perhaps supports Merttens's view (2012) that concrete apparatus has validity if the image or model can support pupils in carrying out an activity independently.

Considering further the individual question responses on this test, there were particular difficulties with items 3.1. and 6. The number of correct responses to these two questions by pupils with SLCN were significantly different from TD pupils' correct responses, which will be discussed in detail below. Figure 9 shows question 6 on the reasoning paper.

Figure 9 - Question 6, reasoning paper



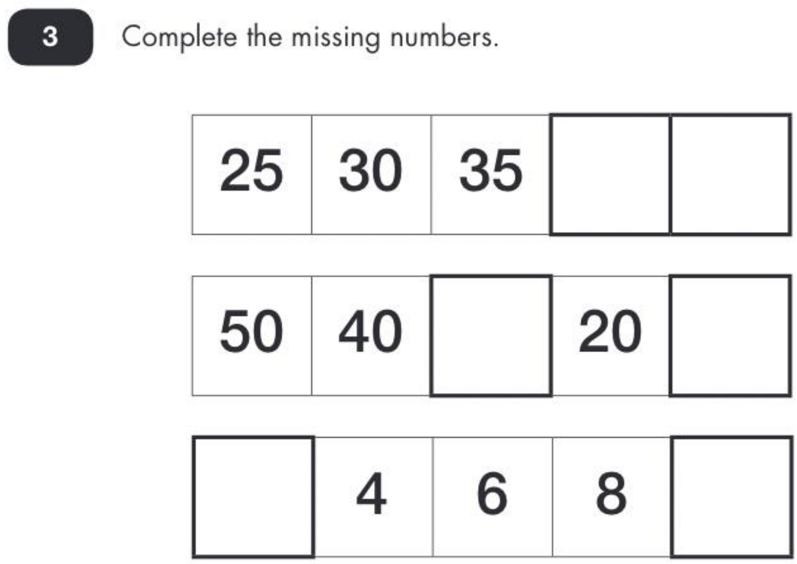
This question corresponds to the Y1 national curriculum expectations that pupils should:

> "Represent and use number bonds and related subtraction facts within 20, add and subtract one digit and two-digit numbers to 20 including zero; solve one-step problems that involve addition and subtraction, using concrete objects and pictorial representations, and missing number problems such as 7 = x – 9" (DfE, 2013, p.7).

This missing number (algebra) problem, 16 - x = 5, is in the same vein as the national curriculum example given above. It is also accompanied by a potentially helpful picture. TD pupils that answered this question correctly often resorted to using the picture and crossing out 5 cars to leave 11 remaining (16 – 5 = 11), showing their ability to manipulate the equation into one that could be solved easily, based on an understanding of related number facts. This approach was not generally used by pupils with SLCN. Instead, they often resorted to 'wild guessing', with no particular logic to their wrong answers. Considering the reasons why this question may have proved so difficult for pupils with SLCN, this is a ‘change unknown’ problem, suggested by Clements and Sarama (2012, p.220) to be “moderately difficult” for all children. A precursor for learning at this stage is having a secure understanding of part-whole models and is generally not reached until the age of six (Clements & Sarama, 2021). For those with SLCN, it has the additional complication of being couched in language, with the numbers and mathematical operation embedded within the question structure. The questions were read aloud by the researcher and so pupils had to listen to the words, listen to the numbers used, look at the picture and try to work out which calculation they were being required to do. This could have led to cognitive overload, with high language demands competing with other items in the working memory. As pupils with SLCN often have difficulties with working memory, and, as teachers had indicated the need to simplify the language used for these pupils, it could be that this question was beyond their linguistic capabilities, rather than their mathematical capability. It could also have been that the language used is confusing, with changes to tense (“There were 16 cars; some cars leave; how many cars have left the carpark?”) and mathematical operation being unclear (‘have left/are left’).

The other question on the reasoning paper that was answered significantly less well by SLCN pupils than those who were TD, was the first part of question 3, 3.1, shown below as figure 10.

Figure 10 - Questions 3.1, 3.2 and 3.3, reasoning paper



3 Complete the missing numbers.

25	30	35		
50	40		20	
	4	6	8	

This corresponds to the national curriculum expectation that year 1 pupils should "count in multiples of twos, fives and tens" (DfE, 2013, p.6) and therefore should be within these pupils' capabilities. However, the question required children to start the count at 25, count forwards in 5s and know the next two numbers in the sequence. It could be that pupils were more used to counting in 5s starting from 0 or 5 and were not used to counting on in 5s for any number. It could also be that their number recognition beyond 20 is not secure. The pattern 2,4,6,8,10 was more familiar, as well as using numbers to 10, and pupils appeared to be able to rely on rote learning to complete this sequence, drawing on prior knowledge. It could therefore be that children had rote learned the number pattern of counting in twos, a relative strength in SLCN pupils (Lum et al., 2012) and could follow the regular pattern counting backwards in 10s. However, it does suggest that pupils with SLCN may lack problem-solving strategies when presented with an unfamiliar exercise. It is possible that pupils with SLCN may not have committed the number sequence of counting in

5s to memory, and so were more reliant on numerical reasoning skills to work it out, with this being an area for weakness for pupils with learning difficulties including SLCN (Hunt & Silva, 2020).

Neither pupil group's errors indicated they had difficulties with reversal place value. Donlan and Gourlay's findings (1999) suggested that pupils with SLCN struggle when double digit numbers are reversed as in 24 and 42; however, from this very limited sample, the same finding was not replicated in this research. The only 'place value' problem was question 2 (Figure 6), which potentially could have had a difficulty with 14 and 40 not being recognised. However, pupils with SLCN performed as well as TD pupils on this question, possibly due to the image of familiar manipulatives. There were also almost no instances of pupils writing two-digit numbers confusing the tens and ones column. No child with SLCN made these errors on either paper and there were only two instances from a child described as TD.

The category 'all other errors' could not be applied to some questions testing measures, which either had an either/or answer, such as questions 2 and 10 on the reasoning paper. These asked the respondents which of two items was the heaviest and which child had the most juice in their cup. This limitation to the study meant that 'number' questions on both the arithmetic and reasoning papers were more likely to have been coded as 'all other errors' than language questions and therefore findings need to be interpreted with caution.

5.1.4 Comparing pupils' performance on reasoning and arithmetic tasks

Considering pupil performance on the reasoning paper used in this study, the language of some questions proved to be challenging for pupils with SLCN. Pupils with SLCN achieved significantly less well than TD pupils on the reasoning paper but not the arithmetic paper, although their scores on the arithmetic paper are lower overall. Considering the reaction times for pupils with SLCN on the reasoning paper, their responses were slower than TD pupils on items answered correctly, but this was not to a significant degree, nor were their reaction times for incorrect answers significant. This suggests that it is the language used in the reasoning test that makes them perform less well, rather than the mathematics used. Daroczy et al. (2015) suggested that mathematical problems with both linguistic complexity and numerical complexity draw on the same resources, such as working memory to reach a resolution, and that a combination of both linguistic and numerical demands together may result in too heavy a demand on working memory. This may be one explanation for the comparative difficulty pupils with SLCN found in answering questions on the reasoning paper compared to their TD peers, as poor working memory has been found to be impaired in pupils with SLCN (Archibald, 2017).

This supports the hypothesis that it is their language difficulties that impair pupils with SLCN's ability to successfully complete tasks that are language-heavy, rather than their mathematical ability. This is similar to the findings of Vukovic and Lesaux (2013) who found from their study of 6-9-year-olds that language ability is not involved in learning how to manipulate quantities and execute algorithms, for example those found in algebra and arithmetic, but is involved in how children learn to make meaning from mathematical content, in other words, reasoning. Reasoning can therefore be seen to be a language-based action, with language being needed to develop pupils' thinking and to communicate it with others (Bragg et al., 2016). Arithmetic and algebra, however, draw on the same cognitive resources, with foundations in arithmetic predicting later success in algebra (Fuchs et. al., 2012).

Unrelated to any language difficulties pupils may have, the second issue that emerged on both the arithmetic and reasoning papers is the error type coded as ‘all other errors’, which included the use of ‘wild guessing’. Despite the limited way this category could be used on the reasoning paper, due to fewer questions being able to be coded in such a way, consideration of error types suggested that the use of ‘all other errors’ was of near significance for the pupils with SLCN, rather than their computational errors, which did not differ from TD pupils. This may be because pupils with SLCN lack specific strategies to answer questions and so resort to ‘wild guessing’, which has the effect of keeping their reaction times on a par with TD peers. Pupils with SLCN used this strategy to a significant degree on the arithmetic paper and a near significance on the reasoning paper, compared to TD pupils. It is important to note that pupils were not asked by the researcher why they had arrived at a particular answer, so this strategy is open to interpretation. Nevertheless, it is worth exploring why guesses that were very wide of the correct answer may have been used to such an extent by pupils with SLCN, although less so for TD pupils.

Teachers indicated in the interviews that they used manipulatives daily for all children, although they commented that not all pupils with SLCN knew how to use them. In a situation such as this under test conditions, working out questions in an unfamiliar context, online with an unknown researcher with no manipulatives provided, pupils with SLCN lacked strategies to tackle problems and could not draw on known number facts to help them resolve problems quickly and easily.TD pupils, on the other hand, often ‘knew’ answers very quickly, or could set about working it out if they did not. Although all pupils could use fingers, jottings or any pictorial clues to help them, many pupils with SLCN in particular were reluctant to use any of these, despite prompting by the researcher. Video footage showed some children furtively counting on their fingers under the table, for example, ‘out of sight’ of the adults present. It is possible that they had been discouraged from using their fingers by class teachers, one of whom indicated that she was trying to get children to subitise instead: “So we have been doing the things like subitising and trying not to count on your fingers.” As all teachers made extensive use of commercial manipulatives, it is possible that the use of fingers may have been overlooked by teachers as a convenient resource and certainly as an important developmental stage in learning mathematics rather than something to be supressed. Indeed, there is evidence that there may be a neuro-functional link between fingers and number processing (Berteletti & Booth, 2015), with a tactile representation of one-to-one correspondence. Fingers also neatly show an emerging base 10 system, representing numbers as a sum or multiple of 10. Stegemann and Grunke (2014, p.193) argue that:

> “Thus, finger-counting is not an unwanted phenomenon during the development of mathematical skills in children that parents and teachers should suppress, but a normal and healthy intermediate step on the way to building complex problem-solving abilities.”

It is also possible that the use of fingers for calculations reduces the demand on working memory, since the fingers remain as a visual reminder when carrying out arithmetic calculations (Stegemann & Grunke, 2014) and their use may have supported pupils to reach the correct answers on the arithmetic and reasoning papers.

Another possible reason for the use of ‘wild guessing’ as a strategy by pupils with SLCN on both papers is the lack of strategies at their disposal and the lack of understanding of what to do next, suggesting difficulties with metacognition. As metacognitive processes develop strongly between the ages of 5 and 7 (Bryce & Whitebread, 2012), it is possible that children in this study, especially as they had missed school because of Covid, may have had limited understanding of these processes and had an inability to draw on them in solving problems, in both arithmetic and reasoning; hence they resorted to 'wild guessing'. Metacognitive knowledge about strategies includes knowing where and how to use them; this knowledge leads into self-monitoring of one's understanding of the task and to regulate one's usage of that strategy (Garofalo & Lester, 1985). Motivation and resilience are also key factors in metacognition, and both are crucial in developing metacognitive skills for mathematics, particularly in solving problems (Schoenfeld, 1992). Mathematical task knowledge is said to be both a belief of the subject of mathematics and beliefs about the nature of mathematical tasks. Mathematical strategy knowledge includes knowledge of algorithms but also strategies to comprehend problem statements, planning to carry out the solution and checking answers (Garofalo & Lester, 1985.; Schoenfeld, 1992). However, because metacognitive knowledge in its widest sense also involves attitudes and emotions (Lucangeli et. al., 2019), it is important to consider this in relation to mathematics, since anxiety can also have a dampening effect on working memory (Ashcraft, 2002). Although this has only a modest effect when carrying out simple addition and subtraction calculations, anxiety increases the more complex the calculation e.g., column addition. Anxiety is also present when young children fear failure (Dowker et al., 2019), which could have been the case with this testing, due to an unfamiliar context (carrying out the task online) and with an unfamiliar adult. Additionally, there is some evidence that students with learning difficulties in mathematics lack self-monitoring. A study by Kingsdorf and Krawec (2014) found that errors made by 13-

and 14-year-olds in solving mathematical problems included the use of what they termed ‘random errors.’ These, they postulated, were the result of a lack of self-monitoring as a metacognitive strategy. Students with learning difficulties used this strategy significantly more often than matched TD peers and this increased in frequency the harder the problems became. Kingsdorf and Krawec (2014) suggested that these pupils lacked awareness of their difficulties and could not draw on skills to address them. This supports the findings from this research, that pupils with SLCN were not able to draw on metacognitive strategies to support their learning and hence resorted to wild guessing, particularly when answering questions on the reasoning paper.

5.2 Key Findings for RQ2

This question sought to enrich the findings from the quantitative data collection through exploring the views of teachers in the case study schools. Its aim was to explore more fully some of the issues experienced by pupils with SLCN in mathematics classrooms and how teachers adapt their planning to take account of pupil needs, as well as exploring what teachers in the case study schools described as effective practice in teaching mathematics.

How does teacher understanding of effective mathematical pedagogy influence the planning of mathematics lessons to meet SLCN pupils’ needs?

Teachers’ views were gathered through semi-structured interviews, with examples of teacher planning and pupil work to inform the questions asked.

5.2.1 Effective pedagogy

Teacher understanding of effective pedagogy has been categorised based on the characteristics of effective teachers given by Husbands & Pierce (2012), Siraj &

Taggart (2014) and Coe et al. (2012). Teachers in this study revealed a good understanding of effective mathematical pedagogy, including mastery approaches aligned with the expectations of the national curriculum. This is perhaps unsurprising given that all were involved in work with an NCETM maths hub or in mathematics CPD through their academy chain, indicating a willingness to explore and improve their practice. All used flexible groupings, intervention groups to allow pupils to catch up, manipulatives to support pupils with their mathematics, and had adapted the language used for pupils with SLCN. Lesson time had been broken up appropriately for the age of the children, although teachers noted how their usual teaching methods had been affected by Covid. Most schools in this study had reverted to sitting children in rows and had minimised movement around the classroom. Teachers were aware that this temporary measure did not represent good primary practice.

5.2.2 Assessment for learning

'Assessment for learning,' or formative assessment, is that which takes place in the moment, making use of assessment strategies such as questioning and constructive feedback. This has been found to be a powerful driver of improvement in learning, more so than summative assessment or formal tests, particularly for lower attaining pupils (Black & Wiliam, 1998; Hattie & Yates, 2013; Hattie and Clarke, 2018). This may be because the more immediate feedback helps to maintain motivation and helps pupils to see themselves as successful learners. Pupils do not compare themselves unfavourably to others and are therefore more likely to remain on task and less likely to become disruptive (Black & Wiliam,1998). The assessment for learning strategies described by teachers in this research would seem to be broadly in line with these effective practices. Teachers spoke enthusiastically about how they grouped pupils, using lesson time flexibly to check for misunderstandings and to pick up specific pupils with difficulties, offering additional support if needed or remodelling using different mathematical manipulatives. Groupings were not fixed in any of the classes studied but varied depending on teacher assessment of pupil understanding, using marking to check for understanding, ‘checking in’ with pupils at various points during the lesson as well as through their marking of pupil work at the end of the lesson. (“If they’ve got any wrong answers we’ll do green pen work”; “we’ll mark in the lesson”). Marking, however, as noted on the samples of pupil work sent, revealed little indication of pupil next steps, nor an evaluation of a child’s understanding of the mathematical topic covered and tended to note merely whether answers were correct or incorrect. Additional support was often provided by teacher or teaching assistant support during or following the lesson, to enable children with SLCN to keep up with their peers, in line with the national curriculum requirements. Of note, however, was the lack of probing questioning to elicit understanding, the use of which was cited by only one teacher. Questioning has been found to be highly effective in promoting pupil progress. Husbands & Pierce (2013) for example, characterised ‘excellent teachers’ as being able to embed assessment for learning through good use of dialogue and questioning. This would appear to be an important omission, although would need to be backed up by classroom observation, since teachers may simply not have mentioned it, taking it as implicit in their practice.

The marking of pupil work did not identify specific difficulties faced by pupils with SLCN when working independently, nor did teacher assessment feed back into teaching design for these pupils. Teachers instead tended to focus on specific teaching and catch-up strategies on pupils that needed support, including those with a SLCN, rather than adapting their lesson design to take these pupils’ needs into account. There was little evidence of how pupils with SLCN were treated differently from other children with learning needs. Adaptations cited were the same for all pupils with difficulty.

5.2.3 Adaptation of language

There were many instances of teachers adapting and simplifying the oral and written language used for pupils with SLCN, with teachers describing how they adapted pre-prepared lesson slides, focused only on key words and practised vocabulary development through ‘talk tasks.’ This was confirmed by planning scrutiny. A domain-general weakness identified by teachers in interviews was the need for repetition of key vocabulary in order to get children to embed this into their lexicon. Teachers gave several examples of supporting written language using symbols or pictures to illustrate meaning, of removing text from slides and doing what was described by one teacher as ‘over-modelling’ of language, to combat this difficulty. The use of images such as those found on specialist IT programs for pupils with SEN may support pupils in the use of ‘dual coding.’ Dual coding, first coined by Paivio (1971) has since been developed and extended. Dual coding assumes that non-verbal and verbal memory systems are independent of one another, and that any given word can evoke numerous images. Images (non-verbal) and descriptors (verbal) depend on functional connections between the different elements of each memory system; one system triggers activity in the other, without them being physically inter-connected. When pictures and words are combined, similarly to when retrieving information previously learned, new connections are made (Paivio,1986). Thus, dual coding can relieve the load on working memory, with pupils using symbols or pictures to trigger the other memory system. In the mathematics lesson, this might involve the use of pictures of representations, such as Numicon images alongside numerals, or of an image next to a mathematical problem to put it into context. As working memory has been found to be a specific difficulty for pupils with SLCN (Archibald, 2017), strategies such as these indicated here may help. The reduction and simplification of language cited by the case study teachers is also important in supporting the learning of pupils with SLCN. Strategies such as the simplification of language support the phonological loop aspect of working memory, in which memory traces are held only for a few seconds before fading. As immediate memory decreases with words of more than one syllable, and as retrieval and re-articulation are used to strengthen memory traces (Baddeley, 2003), keeping vocabulary simple and rehearsing these repeatedly supports those pupils with SLCN.

5.2.4 Lesson structure

Lessons were broken up into smaller units of time, with whole class teaching, individual and group teaching taking place as required. This was seen on teacher planning as well as described in interviews. Teachers described how they took great care to keep children interested, motivated and on task through the provision of short activities. These had had to be adapted due to Covid and social distancing restrictions, with teachers relating how they normally would have moved these young pupils to the carpet and back to desks but were now in the majority of cases constrained to keeping them at their desks. They were thus especially careful to break up the lesson structure to maintain children's attention, using paired work, whiteboard work and teacher exposition. Physical breaks, standing up and sitting down again, were also used by teachers to maintain pupil concentration levels. Teachers tended to keep lesson segments to a maximum length of around 10 minutes. These strategies reflect some of the features identified in Husbands and

Pierce's summary of effective teachers who used… "a range of techniques, including whole-class and structured group work, guided learning and individual activity" (2012, p.3) and Siraj and Taggart's (2014) good use of lesson time. All teachers made use of direct instruction as a mode of teaching, comprising a clear lesson structure with modelling, questioning and feedback. This could be seen from their planning as well as being referred to in the interviews. Guided play was not used as a learning strategy, although it is probable that direct instruction was used more heavily than usual because of Covid-19 restrictions, with one teacher referring to the fact that normally she would have used continuous provision in her year one class, the lack of which "had been hard this year". Although direct instruction, as a component of effective teaching, has been found to be of particular benefit in teaching rules, processes and basic skills, especially those from more disadvantaged backgrounds (Muijs & Reynolds, 2018), guided play has also been found to have a small to medium positive effect on numeracy outcomes (Skene et al., 2022). It is therefore important that for children in year one, lesson structures should normally include both direct instruction and guided play.

5.6.4 Mastery approaches

Although there are differences in how mastery in mathematics is defined, this research has used definitions from NCETM (2016) and Drury (2014; 2018). Thus, mastery in mathematics can be seen as procedural fluency with conceptual understanding being developed together. Conceptual understanding is deepened through concrete apparatus and pictorial representations being used to strengthen understanding and build connections between areas of mathematics. Mastery is achieved after full exploration of concepts, clarification, practice and application has been made, with pupils able to apply their learning to a different situation. Teachers have a high belief in pupil success. This definition builds on earlier work by Askew et al. (1997) who found that the interplay between teacher beliefs, practices, PCK and pupil outcomes are interconnected, with changes in practice impacting upon teacher beliefs, and showed how having high expectations and a belief that mastery techniques work could result in a change to the classroom practice. Teachers in this research were confident in their use of mastery techniques with those who explicitly referred to using a mastery scheme tending to be positive about its benefits in raising attainment: “The maths mastery scheme was the best way to do that”. This reflected the findings from Jerrim and Vignoles (2016) that mastery programmes tended to have more impact when they concorded with teachers’ prior beliefs.

All teachers explained how they taught the class the same content, using mathematical resources such as hundred squares, number lines and bead strings to support pupils, along with interventions such as pre-teaching vocabulary and post-teaching using additional practice to help some children keep up. One teacher spoke of not “having to cap what they learn; they can all learn the same thing” and others suggested all children needed to progress at the same speed. This was confirmed from the teacher planning scrutiny, showing an understanding of one of the aims of the mastery teaching approach from the NCETM, namely that of having high expectations for all and a rejection of the idea that some people are unable to do maths (NCETM, 2016). Four out of five teachers in this study used mixed attainment pairs to group pupils rather than the use of in-class ability groupings. In these cases, pupils with SLCN were seated next to a more confident speaker who might be a more positive role model, although some pupils were grouped randomly or alphabetically. Despite the advent of mastery approaches, grouping by ability remains common both at secondary and at primary school (Francome & Hewitt, 2020), although there are negative reports about its use, particularly for middle and lower attaining pupils (Barclay, 2021; Bradbury, 2019). It was therefore encouraging that teachers in this study maintained high aspirations for all pupils and resisted grouping pupils by 'ability' within class. This could have been as a result of the whole school culture and ethos, which was not explored here.

The relative deprivation of most of the schools used in the research meant teachers were aware of the need to catch children up to where they should be against national norms, from very low starting points. However, these observations were made in a general way about all pupils in the class, rather than being specifically about pupils with SLCN. It was also of note, from analysis of pupils' independent work, that there did not appear to be many adaptations for pupils with SLCN; they tended to complete the same work as more TD pupils, but with adult support or additional resources, often noted on their work. Teachers reported using mathematical manipulatives for all children, for example, not just those with SLCN. Some indicated that because of a domain-general weakness, namely their poor organisation skills, with difficulties in selecting and using correct mathematical equipment, these manipulatives were often given to pupils with SLCN in prepared packs as their own individual set, rather than pupils having to select the appropriate resources themselves. This may also have been a result of Covid-19 restrictions and pupils not being able to move around the room as freely as before to select and collect their own equipment. Houssart (2004) noted that the use of what she termed 'number equipment' may help lower attaining pupils, as they can carry out calculations without having to record their answers and their use may also help to reduce worries, although this support strategy was of most use when it was used regularly. The children with SLCN in the case study schools all used mathematical equipment to support them with their number work. However, on both the arithmetic and reasoning tests, pupils with SLCN lacked strategies to help them to work out answers, resorting more frequently to ‘wild guessing’ than their TD peers. This may have been because the use of manipulatives in class, given as strategies to support pupils by all teachers interviewed, might have led to an over-reliance: when the support was removed, pupils struggled to replicate this strategy on their own using jottings or fingers instead. This would appear to confirm Moscardini’s findings (2009, p.40), that concrete materials such as mathematical manipulatives may be used as a “crutch” rather than a “tool” for pupils, especially those with learning difficulties. He suggests that these pupils over-rely on manipulatives to allow them to carry out procedures, rather than moving onto more abstract strategies, and can hamper their understanding and the development of their mathematical thinking. It could be that pupils with SLCN in this study were over-reliant on concrete manipulatives given to them and hence lacked other strategies to solve problems, leading to their use of wild guessing when these were removed.

There were many positive features of effective mastery teaching described and an awareness of domain-general weaknesses for this group of pupils. Teachers had made adaptations to their teaching strategies because of these. Pupils were also described as having domain-specific weaknesses in particular areas of mathematics, common across the case study schools, which will now be discussed in greater detail here.

5.3 Domain-specific weaknesses

Mathematical domain-specific weaknesses for pupils with SLCN were described by teachers as difficulties in acquiring specific mathematical vocabulary, having an inability to explain mathematical reasoning; difficulties with number bonds, place value and subitising. Considering firstly mathematical language, this may be categorised as both a domain-general variable and a domain-specific variable where the language is content-specific (Purpura et al., 2017). Pupils' difficulties in acquiring a specific mathematical lexicon reflected that described by numerous researchers as being problematic (Landsdell, 1999; C. Leung, 2005*;* Riccomini et al., 2015). Mathematical vocabulary here includes vocabulary used in a mathematical context; determiners such as 'many' and 'few'; spatial language such as 'near' and 'above'; comparative language (e.g. 'combine', 'more', less') as well as mathematics-specific nouns including shapes , ('triangle', 'cube') and specific terminology such as 'graph'. Understanding and using mathematical vocabulary correctly affords access to mathematical concepts and promotes storage and understanding in long-term memory (Riccomini et al., 2015). As children with SLCN are thought to be poor learners of new words (Alt et al., 2014) it is possible that the complex sentence structures and sometimes challenging mathematical vocabulary such as those used in problem-solving are too difficult for children to grasp. For example, question 1 on the reasoning paper was answered correctly by fewer pupils with SLCN than TD, shown earlier as Figure 9. Mathematically specific words here are the word 'left', which might be one such word that could confuse children with SLCN, since it is both a direction and, as used in this case, implies an arithmetic calculation.

It is unsurprising that teachers also cited pupils' difficulties in explaining their mathematics reasoning as a domain-specific difficulty, since this is not only linked to difficulties using mathematical vocabulary but is also related to the nature of mathematics being socially constructed. Pupils' linguistic skills have been said to be a precursor for mathematical learning (Donlan, 1998; Gelman & Butterworth, 2005) and so mathematical learning may be impaired by weak language skills. As more children with a SLCN educated in mainstream schools suffer from expressive than receptive difficulties (Donlan, 1998), it is possible that they may struggle to express themselves verbally to explain their reasoning, although many teachers in this study attempted to support pupils by seating them next to a more confident speaker. This may have had an inadvertently detrimental effect on their mathematical reasoning, however, since the more confident speaker may speak on their behalf, with the child with SLCN remaining a passive partner. Some pupils may develop what has been termed “learned helplessness” (Hattie, 2012, p.112) whereby they become disengaged from learning and rely instead on other children or adults to do the work for them. Mixed attainment pairs therefore should be chosen carefully, rather than randomly or alphabetically as in one of the study schools.

Moving on to discuss mathematical difficulties with place value, cited by one teacher in the study; place value is the term used to describe the value of the digit in the relevant place in a number. For example, the number 342 represents three hundreds, four tens and two ones. It is a complex area and not well understood by many English-speaking primary school children (Fuson, 1990; Ross, 2002). This may be because of the spoken nature of the English language and its irregularities. To illustrate, 16 is written in Hindu-Arabic notation as one ten and six ones yet spoken with the six before the ‘teen’. Many English-speaking children confuse 16 with 60 because of this: they sound similar when spoken aloud yet are written very differently and represent numbers of different magnitudes. For this reason, place value is introduced in year 2 in the English national curriculum, requiring children to understand written and spoken numbers to 20 before moving on to larger numbers and beginning to develop an understanding of regrouping of tens and ones to combine to make different numbers. Pupils were expected though, in the year 1 reasoning and arithmetic tests conducted, to recognise and use numbers to 50 and match numbers to their pictorial representations, which included the numbers 14 and 40, shown in Figure 6. Pupils with SLCN achieved similarly well compared to TD peers on this question, although the pictorial representations using familiar images of manipulatives may have helped. This suggested that pupils have a satisfactory understanding of place value, at least so far as the written numerals and their pictorial representations are concerned. Earlier work by Donlan and Gourlay (1999) suggested, on a test matching spoken to written numerals, that verbal understanding of double-digit numbers place value preceded comprehension and that pupils with specific language impairment did no worse than typically developing peers. It is possible, therefore, that pupils did not have to demonstrate a deep conceptual understanding of place value in this test question, merely matching a pictorial representation to a numeral, which was within their capabilities.

Another domain-specific difficulty cited by teachers for pupils with SLCN was that of number bonds (knowing pairs of numbers to make totals to 20). This was reflected in the quantitative analysis which showed that pupils with SLCN completed arithmetic items, both those marked correct and those marked incorrect, more slowly than their TD peers, suggesting that these pupils perhaps had not committed number facts to memory, slowing their response times (and reducing accuracy) as a result, with calculations having to be worked out afresh each time. There was not the same difference on the reasoning paper, with completion times being similar between groups. Because pupils with SLCN suffer from difficulties with working memory - the temporary storage of information – when this is coupled with undertaking additional cognitive activities such as carrying out an arithmetic equation, working memory becomes overloaded, and they are unable to process information required to complete the task satisfactorily. However, if number facts can be committed to long-term memory, fewer demands on working memory will be made and pupils may be more efficient in calculations (Ding et al., 2017). Ding et al.'s research, although carried out on pupils solving multiplication equations rather than addition, noted that there was a connection between low working memory and tasks involving low automaticity and pupil response times, in which pupils were slower and showed less accuracy than on tasks in which they could retrieve schemas with a high degree of automaticity. However, other research (Lum et al., 2012), has indicated declarative ('knowing that') memory to be intact in pupils with SLCN. They found that number bonds were not easily embedded in long-term memory and so pupils with SLCN were not able to draw on these easily to answer questions. It would appear then, that the issue for this group of pupils is to embed number fact learning into long term memory in order to draw on it to answer arithmetic questions, reducing the load on working memory.

Subitising was another area mentioned by some teachers as being a domain-specific difficulty for children with SLCN, although there was a lack of understanding of this concept, with one teacher suggesting that children should be able to subitise eight objects. Visual or perceptual subitising is defined as the fast and accurate numeration of quantities of between one and four (Katzin et al., 2019), although familiar regular visual patterns, such as those represented canonically as dots on a die, enable quantities to six to be recognised without apparent counting. Subitising is likely to be a pre-cursor to the process of counting and is a useful early number strategy, since it allows larger representations of numbers to be counted more efficiently, through recognising an array through the process of subitising and then counting on from that number (Gelman & Gallistel, 1978). Subitising can also be used in a strategy of what has been termed ‘groupitizing’, where larger quantities comprising groups of dots that can be easily subitised can be counted relatively quickly (Wege et al., 2021) and in combining different values where three dots on one die and four dots on another die are perceptually subitised before combining to make a total, known as conceptual subitising (Sayers et al., 2017). Subitising is linked to the spatial structuring of numbers, comprising the ability to manipulate numbers using a variety of equipment including tens frames and dice. It is unclear why this might be a particular difficulty for pupils with SLCN, although it has been suggested that “linking of number words to the quantity representation system is relevant in counting” (Kroesbergen et al., 2009, p. 234) and hence this may be linked with their language impairment.

5.4 Summary

This discussion has explored each of the themes identified from the analysis of the data, discussing both research questions. Although effective pedagogy was noted, and teachers had a good understanding of pupil difficulties in mathematics and in their general learning, no teacher had had specific training in strategies to best meet the needs of pupils with SLCN. There had not been a noticeable effect on SLCN pupils’ mathematical learning and indeed, pupils with SLCN were found to have significant difficulties on reasoning tasks and in their over-use of ‘wild guessing’ as a strategy, suggesting that they have fewer problem-solving strategies at their disposal than TD children.

5.5 Bringing the research questions together

It will be remembered that this research is of a concurrent, one-phase mixed methods design, in which quantitative and qualitative data are collected and analysed separately and then the findings merged in order to seek connections (Cresswell & Cresswell, 2018). Bringing the two elements of the mixed methods research together presented some challenges. These are shown here in a tabular format (Table 108), drawing together each of the key findings described above, along with possible interpretations and links to practice. Askew et al.'s (1997) characteristics of effective mathematics teachers suggested there was significant interplay between teacher beliefs, practices, pedagogical content knowledge and pupil outcomes and this table has attempted to show the complex nature of teacher input and pupil outcomes with reference to pupils with SLCN. There are also implications for practice at school level and for providers of initial teacher education (ITE).

Table 8 -Summary of key findings, interpretations and links to future practice

Key findings from arithmetic and reasoning paper analyses, teacher planning and interviews	**Possible interpretation**	**Links to practice**
Pupils with SLCN did as well on arithmetic tasks as TD pupils.	Arithmetic skills are not impaired in pupils with SLCN.	Teachers should: Have high expectations that all children can succeed on numerical tasks.
Pupils with SLCN did less well on questions involving language than TD pupils.	Pupils with SLCN struggle when mathematical problems involve language.	Teachers should: 1.Ensure assessment is used accurately to identify pupils' language abilities; 2. Break down instruction into small steps. 3. Use dual coding to support pupils' comprehension.
Pupils with SLCN had mathematical domain-	1.Comprehension and understanding of similar	Teachers should: 1. Ensure numerals are written in words and

specific difficulties including 1. place value, 2. number bonds, 3. subitising, 4. use of mathematical vocabulary and 5. explaining their reasoning.	sounding numbers, e.g. 16 and 60. 2.Difficulties in embedding number bonds into long-term memory. 3.Lack of focus on early numerosity. 4.Pupils with SLCN lack mathematics specific vocabulary. 5.Pupils with SLCN have weak expressive language.	digits, give opportunities for unitising, regrouping and exchanging cubes. Avoid moving onto fixed place value models e.g. Dienes without secure understanding. 2.Build in retrieval practice with spacing of intervals to strengthen knowledge. Avoid over-use of direct instruction: build in guided play opportunities for pupils aged 3-8. 3.Give opportunities to count and enumerate in meaningful contexts with a range of objects. Use dice and dominoes to focus on regular number patterns. 4.Explicitly teach mathematical vocabulary. Seat pupils with SLCN with child with higher oral language ability. 5.Model sentence stems and structures; give pupils with SLCN time to rehearse in context. Give opportunities to reason and solve problems in pairs. Seat pupils with SLCN with child with higher oral language ability.

Pupils with SLCN used the ‘all other error’ strategy more than TD pupils on the reasoning and arithmetic papers.	1.Lack of arithmetic strategies at pupils’ disposal. 2.Difficulties with metacognition. 3.Over-reliance on manipulatives.	Teachers should: 1. Deepen conceptual understanding through conceptual and procedural variation. Use of pictorial representations and concrete manipulatives. 2.Develop motivation and resilience in pupils with SLCN. Frequent teacher feedback including on pupils’ own self-assessment of their work. 3.Encourage use of fingers, multiple pictorial representations alongside manipulatives.
Teachers demonstrated sound understanding of mastery techniques of teaching maths.	Teacher research groups and ongoing CPD in mathematics are having an impact.	Schools should build in time for ongoing classroom research in mathematics.
Teachers adapted their teaching styles to accommodate domain general difficulties.	Teachers have a sound understanding of adaptive teaching strategies for individual needs.	ITE provision should continue to give suitable coverage to adaptive teaching strategies.
Teaching methods did not explicitly cater for those with SLCN. Domain-specific difficulties were not explicitly planned for, and independent work was not always sufficiently adapted to support pupils with SLCN.	Teachers had received no training to identify pupils with SLCN nor specific strategies to support SLCN pupils’ needs.	ITE and in-service CPD should focus on pupils with SLCN, including their particular needs, rather than just on pupils with SEND.
Pupils with SLCN lacked independence in tackling tasks without adult support.	Teachers were over-reliant on teaching assistants and the use of small intervention groups.	Teachers should focus on giving pupils the strategies needed to work independently. The use of mixed attainment paired work would also support pupils.

5.6 Summary and recommendations for future practice

The research has shown that teachers report pupils with SLCN to have a range of domain-specific and domain-general difficulties including problems with working memory and language use; most believed these had impacted on their overall mathematical attainment. In addition, the analysis of test questions showed pupils with SLCN struggled with language-based mathematical problems such as those found on reasoning tests. In particular, they lacked specific strategies to complete reasoning and arithmetic tasks accurately, resulting in unexplained errors rather than using known strategies or number facts. Teachers had a good understanding of effective mathematical pedagogy but had not received specific training in how to support pupils with SLCN. Evidence showed that there was little in the way of specific adaptation for these pupils in mathematics lessons, especially during their independent work. This chapter concludes with recommendations for future practice for teachers, schools and in teacher education, drawing on the key findings given in Table 10.

5.6.1 Recommendations for teachers

1. To develop confidence, motivation and resilience for pupils with SLCN, give frequent teacher feedback and develop metacognitive strategies by giving pupils opportunities to reflect accurately on their own work.
2. To avoid cognitive overload:
   - i) break down instructions into small steps.
   - ii) Use dual coding to support pupils' comprehension.
   - iii) Give opportunities to embed number bonds into long-term memory through retrieval practice. Spaced intervals for retrieval will support this.

3. To develop domain-specific weaknesses for pupils with SLCN:

i) Ensure numerals are written in words and digits

ii) Give opportunities for unitising, regrouping and exchanging cubes

iii) Give opportunities to count and subitise in meaningful real-life contexts with a range of objects including dice and dominoes

iv) Use pictures, concrete manipulatives and fingers as tools and make connections between them.

4. Ensure teaching and assessment strategies are appropriate for pupils with SLCN aged 3-8: avoid over-use of direct instruction and build in guided play opportunities for pupils. To develop spatial skills, teachers should provide opportunities for children to explore mathematics through play, including with 3-D objects and to provide opportunities for problem-solving and reasoning.

5. To develop language skills for pupils with SLCN:

   i) Explicitly teach mathematical vocabulary, including that found in other contexts.

   ii) Seat pupils with SLCN next to a child with higher oral language ability.

   iii) Model sentence stems and structures; give pupils with SLCN time to rehearse in context.

   iv) Give opportunities to reason and solve problems in pairs.

   v) Simplify the language used.

5.6.2 Recommendations for schools

1. To continue to develop teacher confidence in the teaching of mathematics, provide opportunities for professional development including teacher research groups and with maths hubs.

2. To develop teacher confidence in the teaching of pupils with SLCN, provide specific professional development on this area.
3. To develop pupil confidence in approaching mathematical tasks independently, ensure teaching assistants understand its importance.

5.6.3 Recommendations for ITE providers

1. In developing trainees' knowledge on adaptive teaching techniques, ensure coverage is given to the specific needs of pupils with SLCN.

Chapter 6 goes on to summarise the thesis. It will consider the limitations of the research and make recommendations for further study.

Chapter 6 – Conclusion

This conclusion reflects on the research as a whole. It considers its aims, purpose and discusses the claims. It reminds the reader of the conceptual framework and discusses the limitations of this research. It ends with recommendations for future research and debates how the research might be disseminated.

6.1 Research aims and design

This exploratory research has considered effective teaching in mathematics, considering specific areas of mathematical difficulty for year 1 pupils with SLCN educated in mainstream schools following a mastery approach to teaching mathematics. Previous observations on the quality of teaching, along with the researcher's personal philosophy of teaching and learning and low pupil outcomes in mathematics at the end of key stage 2 for this group had indicated that this was an area worthy of further study. It had been aimed to draw together some recommendations for practice to better inform teaching of this increasingly large pupil group in mainstream primary schools and build on work completed for the IFS. Research was carried out during the time of Covid-19 restrictions, with UCL mandating that all research be carried out remotely. The research sought to gather teachers' views and collect detailed pupil data, comparing pupils with SLCN to their TD counterparts using commonly used paper assessments for arithmetic and reasoning. Pupils were also assessed on their language abilities using BPVS.

The research was a mixed methods concurrent complementary design, used to gather data independently and separately before converging for interpretation. The research was set within a pragmatist epistemology, which considers that observation is fallible and that researchers can only approximate the truth (Onwuegbuzie et. al., 2009). Pragmatists believe that theory is linked with engagement with the world and that knowledge is not fixed but can change over time (Denscombe, 2013.; Guyon et al., 2018). Five schools were recruited for this research using purposive sampling, which formed the case study in question. Five teachers were interviewed using a semi-structured interview technique and 28 pupils took part in the testing, which was carried out online.

The theoretical review which informed this research covered the fields of psychology and education. It explored the difficulties faced by pupils with SLCN in learning, particularly in mathematics, the link between mathematics teaching and language, effective pedagogical approaches including the development of teachers' pedagogical content knowledge and the boundaries imposed by the English national curriculum for mathematics. This review showed that while there was significant research into potential difficulties faced by pupils with SLCN, there was little that showed the most effective teaching strategies for these pupils in mathematics. Previous research was often either qualitative or quantitative in design and tended to focus on pupil difficulties in either numeracy or mathematical reasoning without exploring the views of teachers. The conceptual framework for this study, therefore, proposed an inductive mixed methods approach for examining specific differences between pupils with SLCN and TD pupils in arithmetic and reasoning and gathering the views of teachers. The research questions were drawn from this.

RQ1: *How do children with SLCN perform on a mathematics task with high language demands compared to one with low language demands and how does their performance differ compared to TD pupils in terms of error type, overall score and reaction time?*

RQ2: *How does teacher understanding of effective mathematical pedagogy influence the planning of mathematics lessons to meet SLCN pupils' needs?*

It was hoped that this research would make a unique contribution to knowledge in this area and influence the input given both to trainee and serving teachers.

6.2 Research findings

Quantitative data collected were analysed using SPSS; qualitative data using thematic analysis. Findings were discussed separately before merging and interpreting.

To answer RQ1, it was found that pupils with SLCN did less well on the reasoning task than their TD peers. There were significant differences in pupils' responses to two questions, which were explored in detail. One question was language bound and this appeared to suggest that pupils' linguistic difficulties may have contributed to their poor responses to this question. The other was not straightforward and there were many possible reasons for a significant difference here, which included cognitive overload. Pupils with SLCN tended to use 'wild guessing' as a strategy, significantly so in arithmetic, suggesting they may have a lack of strategies to draw on, including metacognitive strategies such as motivation and perseverance.

To answer RQ2, it was found that teachers showed a sound command of a range of pedagogical techniques, including those specifically to do with the teaching of mathematics. Teachers adapted their teaching styles to address domain-general difficulties such as poor organisation skills but did not adapt pupil work sufficiently to allow pupils with SLCN to work independently.

Returning to the personal philosophy which began this thesis, there is a group of pupils, those with SLCN, who may slip through the educational net despite well-meaning and dedicated teachers' intentions. Adaptations to lesson plans for pupils with SLCN in this study suggested that insufficient differentiation is made for pupils with SLCN and that teachers focused to a large degree on keeping the class together, deploying a range of strategies to do so, but not specifically addressing domain-specific difficulties for these children. This resulted in a significant underperformance in reasoning tasks by pupils with SLCN compared to their TD peer group.

6.3 Research limitations

This research was carried out at a time of high stress in education towards the end of the second period of 'lockdown' as a result of Covid-19. Some pupils had not been educated at school for significant periods of time and teachers were under great pressure to catch pupils up to pre-pandemic norms. The fact that the majority of children in this study were from disadvantaged areas is also likely to have had an impact on their attainment; recent government data exploring the impact of the lockdowns on pupil attainment shows that pupils from disadvantaged areas were found to have lost 4.5 months over the course of the year in mathematics (DfE, 2021). The impact that this played on the research should not be underestimated, since teaching was likely to have been narrower in focus than might usually have been expected, and pupil responses may not have been typical. Steps to mitigate this were put in place: pupil testing was carried out using a test usually undertaken earlier in the year to allow for the fact that much of the taught curriculum had been disrupted, and teachers were specifically asked about the impact of Covid-19 during the teacher interviews.

As a result of purposive sampling, all schools recruited were already involved in some research with their local maths hubs and hence the five teachers may not have been representative of all teachers nationally.

Reflecting on the research methods, a mixed methods inductive approach was indicated to be the right one for this study, since it collected teacher views as well as pupil data and attempted to build a picture of current practice for pupils with SLCN in mathematics. There was a large difference between the amount of quantitative and qualitative data collected, however, and with hindsight, teacher questionnaires may have been a useful precursor to the interviews, using a wider sample of schools beyond the case study. Individual responses to questions could then have been picked up in the case study teacher interviews which would have yielded richer data for analysis.

Steps were taken during the research design stage to ensure reliability and validity and the research was carried out on these lines, with careful attention to detail and a consistent approach given to all pupils and teachers. Generalisability (or external validity) is important to consider in this case study since it reflects on the extent to which the findings could be applied to the general school population. As previously stated, the pupil sample size was relatively small, but nevertheless believed to be representative of the population as a whole, since pupils were selected based on their SEN category (SLCN) and confirmed by using a checklist to ascertain their level and type of language impairment and were also gender matched with a typically developing peer. Thus, even accounting for individual school differences, the results are thought to be generalisable beyond the scope of the study, since these children will have similar needs to those found nationally. It also has high ecological validity since the categorisation of pupils as having SLCN is a national one.

An unexpected issue emerged, that of the similarity of the two pupil groups when assessed on the BPVS. Pupils with SLCN were found to have mean average scores lower than TD pupils' scores although these were not found to be statistically different. It should be remembered that the BPVS is a measure of receptive vocabulary and not a more comprehensive test of language, however, which might explain the similarity between the two groups.

The two mathematics tests used, arithmetic and reasoning, were not directly comparable to one another since the questions on each paper tested different mathematical concepts. Some questions were likely to have been beyond the capability of some children, particularly some of the missing number questions on the arithmetic paper. Although they were in line with the national curriculum expectation for year one, this group of pupils had missed significant amounts of schooling due to Covid lockdowns. Some questions were also thought to be ambiguous and did not necessarily test the stated concepts, particularly when read aloud to the children. Therefore, this adds a degree of caution to the interpretation of the results. However, the tests represent a 'real-life' assessment that may be typically used by teachers in the classroom and hence have validity in this context.

6.4 Future research

This case study opens up many possibilities for future research. Further research should be carried out using directly comparable arithmetic and reasoning tests to ascertain whether the findings of this study could be replicated when tests compare the same mathematical concepts. Because mathematical anxiety is a risk factor for low performance in mathematics, it would also be interesting to explore pupil attitude and anxiety on mathematics work to examine whether this is a factor in pupils' underperformance and impact on their working memory.

6.5 Dissemination and contribution to the field

This research would be of interest to practising teachers. The researcher's university plans to develop work with Early Career teachers (ECTs; those in their first two years post-qualification) and this would be a useful addition to their programme, since it is not possible in a one-year PGCE initial teacher training programme to focus on specific details of strategies in mathematics for pupils with SLCN. There is also the possibility of more joined-up thinking with Speech and Language Therapists (SALTs) and more joint working.

6.6 Concluding words

This thesis began with the desire to focus on a specific group of children whose needs often go unnoticed or unmet in the classroom. Their educational outcomes are lower at the end of primary school, in both English and mathematics. Through a focus on five schools, the needs of these children have been explored and possible solutions suggested to help meet their needs.

Through carrying out this research, I have learnt about myself as a practitioner. I have read more extensively around the development of early mathematics and this knowledge will make an impact on my teaching of primary PGCE students. I am also now thinking to the future and how this new knowledge could be used to run additional training for ECTs. As an emergent researcher, this has taught me powers of organisation, resilience and dedication and the ability to extract meaning from data. Not a natural statistician, carrying out mixed methods research has stretched my own mathematics, but to a point where I can see the purpose of a much more analytical approach in future work.

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Appendix 1- Parent consent letter

Institute of Education

Dear Parent/carer,

My name is Helen Williams and I am carrying out some research as part of my doctoral studies at UCL Institute of Education, under the supervision of Dr Jo Van Herwegen. I am carrying out research into effective teaching strategies in mathematics. Part of my research involves looking at teachers' planning, interviewing teachers and looking at pupils' mathematics work. Your child's school and class teacher have agreed to take part in the research.

As a follow-up to the research above, I will be working with some children one-to-one. My research will take place during the summer term 2021.

I would like, with your permission, to work with your child and ask your child to complete three short tasks:

- Two short mathematics tests
- A short vocabulary task

These tasks should take around 30 minutes to complete in total, but we can take breaks as often and for as long as needed. Once the project is completed you will be given the results of these tasks. There is no cost to you for your child taking part in this project.

I am a qualified teacher, employed in teacher education at UCL Institute of Education and have a clear enhanced DBS check.

Because of the coronavirus pandemic, these assessments will take place remotely over Microsoft Teams. These will take place when your child is at school, with a teacher or teaching assistant present at all times.

I will need to record the tests in order to aid my analysis afterwards. Children will not be identified in the recordings (your child will be assigned a code). These recordings will be deleted as soon as your child's tasks have been scored. There will be no further dissemination of the recording.

I hope that you might find this research useful and would be grateful if you could give consent for your child to participate. I will also be checking with children that they are happy to go ahead before each test. UCL's privacy notice about how data is used can be found here: https://www.ucl.ac.uk/legal-services/privacy/ucl-general-research-participant-privacy-notice

Please do not hesitate to contact me if you have any further questions.

Yours faithfully,

Helen Williams
Lecturer (Teaching), UCL Institute of Education
[email address]

Project title: Effective teaching strategies for all pupils in mainstream mathematics classrooms

PARENT CONSENT FORM

I have read the information about the research and I agree that my child may take part.

I agree that my child can be assessed using the British Picture Vocabulary Test (BPVS) and White Rose Arithmetic and Reasoning tests for Year 1.

I agree that this work can take place over Microsoft Teams and will be recorded.

I agree that this work may take place at my child's school

I understand that participation is voluntary and that I am free to withdraw consent from the project at any time without giving a reason.

I understand that I can contact Helen Williams [email address] if I have any questions or if I want to discuss this project further.

The work will take place at your child's school and a member of staff will be present during this task.

I agree that my child can take part in this research project. Yes/No

Parent Name:

Signed:

Name of child:
School use only: Child's identifier code:

Appendix - 2 Pupil consent letter

Photo

June 2021

Dear [Child’s name]

My name is Helen and I am a teacher. I have put my photo on here so you can see who I am. I am hoping that we can do some work together and that you can help me select some pictures and complete a maths task. We can do this work online together using Microsoft Teams. I would like to record your work. Nobody apart from me will get to see the recording.

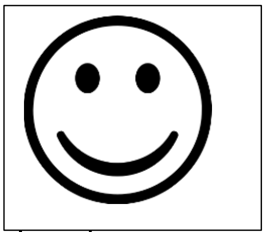
If you are unhappy or uncomfortable when we are working together, I will stop if you ask me to. I’m really looking forward to meeting you soon. If you have any questions, you can ask me when we meet or you can ask your teacher and they can contact me.

Thank you for reading this,

Helen Williams

Please tick the box under the face that best shows how you feel about working with me. Your teacher will email this form back to me.

Today’s date:



I am happy to work with Helen

☐ Helen

☐ I would rather not work with

Appendix 3 – Verbal consent prior to second pupil task

Today we are going to be doing some maths work.

- Are you still happy to take part?
- Yes ☑
- No ☒

I would like to record the session so afterwards I can see how well you answer the questions. I will delete (rub out) the recording when I have finished my work.

- Are you happy for me to record you today?

Yes ☑

No ☒

Appendix 4 - Script for maths task

Today we are going to do some maths tasks, just like ones you usually do in class. I want to see how you work the questions out, so it's OK to use your fingers or do some jottings on the paper to help you. There is space next to each of the questions for this. You don't need to be worried about getting the right answer, I just want you to do the best you can. Try not to ask [your adult] for help if you get stuck, just let me know.

I am going to time each question so tell me when you have finished each one and we will start the next one together.

If you can't do one, remember to tell me so we can move onto the next one. There are two papers, one is arithmetic and the other has word problems. I will read the questions on paper 2 to you.

Do you have any questions?

Let's look at the first one. Are you ready to start? Remember to tell me when you have finished each question so I can stop my timer before we go onto the next one.

Appendix 5- Teacher interview questions

Thank you for your time. I appreciate you taking time out of your busy day to speak to me. I wanted to use this opportunity to explore with you the lessons and pupil work that you kindly sent me, as well as talk to you about the approach you generally use in the teaching of mathematics. There are no right or wrong answers so please give as much detail as is relevant. I will be recording the interview to make transcription easier, so if you don't want to use the video element, feel free to turn off your video camera now. The recording will be solely for the purposes of the research and will be deleted after transcription. I am hoping the interview will last no more than 40 minutes.

<u>Teaching experience and training</u>

1. How long have you been teaching? Is this the only school you have worked at or were there others before? How many years have you been teaching in Y1? What other year groups have you taught in?
2. What is your school's approach to teaching mathematics? E.g. White Rose, Power Maths, own scheme etc. Would you say this is a mastery approach to teaching maths/what do you know about mastery teaching methods in mathematics?
3. What would you say is effective mathematical pedagogy? What training have you had in teaching maths? E.g. school/academy inset, White Rose, maths hub? Do you know who your local maths hub is?

4. What experience have you had of teaching pupils with SLCN? Have you had any specific training e.g. through SALT? Have you undertaken any further study since beginning teaching e.g. MA?

Pupil background

5. Thank you for completing the screening questionnaires. How would you define SLCN? What sub-groups do you identify within the category of SLCN as a whole? Regarding the three children with SLCN in your class, how typical are these of all children with SLCN? How well do pupils with SLCN do compared to others the same age in maths? What do you feel these pupils' general difficulties in maths are? Are there areas and topics they struggle with more than others? Why do you think this might be? Are there difficulties for these pupils across the curriculum? Is this the same as, worse or better than TD pupils? How do you support children with SLCN in mathematics (what strategies do you use)? What do you think the most supportive teaching methods are for these children? Why do you think this is?

Planning

6. How typical is the planning you sent me? How do you adapt plans to suit the needs of your own class (differentiation)? During a typical week, how do you adapt the planned teaching based on pupil misconceptions? How has your teaching had to adapt due to the coronavirus? Describe to me your seating plan. How are pupils with SLCN seated? What resources do you typically use

in your maths lessons? Do you provide anything different for pupils with SLCN? How much time typically would you spend on whole class teaching? Paired or group work? How do you teach pupils new vocabulary?

Focus week's planning and pupil work

7. Tell me about the approaches used when planning this week's work. What additional support was planned for pupils with SLCN? You may want to refer to your notes or your evaluations for the next part of the interview. I noticed that…why was this? Why did you decide to…? What can you tell me about…? How typical is the pupil work sent of TD children? Of SLCN? How did you adapt the lessons as you went along? If you were to re-plan these lessons, is there anything you might do differently next time? How has your next steps marking informed future practice? Were the outcomes as expected? If they were not, how were they different? Did anything surprise you about children's responses? Was there anything that pupils with SLCN particularly struggled with?

Is there anything else you'd like to tell me about pupils with SLCN? Anything else at all that we haven't covered?

Appendix 6 -Interview transcript extract

1
00:00:02.879 --> 00:00:03.750
Researcher: Okay, so.

2
00:00:04.830 --> 00:00:07.589
Researcher: Can you just tell me [Teacher name] How long have you been in teaching?

3
00:00:08.790 --> 00:00:11.309
Teacher: Well, I think 10 or 11 years now, I think it is.

4
00:00:12.150 --> 00:00:16.920
Researcher: And is it just at the school that you're at or have you taught elsewhere or…

5
00:00:17.609 --> 00:00:25.740
Teacher: Err, I well I did teacher training, obviously in a couple of different schools but I got my job here, straight after my NQT…

6
00:00:25.830 --> 00:00:28.650
Researcher: Alright, so you've just worked there Yeah okay.

7
00:00:30.090 --> 00:00:39.210
Researcher: And I've I've looked obviously up your school and you've recently joined the [school] trust is that right, or fairly recently?

8
00:00:39.210 --> 00:00:41.250
Teacher: Yeah that's right Yeah.

9
00:00:41.610 --> 00:00:52.920
Researcher: So have things changed in terms of maths. so I know you use the maths mastery scheme and did the school use maths mastery before it was part of the [school] trust?

10
00:00:53.520 --> 00:00:59.130
Teacher: Yeah, it's it's had a bit of a turbulent time, school umm.

11

00:01:00.540 --> 00:01:04.290
Teacher: For the first few years we weren't using anything like that, but…

12
00:01:05.670 --> 00:01:25.620
Teacher: We started using maths mastery and what's it, must have been, about three years ago now, I think it was, and and it was working really well, umm but, obviously with a new scheme brought in, and children not being at the expected level

13
00:01:25.920 --> 00:01:45.150
Teacher: a lot of, a lot of the children school found it very difficult. Umm and we got a new head and she decided that the maths mastery programme was too advanced for our children, let’s say, and took it away.

14
00:01:46.530 --> 00:01:53.070
Teacher: And didn't really replace it with a scheme umm and it was a bit chaotic for a year or so.

15
00:01:54.090 --> 00:01:59.820
Teacher: Umm, and we were just planning from national curriculum objectives and we weren't allowed to

16
00:02:01.410 --> 00:02:03.810
Teacher: break them down or simplify them at all.

17
00:02:05.760 --> 00:02:15.600
Teacher: And then that head left and we got [new EHT name] and he took us back to maths mastery umm.

18
00:02:16.830 --> 00:02:30.660
Teacher: And Yeah just expectations really around children being able to catch up and and being where they should be nationally, it was the feeling that we need to get them all, where they should be.

19
00:02:31.020 --> 00:02:33.900
Teacher: And the maths mastery approach was the best way to do that.

20
00:02:34.440 --> 00:02:41.340
Teacher: I felt before it was a really good programme before it was removed and I wasn't

21

00:02:42.420 --> 00:02:50.880
Teacher: I wasn't, I didn't agree with why it was taken out in the first place umm but Yeah I’m glad we’re back to Mathematics Mastery now.

22
00:02:51.300 --> 00:02:51.750
Researcher: I think that's an

23
00:02:52.140 --> 00:02:53.580
Researcher: Interesting journey.

24
00:02:54.000 --> 00:02:55.440
Teacher: Yeah I think it really

25
00:02:56.820 --> 00:03:14.880
Teacher: I think it takes a while doesn't it for the ones who were older to catch up where they need to be right, like the stage two children. Yeah, but I think once they've had maths mastery all the way through it excels them at a great length if you know I mean.

26
00:03:15.270 --> 00:03:24.330
Researcher: Yeah so the intention is obviously that when we originally started it, it was starting with reception and year one, and it was rolling out one year, at a time.

27
00:03:24.510 --> 00:03:33.060
Researcher: So there is an issue if you join and you take it in in year four on the children haven't had that mastery scheme, all the way through, so the intention always was

28
00:03:33.450 --> 00:03:33.810
Teacher: I think that was.

29
00:03:33.870 --> 00:03:34.230
Teacher: the problem is

30
00:03:34.860 --> 00:03:36.960
Teacher: it's cumulative from

31
00:03:37.140 --> 00:03:43.800
Teacher: from when we first introduced it, it was just kind of out of the children's depth, especially in key stage two.

32
00:03:43.890 --> 00:03:44.520
Researcher: Yeah.

33
00:03:45.030 --> 00:03:56.250
Teacher: Instead of staying with it, and I said in passing it on and as they get older and adapting it, I think, it was just too quickly removed.

34
00:03:56.520 --> 00:04:00.870
Researcher: Yeah. And did you go to the training, the maths mastery training?

35
00:04:01.230 --> 00:04:02.400
Teacher: Yes, so did I went

36
00:04:03.450 --> 00:04:04.680
Teacher: twice actually.

37
00:04:05.040 --> 00:04:05.940
Teacher: Yeah there's…

38
00:04:06.750 --> 00:04:12.210
Researcher: I’ve met you I think then, haven't I? Did I do the training, I did it at [school name]?

39
00:04:12.630 --> 00:04:14.610
Teacher: No, I did the initial training at umm

40
00:04:17.730 --> 00:04:21.180
Teacher: What was it called the [another school name]?

41
00:04:21.480 --> 00:04:22.470
Researcher: Yeah, yeah I did that.

47
00:04:50.790 --> 00:05:05.520
Researcher: So I’ll talk to you a little bit about that later. So, then thinking about these children with a particular speech and language difficulty, what would you say the strengths are to that mastery programme? How does it support those children's learning?

48
00:05:06.690 --> 00:05:17.580
Teacher: I think just that expectation that they need to speak in a full sentence. The sentence stems that are in there ready for the children to use.

49
00:05:18.240 --> 00:05:24.690
Teacher: The talk tasks are modelled so that they've got that expectation that they need to speak in a sentence to their talk

50
00:05:25.200 --> 00:05:33.930
Teacher: partner there's lots of opportunities for turning to your partner and discussing your ideas. it just gives them lots of opportunities really to

51
00:05:34.380 --> 00:05:40.320
Teacher: develop those language skills. When mine first came in, I think, because of the lockdown and everything

52
00:05:41.130 --> 00:05:51.210
Teacher: they'd just like give you one word answers all the time, and it was just training them, and I think the maths mastery programme allows you to train them really well because it's in-built in the programme.

53
00:05:51.900 --> 00:05:59.130
Teacher: And they are, I just really think it's a really good, good programme for that development of language in maths.
57
00:06:24.630 --> 00:06:39.960
Researcher: And, and what particular difficulties do you think those children have? do they have difficulties in speaking, listening, communicating ,what's, or are they just very varied. you've sent me their checklists haven't you?

58
00:06:40.170 --> 00:06:54.060
Teacher: Yeah I've got a very like a very varied class I'd say and but coming from really low starting points and some children are very disadvantaged from [town] in our area, local area.

59
00:06:54.630 --> 00:07:12.780
Teacher: And speech and language is a huge issue from early years, children not being able to speak in sentences and not having language modelled correctly so "down't road", and you know we have colloquialisms around here.

60

00:07:13.410 --> 00:07:16.680
Teacher: Yeah so they don't they don't speak

61
00:07:18.960 --> 00:07:36.240
Teacher: In the way that we would expect them to from, from early age umm and the.. I don't know if they don't have access to books and storytelling I don't know if their parents read to them every night and things like that umm.

62
00:07:38.370 --> 00:07:48.960
Teacher: My children I'll send reading books home, and I have to remind them every week to bring the reading book back, and please read with your child every night there's some that will and they do it

63
00:07:49.650 --> 00:07:57.630
Teacher: religiously, there's others that don't and then I have to nag really nag some parents to, to do that activity with them.

64
00:07:58.950 --> 00:08:05.880
Teacher: And so it's a real mixed real mixed bunch. Yeah start, really low starting points.

65
00:08:06.090 --> 00:08:11.490
Researcher: Okay, and you've got quite high pupil premium haven't you in your school as well I've looked

66
00:08:11.790 --> 00:08:26.100
Researcher: up your, your figures. Yeah, so the children that you've given me are sort of target children and those children would they be typical of the sort of speech and language needs in your class?

67
00:08:26.610 --> 00:08:30.990
Teacher: Yeah, yeah, there's a good mix of children.

68
00:08:31.860 --> 00:08:33.060
Teacher: Okay over half of them in there.

69
00:08:33.060 --> 00:08:48.480
Researcher: OK and then thinking about them in maths so what you've said is that they, they really struggle with language and they're using colloquialisms they don't get heard reading at home they don't bring reading books back, how do you think their language difficulties impact on maths?

70
00:08:49.530 --> 00:08:50.130
Teacher: I think

71
00:08:51.450 --> 00:08:55.230
Teacher: It depends on, on the, on the skill

72
00:08:59.100 --> 00:09:00.630
Teacher: Whether it affects them

73
00:09:01.860 --> 00:09:14.580
Teacher: or not. It's strange to have to explain that, in a way, if it was just a sum and it was written down and they had equipment umm they'd probably be okay.

74
00:09:15.150 --> 00:09:25.110
Teacher: But as soon as the maths develops and they have more than one part to the maths or they've got to explain how they got there they become a little bit unstuck.

75
00:09:25.920 --> 00:09:36.960
Teacher: And because they can't sometimes put into words how they've got there so it's breaking down those small steps for them, enabled, so that enables them to

76
00:09:37.500 --> 00:09:51.390
Teacher: be able to tell you how they've done something and address misconceptions because they just want to tell you the answer all the time and not talk around how they got there, so you have to like teach and train them to do that.

84
00:11:00.150 --> 00:11:10.170
Teacher: Definitely yeah but their, their working memory is stretched all the time, because I don't think they easily put things into long term memory.

85
00:11:12.000 --> 00:11:26.370
Teacher: But sometimes I’ll have to adapt with maths mastery so we go on for a little bit longer to just embed it before we move on to a new topic and, like they don't, they didn't know number bonds they didn't know

86
00:11:27.390 --> 00:11:41.760

Teacher: and they didn't even know to count to, right, 20, 30, backwards and forwards, so if we included that in the maths meeting really early on and just make them secure and those things and I've carried on doing

87
00:11:42.570 --> 00:11:50.880
Teacher: like number bonds every day for the whole year from you know number bonds to five number bonds to six and number bonds to seven.

88
00:11:51.330 --> 00:11:53.250
Teacher: all the way up to number bonds to 20,

89
00:11:53.640 --> 00:12:03.300
Teacher: just to try and get it processed in their long term memory and recall those number facts to help them as much as I can really.

90
00:12:03.540 --> 00:12:12.420
Researcher: Yeah and in terms of instructions, so if you gave children a set of instructions do they find it difficult to process a string of instructions?

91
00:12:12.930 --> 00:12:23.670
Teacher: Umm some do and some don't but the ones that don't really don't, so I do kind of tried to really simplify what I'm asking them to do or give them.

92
00:12:24.150 --> 00:12:33.060
Teacher: One instruction do we all get that part, but what do we do next? So like if it's, if it's an equation where, they have to do three different

93
00:12:33.690 --> 00:12:51.210
Teacher: things, like that is really difficult for them so I'd break that down for them and say what do we do first, what do we do next, what's the next part of the.. and just really trying to help them understand that process that we've got to work through.

94
00:12:51.270 --> 00:12:56.580
Researcher: Yeah so do these children get an awful lot of in-class additional support?

95
00:12:57.630 --> 00:13:10.200
Teacher: Umm they do get a lot of support, but I've not got a classroom TA, so it is, it is me doing one intervention. I sometimes collect them at dinner times and just

96

00:13:10.920 --> 00:13:22.500
Teacher: if they've got any wrong answers I'll go through and we do green pen work umm and they have a lot of intervention time for read write inc., obviously reading.

97
00:13:22.800 --> 00:13:31.890
Teacher: Yes so that's taken priority really but just as much as I can squeeze in, and we did, we did have

98
00:13:33.060 --> 00:13:46.410
Teacher: like in an afternoon at the beginning of the year, we had that continuous provision out so, while the children were accessing the continuous vision, I'd do small group intervention time then with them.

Appendix 7 - Emerging themes from thematic analysis

Key words & phrases	Theme
Low, levels, below, expected levels, basic, out of depth	Attainment
Seating plan, changes, social and emotional, lack of carpet time, movement around room, different, sitting in twos, no continuous provision, difficult	Covid disruption
Shocked, not helpful	Negative teacher attitude
Nice, help/ful, better, working well, best way	Positive teacher attitude
Keeping them together, progress at same rate, learn/teach the same, don't cap what they learn, extend, not fall behind	Keeping all children together, high expectations
Extra, resources, support, intervention, visuals, concrete apparatus, manipulatives, additional, pre-teach/learn, differentiate/ion, practical/ly, small group, teaching assistant, repeat/repetition	Adaptation - support
Simplify, text, format/ting, adapt, instructions, talk tasks, full sentence, model/ling, vocabulary, tens/hundreds of times, dictionary, paired/partner talk, (positive) role model, rich vocab, sentence stems	Adaptation - language
Break/ing down into sections, movement, listening, concentration, teacher-led, practical	Adaptation – lesson structure
Working, short-term, long-term memory, new language, cognitive overload, process/ing, poor organisation, forget	Domain-general difficulties
Pick up new/maths vocabulary/language, understand/ing, word problem, subitising, number bonds, fluency, place value, positional language, determiners, suffixes, grammar, complex, barrier, explain/ation, discuss, represent	Domain-specific difficulties
Assess, re-assess, marking, as we go along, wrong answers	Assessment

Appendix 8 – Checklist to support identification of pupils with SLCN

Checklist

For ages 5-11

Use this checklist if there is a child in your care who you think may have speech, language and communication needs. Read each statement and then tick the 'R' (red) column if the child strongly matches the statement, 'A' (amber) column if they occasionally match the statement wand 'G' (green) if they do not match the statement.

Talking difficulties – what you might see and hear	R	A	G
1. Do they have a limited vocabulary? Do they...			
a. Use less words than other children their age			
b. Over-use general words – 'thingy', 'that', 'put', 'get'			
c. Use the wrong words for things - 'shark' instead of 'whale', or make up their own words like 'cuttergrasser' (lawnmower)			
d. Use lots of fillers or hesitates a lot – 'um', 'er', 'y'know... like'			
2. What are their sentences like? Do they...			
a. Miss out the small words in sentences that carry less meaning – 'a', 'the', 'is/was', 'and'			
b. Miss off the endings of words – 'ing', 'ed', 's'			
c. Sound muddled or disorganised when talking in longer sentences			
d. Recall and re-tell events in a way that makes them difficult to follow			
3. Is their speech unclear? Do they...			
a. Miss out sounds from the beginning, middle or end of words, or use only a limited range of different speech sounds in their talking			
b. Substitute one sound for another – 'a tup of toffee' (a cup of coffee), 'lellow' (yellow)			
4. Do they have a stammer or stutter? Do they...			
a. Prolong or repeat some sounds or words, e.g.(b___all, or b-b-b-ball, or ball-ball-ball) or get 'stuck' on a word and no sound comes out			
b. Try to hide their difficulties by avoiding speaking in certain situations, or change what they were going to say mid sentence to avoid a word they find difficult			
5. Do they have literacy difficulties? Do they...			
a. Struggle to recognise initial sounds or sound out words			
b. Struggle with organising text in written work, with words missed out, and lots of grammar errors you wouldn't expect for their age			
6. Do they have behaviour difficulties? Do they...			
a. Have low self-esteem, seem withdrawn, do not initiate speaking in class, or become frustrated			
7. Do they have social interaction difficulties? Do...			
a. Other children find it difficult to understand them or possibly tease them about their talking			

Listening difficulties – what you might see and hear	R	A	G
1. Do they find it difficult to listen or understand? Do they...			
a. Fidget or not engage with tasks			
b. Struggle to follow long or complex sentences			
c. Watch other children so they can work out what to do or are the last to follow instructions			
d. Concentrate on non-verbal tasks for much longer than verbal ones			
2. Can they understand questions? Do they...			
a. Answer with an irrelevant comment			
b. Repeat part of the question			
c. Answer a slightly different related question			
d. Not respond			
3. Does new or less frequently used vocabulary take a long time to learn?			
4. Do they struggle to distinguish the difference between sounds in words? Do they...			
a. Struggle to break up words in order to read or spell			
b. Struggle to count out syllables in words			
c. Struggle to match sounds and letters			
5. Do they have literacy difficulties? Do they...			
a. Have difficultiy understanding what they've read and making inferences			
6. Do they have behaviour difficulties? Do they...			
a. Have disruptive behavior or do they withdraw from activities/conversations			
7. Do they have social interaction difficulties? Do they...			
a. Have difficulties making friends or joining in with group activities			

Difficulties taking part – what you might see and hear	R	A	G
1. Do they find it hard to understand the rules of conversation? Do they...			
a. Avoid eye contact or stare at people when they are talking			
b. Struggle to take turns, interrupt too much, take over conversations or struggle to get involved			
c. Misunderstand other people's feelings and facial expressions			
2. Do they struggle to talk and listen with other children? Do they...			
a. Have difficulties joining in with group conversations, games and activities			
b. Fail to notice what others are doing or fail to pick up clues about how they are feeling			
c. Take over, get things wrong, or disrupt games			
d. Have situations when other children do not want to play or partner with them			
3. Do they take things literally? Do they...			
a. Struggle to understand jokes, idioms, sarcasm or metaphors			

On completing the checklist, if a child rates amber or red, this may be a cause for concern, so in the first instance you may find it useful to refer back to the Universally Speaking booklet to check their development in more detail and talk to their parents about your concerns. Universally Speaking may also be useful in supporting you to monitor progress. Where children have mainly red and amber ratings, it will be important to consider further assessment, so discussing this with your SENCo and the child's parents will be an important next step.

You could also consider other assessments (there is a range of assessments on Pearson Assessment's website: www.psychcorp.co.uk) or use a Progression Tool to help identify where children are at in relation to their age and how they are progressing with developing these vital communication skills. The Progression Tools will give information to help you decide whether a child would benefit from a targeted intervention or whether they may need more specialist assessment and support and need referring to a speech and language therapist. More information about the Progression Tools can be found at www.thecommunicationtrust.org.uk/resources/resources/resources-for-practitioners/progression-tools-primary/

Universally Speaking Age 5-11

The Communication Trust
Every child understood

PEARSON

Visit www.talkingpoint.org.uk for more information or use the more detailed checklist in the publication *Don't Get Me Wrong* available at www.talkingpoint.org.uk/resources/dont-get-me-wrong

Appendix 9- Detailed thematic analysis based on five teacher interviews, transcribed.

(School pseudonyms and segment codes included.)

Data extract	Coded for
They were very low. I was very shocked when I went in. They've had a difficult year and their teacher went off on maternity, they had a supply for a bit and yeah they were, they were very very low when I went in. (Ashwood05) We started using maths mastery and what's it, must have been, about three years ago now, I think it was, and it was working really well, umm but, obviously with a new scheme brought in, and children not being at the expected level a lot of the children school found it very difficult (Best Street12-13) it was just kind of out of the children's depth, especially in key stage two. (Best Street31) I've got a very like a very varied class I'd say and but coming from really low starting points and some children are very disadvantaged from [town] in our local area. (Best Street58) I think I was kind of expecting it to have more of an impact on learning than it actually has. I think for me that impact has been more sort of social and emotional than learning (Church Street04). At the start of the year, they're receptions aren't they, so there's a lot of life teaching that you need to still do I suppose. Like sort of not really basic needs, but things that, shouting out, getting used to being in a proper classroom environment that obviously they've had a lot of free play in reception. So getting them used to… especially this year, and obviously sitting, we've had to sit in twos instead of groups and…There's been a lot of, well, there's been no continuous provision. Uh, so that that's been hard with year one this year (Dunwood05)	1. Low pupil attainment 2. disruption, difficult year 3. Teacher attitude
Making sure that they're all at the same point and keeping them together, and we don't want any children falling behind, but then extending knowledge for children that are able to access that, but making sure that they all progress at the same speed. (Ashwood08)	1. Effective pedagogy/Mastery approaches 2. Specific resources used for SLCN

you don't need to cap what they get to learn, they can learn the same thing (Eastern Grove39) expectations really around children being able to catch up and being where they should be nationally, it was the feeling that we need to get them all, where they should be. And the maths mastery approach was the best way to do that. (Best Street18-19) We teach the class, they all get taught the same. In terms of differentiation it might be with the resources that might be given, they might be given extra like maybe Numicon, multilink, classroom support as well. They might have me or the teaching assistant and they might, maybe in the afternoons if they've not quite got something in the morning. They'll go off and have a little bit of an intervention with that (Dunwood06).	3. Teacher positive attitude
We do like practical activities first for every lesson, and then we always go on to the sort of concrete and then lastly abstract for each lesson (Ashwood09) It's well, they'll do like 5 minutes listening, 5 minutes on a task, 5 minutes listening, five minutes on task, never longer than five minutes listening. Then the longest we spend on the independent task is about 10 minutes before moving on to something else. (Ashwood33) because concentration was a really big issue at the beginning of the year I sat with the SLE for maths and we talked about breaking down that six part lesson so sometimes, we'll do the 'Do Now' as a whole class on the carpet (Best Street142) At the beginning five minutes, they normally come in from break, they have a starter activity at their tables, then they come to the carpet for 2-5 minutes for an on-carpet talk task with their partner, there'll be like a reasoning problem or an error on the board, and they have to discuss with their partner what that is, just to settle them into the lesson. And then the input is between five to 10 minutes long before the talk tasks so that's all I would say, high demand listening time is between five and 10 minutes (Church Street33).	1. Lesson structure (Unhighlighted) 2. Disruption

it's quite a long time I suppose, especially at the moment and it used to be… we might do a lot more teacher-led group work so we have a little bit of class teaching time. Some of them would go off into groups and then they'd be provision, maths provision for them to go to. If you finish your job, go to the maths area, do your maths work. Obviously haven't been able to have that this year and so they do listen a lot longer. We don't have carpet time, obviously. We usually would, but obviously COVID we haven't had that erm, so the percentage of time they're probably listening to me, I bet it's, I bet it's good 40, 50% of listening…(Dunwood39) So you might see from the slides, so we'll have like, 'what do you notice slides'? So they'll be talking to their partners. Then they'll bring it back to tell me. Then it'll be like right, we'll share our ideas and then they'll be some whiteboard work we'll do some well. That might come first actually. So there might be some whiteboard work, write there, some questions on the board. Get your white boards out. Then we'll do something practical like that, so they are listening, but then I try to get them doing that. They might have number fans. They might have to stand up, sit down, things like that to keep them going and then we have the like 'let's learn' section so that they'll be mainly listening. But I'll I try and ask questions as I'm going along with maths. Do some more things like that. Stand up, sit down and hold up your answer on your whiteboard. "What do you think it is? Talk to your partner." And then when it comes to the doing the activity, I might, we'll do some examples together and because I've got another white board like now my boards my interactive whiteboard has been really dodgy. So I've got a little normal white board so you will have that in in in the planning. But we'll we might do some more examples on there. I might do a mistake, they've got to fix it, so I've tried, I've tried keeping them as practical as possible 'cause we can't move around the room (Dunwood40).	
Yeah, the support is from me or the TA having additional time and a longer practical input before they get on with their written. (Ashwood25) just keeping them longer [on the carpet], work in a small group. We might do a pre-teach the	1. SLCN support/specific teaching strategies/adaptation 2. Assessment

day before, but some of the children that we know will probably need it. (Ashwood26) they are in groups and so the support is differentiated to the group at the moment (Eastern Grove33) so they would probably also go out with me or my TA in one, there's just five of them in that group, so that it's quiet. They can have the support that they need with the fewest distractions as possible and I would have the rest of the class in here (Eastern Grove36) If they're not getting it, then I would have said “right let's go to the tables and let's do it practically with some resources”.(Eastern Grove38) Sometimes I’ll have to adapt with maths mastery so we go on for a little bit longer to just embed it before we move on to a new topic (Best Street85) I do kind of tried to really simplify what I’m asking them to do or give them.(Best Street91) they do get a lot of support, but I’ve not got a classroom TA, so it is, it is me doing one intervention. I sometimes collect them at dinner times and just if they've got any wrong answers I’ll go through and we do green pen work (Best Street95-96) Sometimes, if the text isn't needed, I’ll take it out or might add another slide in just so it's not too much or too busy for them (Best Street129) I do tend to make adaptations mainly to like the written tasks. I tend to adapt those and I will adapt the talk tasks if I feel that they need to be adapted and I do slight alterations to the formatting of the Actives [whiteboard slides] (Church Street06) One of the changes I made in the planning is I will change how I deliver the instructions (Church Street15) We know which children we’ll need to check in with and we tend to mark, both my TA and I will mark in the lesson, so that we can identify any children that need a same-day intervention and we'll do that afterwards (Church Street35).	

So they have their pre learning in the morning and then we'll kind of reassess as we're marking in the lesson and any children, we feel still need support and we'll kind of do and sort of a 15 minute session, either with myself or the TA re-covering… so, for example, it tends to be more the practical things (Church Street36). I might need to model it again, or I might move onto something a bit more complex with it, so it tends to be more that kind of practical skill (Church Street36) We teach the class, they all get taught the same. In terms of differentiation it might be with the resources that might be given, they might be given extra like maybe Numicon, multilink, classroom support as well. They might have me or the teaching assistant and they might, maybe in the afternoons if they've not quite got something in the morning. They'll go off and have a little bit of an intervention with that (Dunwood08). We might get them something else or they might do a more practical activity (Dunwood08)	
Um well, because of the pandemic, they're all sat in rows all year and they've just been placed in alphabetical order, and that's how they are for all the lessons. (Ashwood29) All of them I think are sat next to the sort of higher ability children (Ashwood31). We are doing group work, no we're not sitting them in twos (Eastern Grove32). They're in mixed ability pairs so I've got a more able child with a lower ability child just and they've got, they've got some facing tables in pairs, as well, so they stick with the pairs at the table the same pairs on the carpet. (Best Street164-166) All of the seating is mixed ability. I have sort of, roughly done it. You know it's not like a kind of Kagan principle, but I have you know, obviously considered that they're with you know, positive models for language and things like that (Best Street18). They're in twos, so we used to be in groups and it would probably be ability groups. And I do move away from that. I do mix my classes	1. Seating plan 2. Challenges, difficult year 3. Teacher positive attitude

up quite a lot. This year obviously things have been a bit different, so they're in groups of two at tables of two, and I've sat them in mixed ability so that they're sat with somebody, somebody of completely different ability to them, which has been quite nice (Dunwood31).	
[Child's name] gets her numbers mixed up ..really difficult to represent. [Child's name] is actually really strong at maths, so I don't think his speech impacts him. And then [Child's name] finds it really difficult to discuss things or answer questions in class. So it's very hard for me to tell how he's getting on because he really struggles representing things. (Ashwood19) But as soon as the maths develops and they have more than one part to the maths or they've got to explain how they got there they become a little bit unstuck. And because they can't sometimes put into words how they've got there. (Best Street74-75) It is a lot to do with that language barrier that they don't always understand what's being asked of them during the lesson (Best Street81) Understanding more complex sentences, I think, longer instructions, communicating with peers effectively; misuse of smaller words, determiners and suffixes. Things like that used incorrectly or a lack of awareness or intuition about how to use that type of verbal grammar um, yeah, those would be the, definitely positional language for some of those children. Building more complex sentences. (Church Street13) I think sometimes they do struggle with using that new vocabulary because I think some of the children that have those, particularly ones that have diagnosed speech needs, what I kind of notice as their class teacher is they need to hear language I would say tens of times before they can pick it up as something that they would use. So hearing it, even when we repeat it at the start of the lesson even if it's repeated through the lesson, they really struggle to pick up that new language that quickly, because they would need sort of hundreds of times to hear it over a period of time to pick up that language (Church Street14)	1. Mathematical difficulties faced by pupils with SLCN. 2. SLCN does not affect maths ability. 3. Assessment 4. Subitising

That cognitive overload is, I would say quite typical of all those children and something that they, they definitely need support with and those children as well think about what they struggle with in in maths, place value and things like that are quite a struggle for them (Church Street19) Either they can't use the manipulatives in the right way, or you know, they kind of don't understand the process (Church Street36). I think it is the number topic. So do you know the basic number bonds and getting those fundamentals? They're not as fluent as some of the other children. So we have been doing the things like subitising and trying not to count on your fingers. It's like showing them the counters say 8 counters and not having to count them individually to just know that there's eight. They do seem to struggle a little bit more with that (Dunwood21). If there's an actual worded problem, then it's not strong. With those, they don't enjoy them as much either as opposed to the practical activities. Moving the cubes around for division and multiplication and being a bit more hands on (Dunwood21). I wouldn't say that their abilities are massively different either. So there are some children erm like the ones that I picked, the typical children, there are some children who don't have a speech and language that are probably less able than the others (Dunwood44)	
Um not no, not for them children. I do have a child that's a selective mute and a child that is nonverbal. So I had training for them, but not particularly for the children that have sort of more umm the other kind of need. (Ashwood14)	1. Training for SLCN
I think that the skill base for a nurse [*previous employment*], and for a teacher are very similar and very transferable skills. Being able to identify perhaps a child who isn't processing information in a "normal" way [air speech marks] and just perhaps having a bit more insight into seeing when a situation isn't, or someone isn't responding in a way that you would expect. (Eastern Grove02)	1. Assessment

Yeah, it is a bit tricky when it comes to assessment, so obviously we assess as we go along and and 'cause it's in blocks, like when we're assessing things like time and money, it looks like none of the children are any good at time and money 'cause we don't do it till the very end (Dunwood10)	
So definitely with them, I use a lot, a lot more resources, so this particular child works well with the unifix cubes, I might also use Numicon because they use them a lot in early years and they are familiar with the Numicon so they're able to recognize oh that one's five without counting it, which I think is quite helpful and yeah I would say, those are the sort of the main ones that we use for them and not for other groups, we, I mean we tend to use sort of like number lines and hundred squares for all the children, that wouldn't be a different thing. (Eastern Grove19) They work much better with visuals than just listening to me talk (Eastern Grove39). That working memory's working so hard, if they've got that visual representation of the colours of the Numicon it it's taking that strain away from them to be able to process what they need to do to get there, and I think the equipment really helps them to understand the maths behind things and it brings that visual element to it. We're doing a lot of work really about using concrete apparatus. (Best Street104-106) I do tend to use either cubes or Numicon or base ten to support them. (Best Street108) All the children they have always access to a range of manipulatives, so bead strings counters, cubes. I don't use anything specific for those children, other than that I make sure they always have those accessible. Some of the children on that list have that own workstation and, and so they have like, they have their own discrete resources (Church Street21). We teach the class, they all get taught the same. In terms of differentiation it might be with the resources that might be given, they might be given extra like maybe Numicon, multilink,	1. Specific resources used for SLCN 2. Subitising

classroom support as well. They might have me or the teaching assistant and they might, maybe in the afternoons if they've not quite got something in the morning. They'll go off and have a little bit of an intervention with that (Dunwood06).	
[Discussing text on slides] it's to highlight that this is the language that I want to use, because this is the vocabulary that applies to this part of the maths that I want them to take away from it, so the 'equal' and 'unequal' was really important and so it is repeated many times over. (Eastern Grove20) That expectation that they need to speak in a full sentence. The sentence stems that are in there ready for the children to use. The talk tasks are modelled so that they've got that expectation that they need to speak in a sentence to their talk partner. (Best Street48-49) I do feel that [use of Widgets] really supports their understanding of the star words, especially. If they've not understood what it means they can't use it in the maths lesson, so yeah to spend a lot of time explaining what those words mean because some of them won't have come across them before or used them in the way, in the maths term. They might have heard in a different subject area (Best Street111-113). If it's not really going to, it's not impacting the maths, I'll find that I'll just simplify the language, just so they know what they're being asked to do and I'm not having to you know teach them a new word in a way (Best Street119-120) Sometimes, if the text isn't needed, I'll take it out or might add another slide in just so it's not too much or too busy for them (Best Street129) I often spend quite a bit of time adapting the talk tasks so they can remember what the language I am asking them to use (Best Street133). I think just that constant over-modelling of language has really helped them (Best Street186). I do think it's important if you've got children with speech and language difficulties, if you	1. Vocabulary/language use 2. Repetition/language frequency 3. Mathematical difficulties faced by pupils with SLCN.

have a good role model next to them, and in terms of them hearing new sentences modelled correctly and that rich vocab coming from the teacher as well (Best Street238) I think sometimes they do struggle with using that new vocabulary because I think some of the children that have those, particularly ones that have diagnosed speech needs, what I kind of notice as their class teacher is they need to hear language I would say tens of times before they can pick it up as something that they would use. So hearing it, even when we repeat it at the start of the lesson, even if it's repeated through the lesson, they really struggle to pick up that new language that quickly, because they would need hundreds of times to hear it over a period of time to pick up that language (Church Street14). the other children would be able to hear that, you know, a couple of times in a couple of different lessons be able to use it, but those children, they would need to hear it, you know 10s of times before they could start to use it (Church Street14) We've got a maths dictionary and there's the maths working wall that's got the vocab and things on. It's quite bare in our school in terms of what we have on the walls and things (Dunwood24).	
Like he'll never speak in a full sentence to them [talk partner]. It'll be one word answers. (Ashwood32) Because paired talk and group talk is a skill that some of them really struggle with and if it's not the learning intention, I don't know how helpful that would be in terms of their maths because in this school 80% are EAL and, as I said, that's a skill that we're still sort of working on in year one. (Eastern Grove22) there's lots of opportunities for turning to your partner and discussing your ideas. It just gives them lots of opportunities really to develop those language skills. (Best Street50-51) I do think it's important if you've got children with speech and language difficulties, if you have a good role model next to them, and in terms of them hearing new sentences	1. Paired talk 2. Teacher negative attitude

modelled correctly and that rich vocab coming from the teacher as well (Best Street238)	
They would need to be supported to find that book, sit down, pick up a pencil, turn to this page, they would need support with that, before you've even begun the task (Eastern Grove35). [Child's name] often needs me to go over and give her instructions herself, and then [Child's name] really struggles. He'll often do the totally wrong thing I've asked him to do, even if I've spoken to him and giving him a task planner and everything like that. (Ashwood21) You need one thing at a time. "Open your page" and then you have to check, have they got the page open, get your pencil. "Right, we're going to look at this one question" and we might go through them on the board as a class as an example and we'll do one as an example together, and then they go off and do the rest of them. Sometimes they'll have forgotten which question they're doing, even though it's right in front of them (Dunwood30).	Organisational problems faced by pupils with SLCN
Their working memory is stretched all the time, because I don't think they easily put things into long term memory (Best Street84). That working memory's working so hard, if they've got that visual representation of the colours of the Numicon it's taking that strain away from them to be able to process what they need to do to get there (Best Streeet104).	Working memory

Appendix 10 - White Rose Spring Term Arithmetic Test

Spring Progress Check

Year 1

Mathematics

Paper 1: arithmetic

First name						
Middle name						
Last name						
Date of birth	Day		Month		Year	
Teacher						

These assessments have been designed by White Rose Maths. For more information, please visit **www.whiterosemaths.com**

[BLANK PAGE]

Please do not write on this page.

1

$3 + 5 =$

2

$9 - 0 =$

3

4 + $\boxed{}$ = 20

4

Add together twelve and six.

5

18 – 17 = $\boxed{}$

6

13 = 5 + $\boxed{}$

7

$\boxed{} + 4 = 12 + 2$

8

12 is one more than $\boxed{}$

9

$17 - 3 = \boxed{} - 2$

10

$20 - 8 = \boxed{}$

Appendix 11 - White Rose Reasoning Test Year 1

Spring Progress Check

Year 1

Mathematics

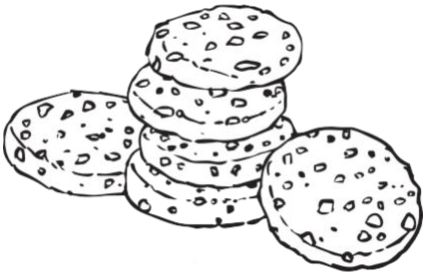
Paper 2: reasoning and problem solving

First name						
Middle name						
Last name						
Date of birth	Day		Month		Year	
Teacher						

These assessments have been designed by White Rose Maths.
For more information, please visit **www.whiterosemaths.com**

1 There are 6 cookies in a jar. Tom eats 4 cookies.

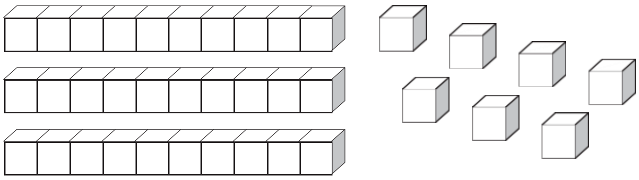
How many are left?



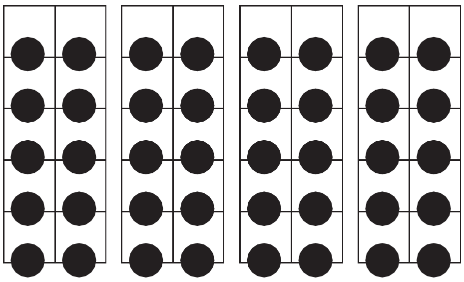
[ ] cookies

1 mark

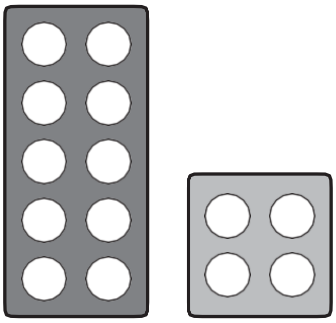
2 Match each representation to the correct number.



14



37



40

2 marks

3 Complete the missing numbers.

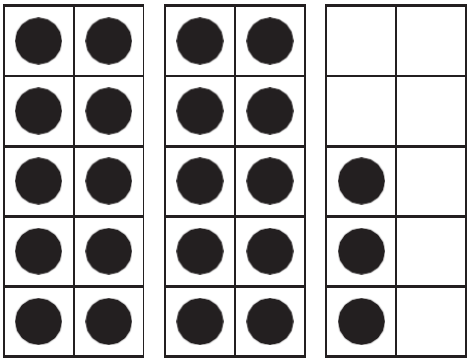
25	30	35		

50	40		20	

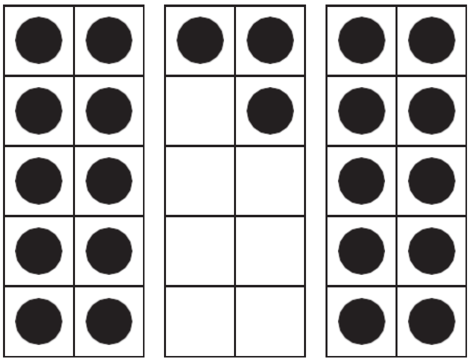
	4	6	8	

3 marks

4 Kim and Tom have each made a number.



Kim's number



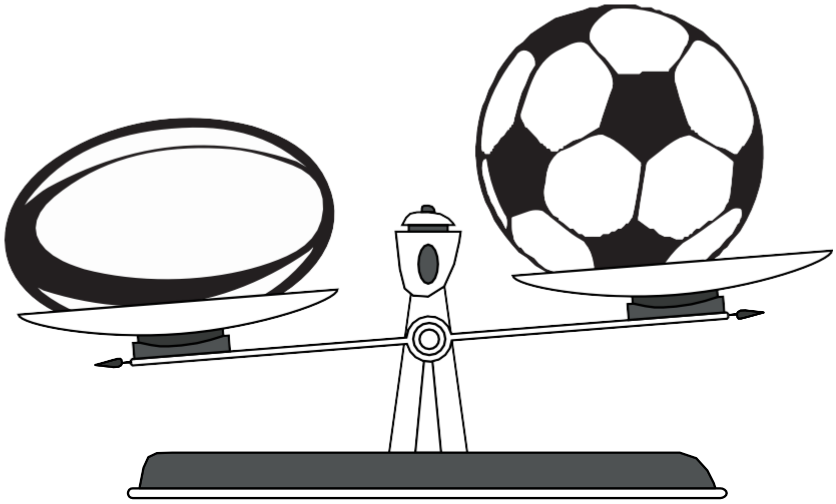
Tom's number

Choose a card to make the sentence correct.

more than	equal to	less than

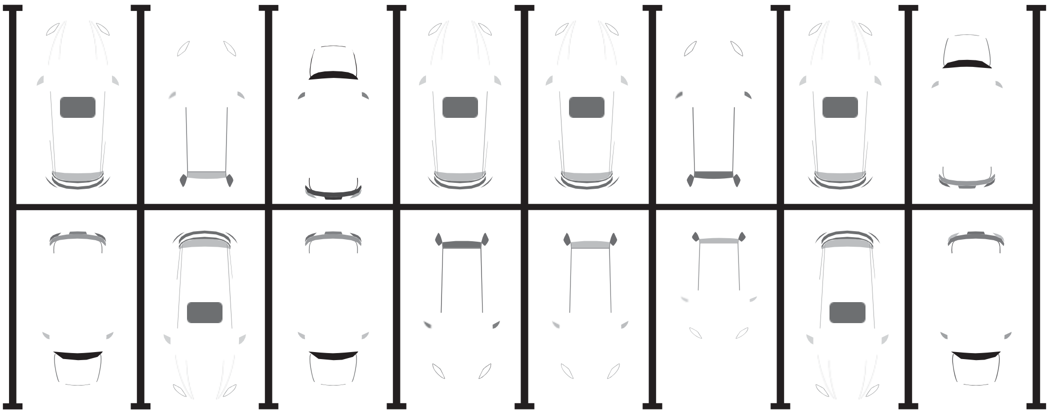
Kim's number is ______________________ Tom's number.

5 Which item is the heaviest? Tick your answer.



1 mark

6 This morning, there were 16 cars in the carpark.

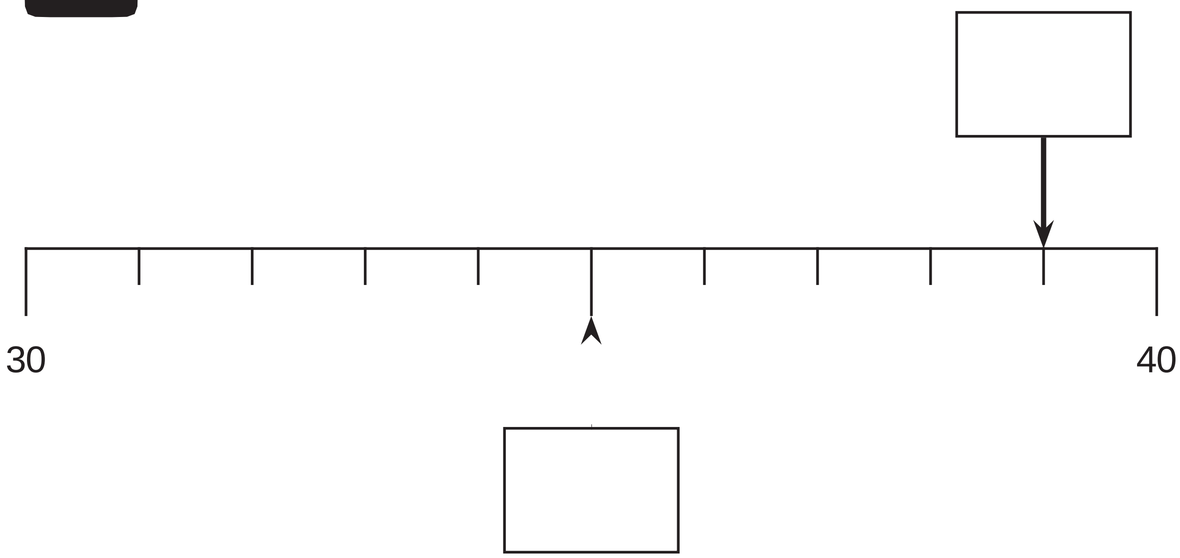


Some cars leave. Now there are 5 cars.

How many cars have left the carpark?

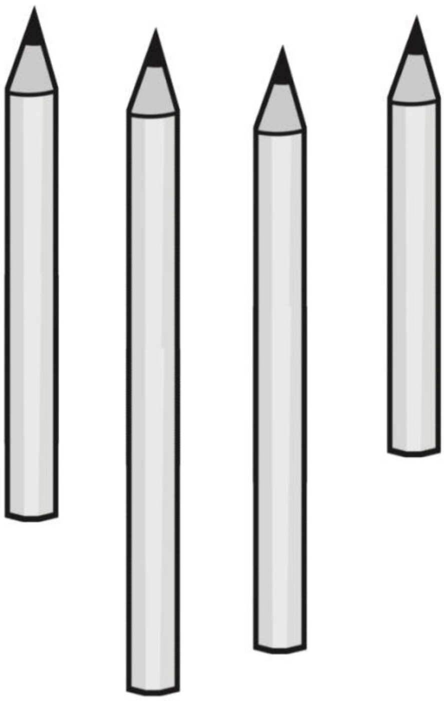
[ ] cars

7 Write the correct number in each box.



2 marks

8 Tick the longest pencil.



9 Complete the sum.

$$\boxed{9} + \boxed{} = \boxed{15}$$

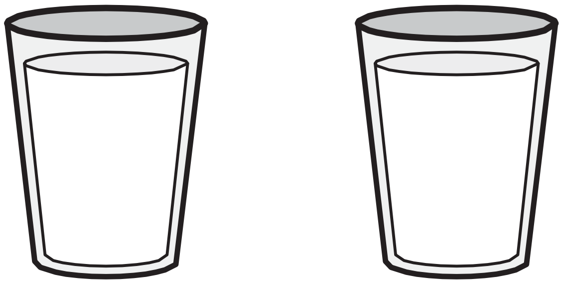
1 mark

Two different **1-digit** numbers are added to make 15. Complete the boxes.

$$\boxed{} + \boxed{} = \boxed{15}$$

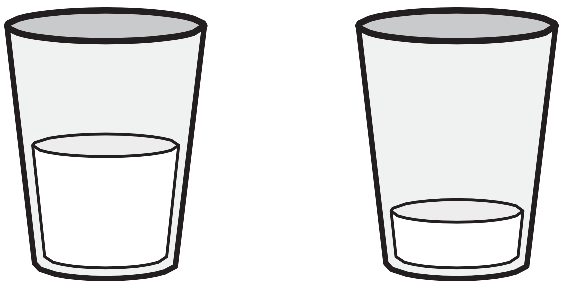
1 mark

10 Kim and Tom each have the same amount of juice in their glass.



Kim Tom

Kim and Tom drink some juice. Here is what is left.



Kim Tom

Who drank the most juice?

END OF TEST

Kim

1 mark